TEK APPLICATION INFORMATION

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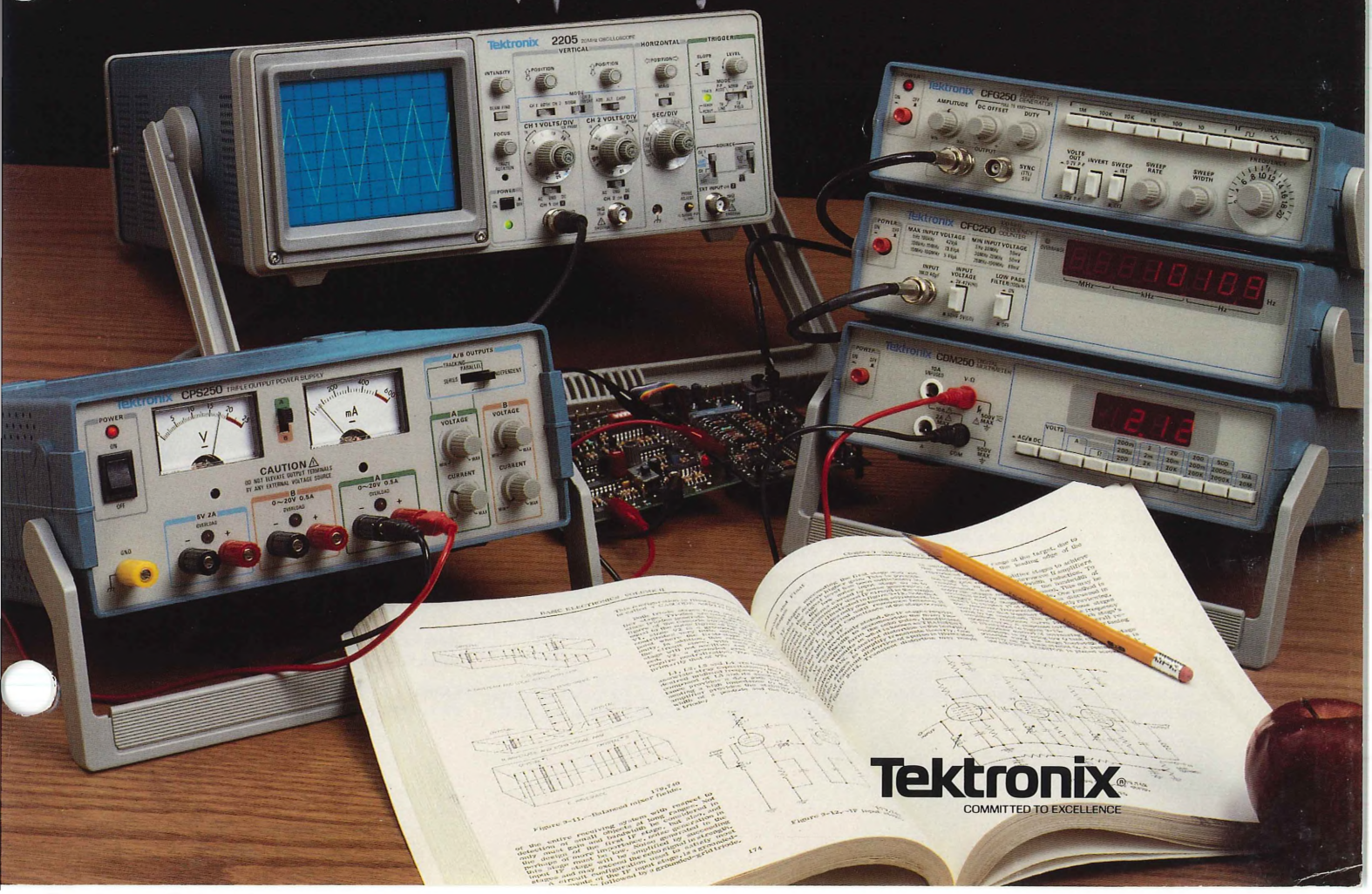
HANDSHAKE

NEWSLETTER OF INSTRUMENTATION AND INSTRUMENT SYSTEMS

Tektronix Goes to School



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Educating for industry

This issue of **HANDSHAKE** is a little different. Rather than providing solutions to the measurement problems faced in industry, it deals with the dilemmas faced by educators as they train students for the work force. But before you decide that this issue has nothing to say to industry, we urge you to read on. We feel there's something here for each of our readers because education affects all of us — whether as students, employers of former students, or supporters of educational institutions through our tax dollars and contributions.

