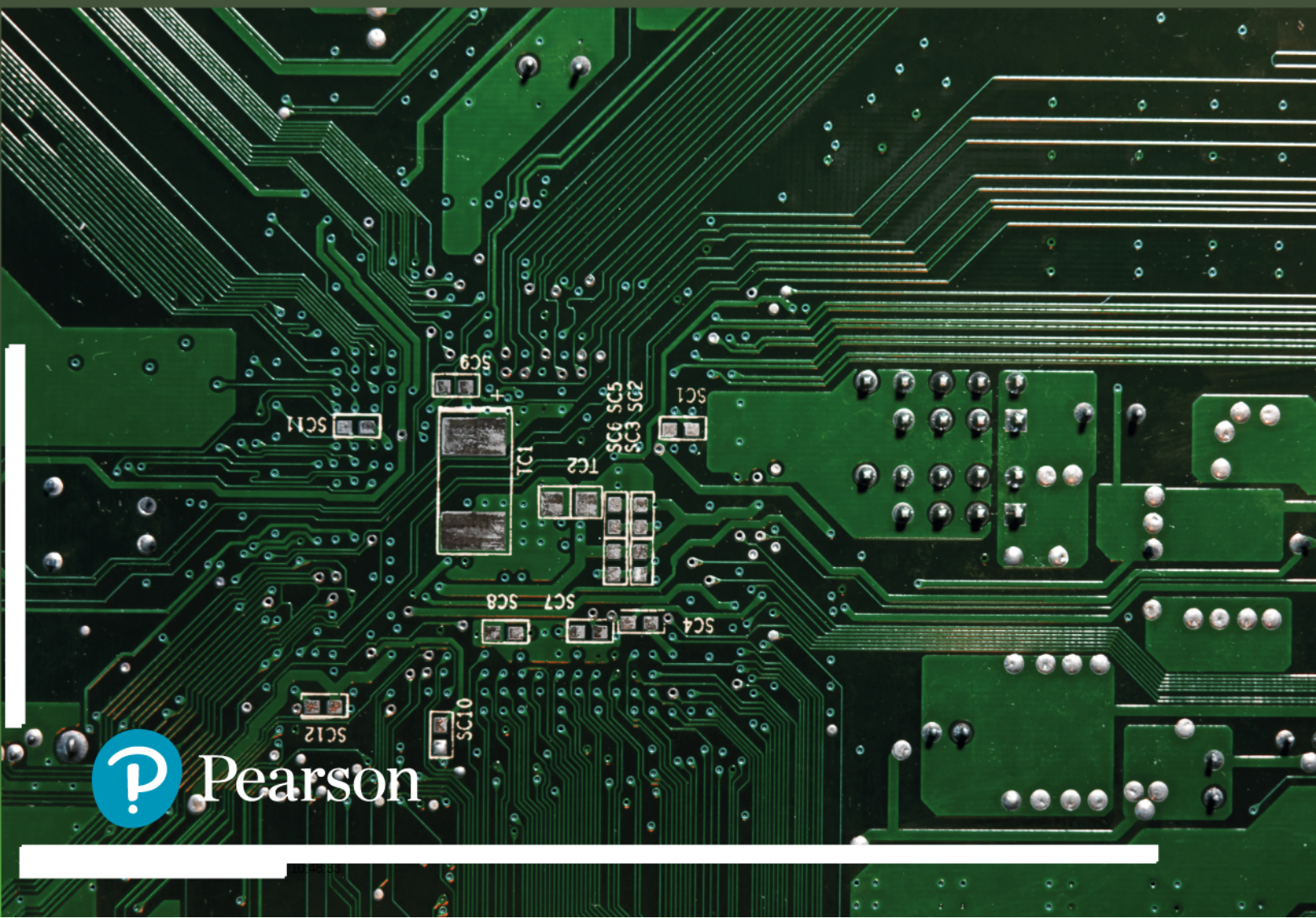
GLOBAL EDITION

Electronic Devices

Conventional Current Version

TENTH EDITION

Thomas L. Floyd



Pearson

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PREFACE

This tenth edition of *Electronic Devices* reflects changes recommended by users and reviewers. As in the previous edition, Chapters 1 through 11 are essentially devoted to discrete devices and circuits. Chapters 12 through 17 primarily cover linear integrated circuits. Multisim® circuit files in version 14 and LT Spice circuit files are available at the website: www.pearsonglobaleditions.com/Floyd.