For readers involved in education, the benefits described in these articles are obvious — practical information about tools and techniques to help teachers best prepare students for the work force.

For readers in industry, the benefits are less direct but no less important. There's a conduit of mutual interest between industry and education. Students flow from education into industry, so educators and students alike are concerned with getting an education that best prepares them for that transition. In turn, industry looks to educational institutions to train work-ready graduates. Besides direct employment, the industry/education relationship also includes programs such as schools conducting on-location classes for a company's employees or a company sponsoring research and development programs within an educational institution.

The articles in this edition of **HANDSHAKE** focus on this conduit in terms of the flow of students into industry. Readers who work in industry will get a good understanding of the dilemmas faced by educators as they struggle to provide a sound education for their students and how Tektronix is working with schools to solve those dilemmas. You'll be able to appreciate the role Tektronix is playing in helping schools produce better educated students, who in turn become better employees. You may also be able to get some ideas to help market your own products into educational institutions to strengthen this all important industry/education link.

We should all be concerned with the quality of education and be working to improve it. The funds available for education often fall short of the need. Tektronix understands the importance of learning on up-to-date equipment that is used in industry. With the Classroom Series, Tektronix is helping to provide quality equipment designed for the classroom at a lower cost.

If you are associated with an educational institution in any way that could benefit from these new products — as a student, teacher, consultant, or concerned citizen — please pass this issue on for their review after you've read it.

Thank You!

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Use the reply card in this issue to request a free subscription to **HANDSHAKE**.

HANDSHAKE turns thirteen!

It hardly seems like thirteen years have gone by since a small group of technical manual writers in the Tektronix Signal Processing Systems group came up with an idea for a newsletter which was named **HANDSHAKE**. Most of those people have moved on to other jobs, but the concept on which this newsletter was formed still remains — to provide application information so you can make your measurements faster, better, more accurately, or easier.

We've made some changes this past year that we hope have made **HANDSHAKE** more interesting and informative. To name a few: Three-column format for easier reading, identifying headlines to help you find articles of interest more easily, tutorial emphasis in our **Technology Update** section to keep you informed, and a **Q&A** column to help answer your signal measurement questions. But through all this, our goal remains to keep you informed on the latest developments in instrumentation and techniques for making signal measurements using Tektronix equipment.

Now, we're ready for another year of publishing **HANDSHAKE** with many exciting new products and articles lined up. The only thing missing is your articles and ideas on how you use Tektronix instruments in your measurements. Just drop us a line or check the "Article Idea" box on the reply card. We'll get in touch to help get your article idea into print.

We'd also like to hear from you on how we're doing or changes that could make **HANDSHAKE** even more useful. Drop us a line or use the "Comments" section of the reply card.

FOR MORE INFORMATION:

United States readers can use the postpaid reply card in this issue to request a free subscription to **HANDSHAKE** or more information on products described in this issue. For product prices and information, call the Tektronix National Marketing Center 1-800-426-2200.

International readers please contact the Tektronix Sales Representative for your country. To find the address of your representative, contact the following Tektronix area offices:

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A look inside

From our earliest days as a company, Tektronix instruments have played an important role in education. However, the cost of industrial-quality instruments has often limited their use in many schools. Now, the new Classroom Series from the Portable Test Instruments Division makes Tektronix-quality instruments affordable for many classrooms that previously had to settle for "second best."

In the article **Choosing equipment for the classroom — the instructor's dilemma,** we can see an instructor's view of instrumenting the electronics classroom. To learn about Tek's answer to this dilemma, read the articles **Tektronix goes to school** and **A total educational package.**

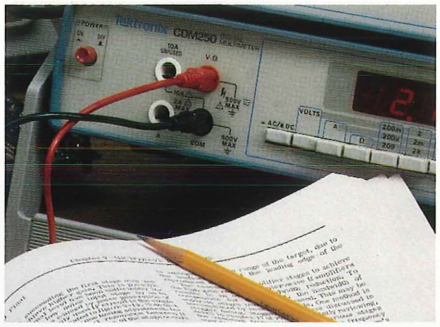
Continuing in the educational theme, the application article **Teaching automatic test equipment concepts at Purdue University** tells how one school solved the problem of outfitting a lab to teach ATE concepts. Besides the Classroom Series in the feature article, we also introduce some new products from the Logic Analyzer Division and the Murdock Park Division that are well suited for educational applications.

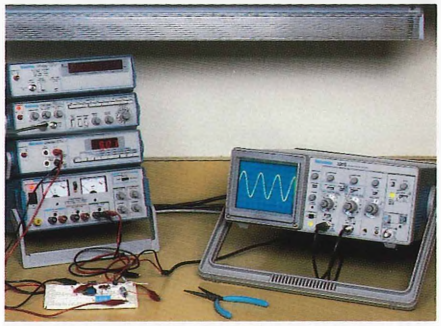
The Technology Update section covers an area that should be of utmost importance to each one of us — **Electrical safety.** As an added bonus in this issue, we've included an index covering the last four issues of **HANDSHAKE** so you can check if you've missed any important articles.

We hope you enjoy reading about these instruments that meet the needs of education but are ideal in industry as well. To find out more about any of the products described in this issue, or for help with your other signal measurement needs, contact your local Tektronix Field Office or representative. And be sure to tell them you saw it in **HANDSHAKE.**

A. Dale Aufrecht
HANDSHAKE Editor

For information or prices on products described in this issue, call the Tektronix National Marketing Center 1-800-426-2200





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Choosing equipment for the classroom the instructor's dilemma

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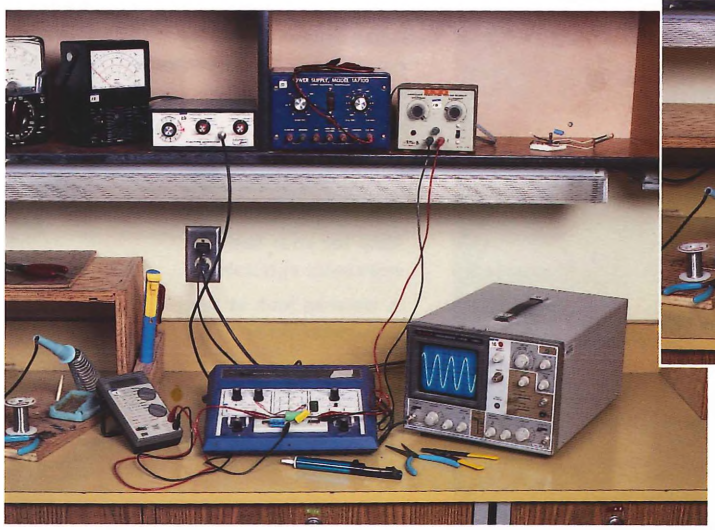
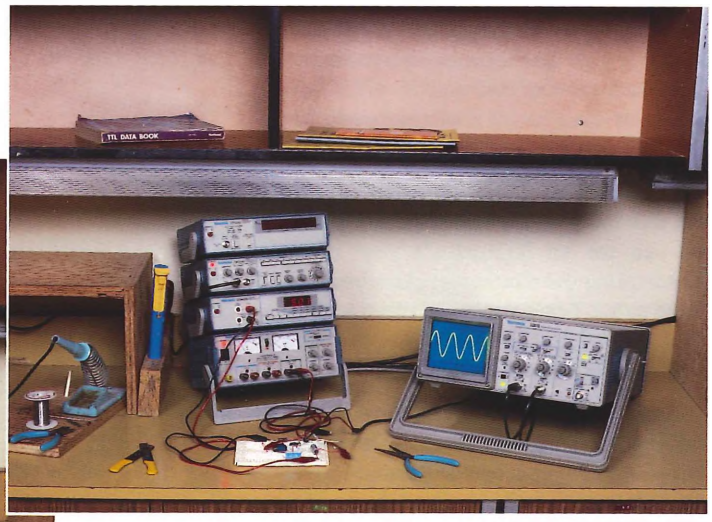




Bringing order to the classroom. Assorted equipment from a variety of manufacturers leads to cluttered and confusing lab benches (left). The new Classroom Series from Tektronix (above) brings order to the bench as well as to the electronics curriculum. Photos courtesy of Kelso High School.