New Features

- LT Spice circuit simulation.
- Mutlisim files upgraded to Version 14 and new files added.
- Several new examples.
- Expanded coverage of FETs including JFET limiting parameters, FINFET, UMOSFET, Current source biasing, Cascode dual-gate MOSFET, and tunneling MOSFET.
- Expanded coverage of thyristors including SSRs using SCRs, motor speed control.
- Expanded coverage of switching circuits including interfacing with logic circuits.
- Expanded PLL coverage.
- Many new problems.

Standard Features

- Full-color format.
- Chapter openers include a chapter outline, chapter objectives, introduction, key terms list, Device Application preview, and website reference.
- Introduction and objectives for each section within a chapter.
- Large selection of worked-out examples set off in a graphic box. Each example has a related problem for which the answer can be found at: www.pearsonglobaleditions.com/Floyd
- Multisim® circuit files for selected examples, troubleshooting, and selected problems are on the companion website.
- LT Spice circuit files for selected examples and problems are on the companion website.
- Section checkup questions are at the end of each section within a chapter. Answers can be found at: www.pearsonglobaleditions.com/Floyd.
- Troubleshooting sections in many chapters.

- A Device Application is at the end of most chapters.
- A Programmable Analog Technology feature is at the end of selected chapters.
- A sectionalized chapter summary, key term glossary, and formula list at the end of each chapter.
- True/false quiz, circuit-action quiz, self-test, and categorized problem set with basic and advanced problems at the end of each chapter.
- Appendix with answers to odd-numbered problems, glossary, and index are at the end of the book.
- Updated PowerPoint® slides, developed by Dave Buchla, are available online. These innovative, interactive slides are coordinated with each text chapter and are an excellent tool to supplement classroom presentations.
- A laboratory manual by Dave Buchla and Steve Wetterling coordinated with this textbook is available in print.

Student Resources

Digital Resources (*www.pearsonglobaleditions.com/Floyd*) This section offers students an online study guide that they can check for conceptual understanding of key topics. Also included on the website are tutorials for Multisim® and LT Spice. Answers to Section Checkups, Related Problems for Examples, True/False Quizzes, Circuit-Action Quizzes, and Self-Tests are found on this website.

Circut Simulation (*www.pearsonglobaleditions.com/Floyd*) These online files include simulation circuits in Multisim® 14 and LT Spice for selected examples, troubleshooting sections, and selected problems in the text. These circuits were created for use with Multisim® or LT Spice software. These circuit simulation programs are widely regarded as excellent for classroom and laboratory learning. However, no part of your textbook is dependent upon the Multisim® or LT Spice software or provided files.

Instructor Resources

To access supplementary materials online, instructors need to request an instructor access code. Go to www.pearsonglobaleditions.com/Floyd to register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail including an instructor access code. Once you have received your code, locate your text in the online catalog and click on the Instructor Resources button on the left side of the catalog product page. Select a supplement, and a login page will appear. Once you have logged in, you can access instructor material for all Pearson textbooks. If you have any difficulties accessing the site or downloading a supplement, please contact Customer Service at: http://support.pearson.com/getsupport

Online Instructor's Resource Manual Includes solutions to chapter problems, Device Application results, summary of Multisim® and LT Spice circuit files, and a test item file. Solutions to the lab manual are also included.

Online Course Support If your program is offering your electronics course in a distance learning format, please contact your local Pearson sales representative for a list of product solutions.

Online PowerPoint® Slides This innovative, interactive PowerPoint slide presentation for each chapter in the book provides an effective supplement to classroom lectures.

Online TestGen This is a test bank of over 800 questions.

Chapter Features

Chapter Opener Each chapter begins with an opening page, as shown in Figure P–1. The chapter opener includes a chapter introduction, a list of chapter sections, chapter objectives, key terms, a Device Application preview, and a website reference for associated study aids.

▲ FIGURE P–1

A typical chapter opener.

Section Opener Each section in a chapter begins with a brief introduction and section objectives. An example is shown in Figure P–2.

Section Checkup Each section in a chapter ends with a list of questions that focus on the main concepts presented in the section. This feature is also illustrated in Figure P–2. The answers to the Section Checkups can be found at: www.pearsonglobaleditions.com/Floyd.

Troubleshooting Sections Many chapters include a troubleshooting section that relates to the topics covered in the chapter and that illustrates troubleshooting procedures and techniques. The Troubleshooting section also provides Multisim® Troubleshooting exercises.

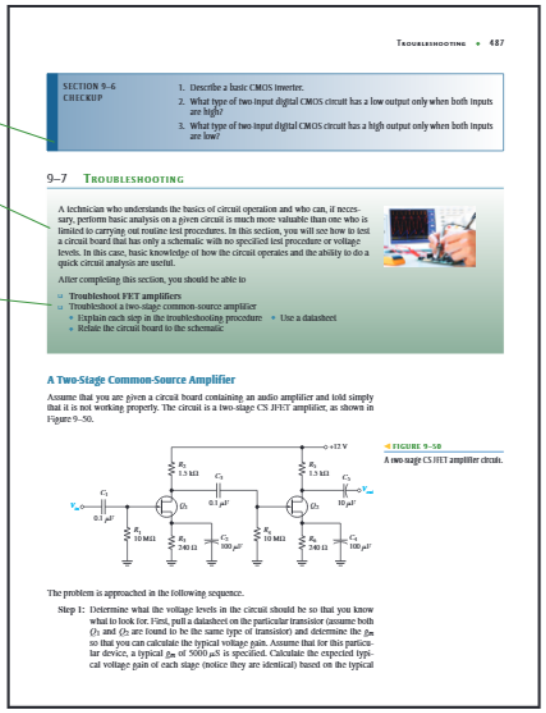
▶ **FIGURE P–2**

A typical section opener and section review.

Section checkup ends each section.

Introductory paragraph begins each section.

Performance-based section objectives



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SECTION 9–6 CHECKUP

1. Describe a basic CMOS inverter.
2. What type of two input digital CMOS circuit has a low output only when both inputs are high?
3. What type of two input digital CMOS circuit has a high output only when both inputs are low?

9–7 TROUBLESHOOTING

A technician who understands the basics of circuit operation and who can, if necessary, perform basic analysis on a given circuit is much more valuable than one who is limited to carrying out routine test procedures. In this section, you will see how to test a circuit board that has only a schematic with no specified test procedure or voltage levels. In this case, basic knowledge of how the circuit operates and the ability to do a quick circuit analysis are useful.

After completing this section, you should be able to

- Troubleshoot FET amplifiers
  - Troubleshoot a two-stage common-source amplifier
    - Explain each step in the troubleshooting procedure
    - Use a datasheet
    - Relate the circuit board to the schematic

A Two-Stage Common-Source Amplifier

Assume that you are given a circuit board containing an audio amplifier and told simply that it is not working properly. The circuit is a two-stage CS JFET amplifier, as shown in Figure 9–50.

FIGURE 9–50
A two-stage CS JFET amplifier circuit.

The problem is approached in the following sequence.

Step 1: Determine what the voltage levels in the circuit should be so that you know what to look for. First, pull a datasheet on the particular transistor (assume both Q_1 and Q_2 are found to be the same type of transistor) and determine the g_m so that you can calculate the typical voltage gain. Assume that for this particular device, a typical g_m of 5000 μS is specified. Calculate the expected typical voltage gain of each stage (notice they are identical) based on the typical

Worked Examples, Related Problems, and Circuit Simulation Exercises Numerous worked-out examples throughout each chapter illustrate and clarify basic concepts or specific procedures. Each example ends with a Related Problem that reinforces or expands on the example by requiring the student to work through a problem similar to the example. Selected examples feature a Multisim® or LT Spice exercise keyed to a file on the companion website that contains the circuit illustrated in the example. A typical example with a Related Problem and a Multisim® or LT Spice exercise are shown in Figure P–3. Answers to Related Problems can be found at: www.pearsonglobaleditions.com/Floyd.

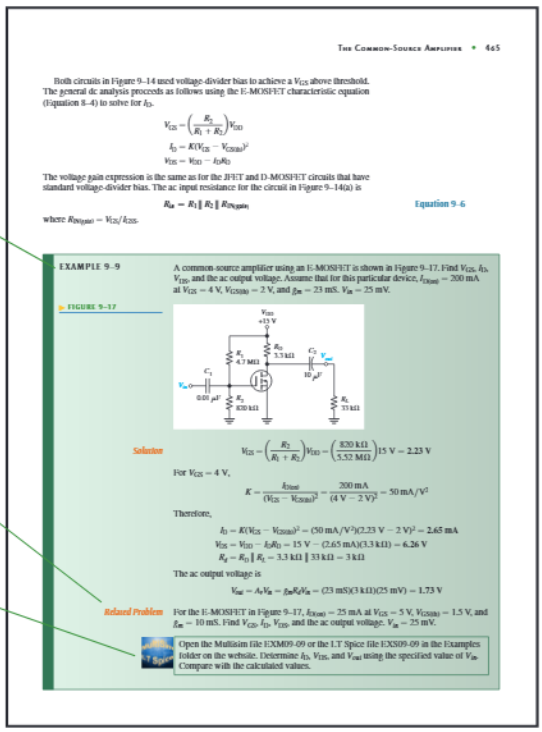
▶ **FIGURE P–3**

A typical example with a related problem and Multisim®/LT Spice exercise.

Examples are set off from text.

Each example contains a related problem relevant to the example.

Selected examples include a Multisim®/LT Spice exercise coordinated with the circuit simulation files on the website.



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Both circuits in Figure 9–14 used voltage-divider bias to achieve a V_{GS} above threshold. The general dc analysis proceeds as follows using the E-MOSFET characteristic equation (Equation 8–4) to solve for I_D.

$$V_{GS} = \left(\frac{R_2}{R_1 + R_2}\right)V_{DD}$$

$$I_D = K(V_{GS} - V_{GS(th)})^2$$

$$V_{DS} = V_{DD} - I_D R_D$$

The voltage gain expression is the same as for the JFET and D-MOSFET circuits that have standard voltage-divider bias. The ac input resistance for the circuit in Figure 9–14(a) is

$$R_{in} = R_1 \| R_2 \| R_{IN(gate)} \qquad \text{Equation 9–6}$$

where $R_{IN(gate)} = V_{GS}/I_{GSS}$.

EXAMPLE 9–9

A common-source amplifier using an E-MOSFET is shown in Figure 9–17. Find V_{GS}, I_D, V_{DS}, and the ac output voltage. Assume that for this particular device, $I_{D(on)} = 200$ mA at $V_{GS} = 4$ V, $V_{GS(th)} = 2$ V, and $g_m = 23$ mS. $V_{in} = 25$ mV.

FIGURE 9–17

Solution

$$V_{GS} = \left(\frac{R_2}{R_1 + R_2}\right)V_{DD} = \left(\frac{820\text{ k}\Omega}{5.52\text{ M}\Omega}\right)15\text{ V} = 2.23\text{ V}$$

For $V_{GS} = 4$ V,

$$K = \frac{I_{D(on)}}{(V_{GS} - V_{GS(th)})^2} = \frac{200\text{ mA}}{(4\text{ V} - 2\text{ V})^2} = 50\text{ mA/V}^2$$

Therefore,

$$I_D = K(V_{GS} - V_{GS(th)})^2 = (50\text{ mA/V}^2)(2.23\text{ V} - 2\text{ V})^2 = 2.65\text{ mA}$$

$$V_{DS} = V_{DD} - I_D R_D = 15\text{ V} - (2.65\text{ mA})(3.3\text{ k}\Omega) = 6.26\text{ V}$$

$$R_d = R_D \| R_L = 3.3\text{ k}\Omega \| 33\text{ k}\Omega = 3\text{ k}\Omega$$

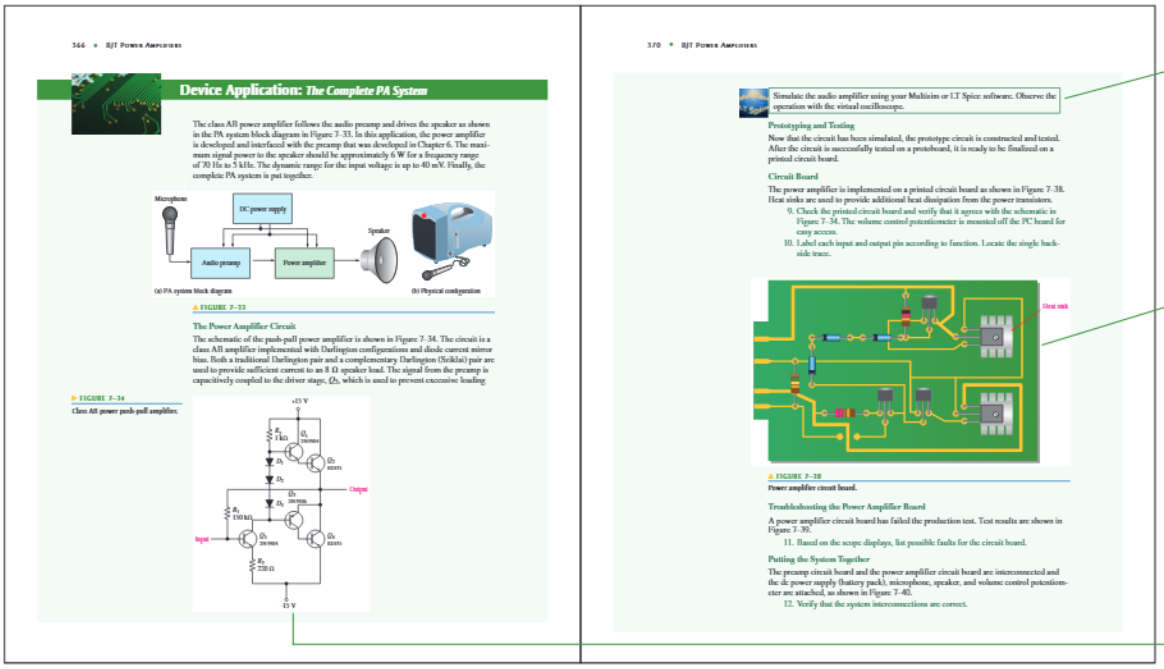
The ac output voltage is

$$V_{out} = A_v V_{in} = g_m R_d V_{in} = (23\text{ mS})(3\text{ k}\Omega)(25\text{ mV}) = 1.73\text{ V}$$

Related Problem For the E-MOSFET in Figure 9–17, $I_{D(on)} = 25$ mA at $V_{GS} = 5$ V, $V_{GS(th)} = 1.5$ V, and $g_m = 10$ mS. Find V_{GS}, I_D, V_{DS}, and the ac output voltage. $V_{in} = 25$ mV.

Open the Multisim file EXM09-09 or the LT Spice file EXS09-09 in the Examples folder on the website. Determine I_D, V_{DS}, and V_{out} using the specified value of V_{in}. Compare with the calculated values.

Device Application This feature follows the last section in most chapters and is identified by a special graphic design. A practical application of devices or circuits covered in the chapter is presented. The student learns how the specific device or circuit is used and is taken through the steps of design specification, simulation, prototyping, circuit board implementation, and testing. A typical Device Application is shown in Figure P–4. Device Applications are optional. Results are provided in the Online Instructor's Resource Manual.



▲ **FIGURE P–4**

Portion of a typical Device Application section.

Chapter End Matter The following pedagogical features are found at the end of most chapters:

- Summary
- Key Term Glossary
- Key Formulas
- True/False Quiz
- Circuit-Action Quiz
- Self-Test
- Basic Problems
- Advanced Problems
- Datasheet Problems (selected chapters)
- Device Application Problems (many chapters)
- Multisim® Troubleshooting Problems (most chapters)

Suggestions for Using This Textbook

As mentioned, this book covers discrete devices and circuits in Chapters 1 through 11 and linear integrated circuits in Chapters 12 through 17.

Option 1 (two terms) Chapters 1 through 11 can be covered in the first term. Depending on individual preferences and program emphasis, selective coverage may be necessary. Chapters 12 through 17 can be covered in the second term. Again, selective coverage may be necessary.

Option 2 (one term) By omitting certain topics and by maintaining a rigorous schedule, this book can be used in one-term courses. For example, a course covering only discrete devices and circuits would use Chapters 1 through 11 with, perhaps, some selectivity.

Similarly, a course requiring only linear integrated circuit coverage would use Chapters 12 through 17. Another approach is a very selective coverage of discrete devices and circuits topics followed by a limited coverage of integrated circuits (only op-amps, for example). Also, elements such as the Multisim® and LT Spice exercises, and Device Application can be omitted or selectively used.

To the Student

When studying a particular chapter, study one section until you understand it and only then move on to the next one. Read each section and study the related illustrations carefully; think about the material; work through each example step-by-step, work its Related Problem and check the answer; then answer each question in the Section Checkup, and check your answers. Don't expect each concept to be completely clear after a single reading; you may have to read the material two or even three times. Once you think that you understand the material, review the chapter summary, key formula list, and key term definitions at the end of the chapter. Take the true/false quiz, the circuit-action quiz, and the self-test. Finally, work the assigned problems at the end of the chapter. Working through these problems is perhaps the most important way to check and reinforce your comprehension of the chapter. By working problems, you acquire an additional level of insight and understanding and develop logical thinking that reading or classroom lectures alone do not provide.

Generally, you cannot fully understand a concept or procedure by simply watching or listening to someone else. Only hard work and critical thinking will produce the results you expect and deserve.

Acknowledgments

Many capable people have contributed to the tenth edition of *Electronic Devices.* It has been thoroughly reviewed and checked for both content and accuracy. Those at Pearson who have contributed greatly to this project throughout the many phases of development and production include Faraz Sharique Ali and Rex Davidson. Thanks to Jyotsna Ojha at Cenveo for her management of the art and text programs. Dave Buchla contributed extensively to the content of the book, helping to make this edition the best one yet. Gary Snyder created the circuit files for the Multisim® and LT Spice features in this edition. I wish to express my appreciation to those already mentioned as well as the reviewers who provided many valuable suggestions and constructive criticism that greatly influenced this edition. These reviewers are David Beach, Indiana State University; Mahmoud Chitsazzadeh, Community College of Allegheny County; Wang Ng, Sacramento City College; Almasy Edward, Pennsylvania College of Technology; and Moser Randall, Pennsylvania College of Technology.

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