Electronics instructors at all levels face common problems when purchasing equipment, whether for existing laboratories or when starting a new lab. Instructors use several criteria to determine the content of electronics and physics courses and the type of lab exercises required to demonstrate the course material. Then, they select equipment, based on that same criteria, which best fits the course requirements. However when the purchase request is submitted, purchasing agents often base their buying decisions on different criteria. The result? The equipment purchased often doesn't match the requirements of the course, the instructor, or the student.

The two fundamental considerations in the selection of course content and lesson difficulty are the needs of the student and the needs of the future employer. Instructors try to address both considerations when selecting test equipment to demonstrate the practical application of the theory being taught.

A typical basic electronics course includes lessons about diodes, transistors, integrated circuits, power supplies, amplifiers, operational amplifiers, oscillators, troubleshooting techniques, and test equipment operation. A typical set of basic experiments in AC theory requires a regulated DC power supply with variable output, a function generator, a digital multimeter, an analog multimeter, and a triggered-sweep oscilloscope. A frequency counter is often required to verify oscilloscope period-to-frequency calculations.

A brief history of one high school lab

In order to better understand the dilemma faced by many electronics instructors, let's take a look at what occurred in a typical high school electronics laboratory. While this scenario is from the high school level, it's similar to the experiences at other secondary, vocational schools, and colleges as they moved into an electronics curriculum.

During the 1960s, electricity was taught as part of the physics classes — there were no specialized courses in electronics. The instructor usually obtained equipment wherever available — often surplus or used equipment, ill-fitted for its new role. Equipment needs were simple: An oscilloscope, an audio generator, and several analog multimeters. Often, six-volt battery eliminators were used as power supplies.

In the early 70s, a vocational instructor with an electronics background started a basic electronics class. Equipment purchased for the new curriculum included five Telequipment S51 Oscilloscopes, two or three sine-square wave generators in kit form, and several other instruments specific to amateur radio testing.

By the end of the 70s, the program had grown, the original instructor had left, and more equipment (including four Telequipment S61 Oscilloscopes) had been purchased. Since then several instructors have modified the course content and purchased more equipment.

In its present condition, the lab has six different models of oscilloscopes, 15 function generators by seven different manufacturers, six types of power supplies, four models of analog volt-ohmmeters, and four models of digital multimeters. The only equipment common to each of the 12 work stations is a multi-function student trainer which consists of a variable DC power supply, a low-voltage line-frequency supply, and a sine-square wave generator, all in a desk-top unit. Several pieces of obsolete or non-functioning equipment sit unused in the storeroom — too expensive

to fix or outdated for present needs. The newest equipment in the lab is five years old.

One might rationalize that this diversity of equipment provides an advantage to the student. However, it actually becomes a detriment to learning since each student may be using a different set of equipment, requiring time-consuming individualized instructions for each unique setup. This not only adds to the complexity of learning, but also requires the instructor to prepare individual training instructions for each of the many lab setups in use.

In addition, the equipment is often obsolete, no longer used in industry, or of a lower quality never used in real-life industrial applications. The training resulting from this scenario cannot equal the needs of industry. When the student graduates, retraining is often required for familiarization with the actual equipment in use in industry.

This three-decade equipment chronology has, no doubt, been repeated in many secondary schools and colleges across the country today. The result is a collection of mis-matched, often non-functioning equipment, which is poorly-fitted for the training task at hand.

Instructors recognize quality equipment

Most electronics instructors have used quality test equipment and are aware of the advantages it offers. Even those who have had few opportunities to use industry-standard equipment recognize the value of high-quality instrumentation in the training lab. No instructor would choose poor or second-best equipment for their lab.

If course content is determined by the needs of the student and the future employer, equipment should be selected on the same basis. Given a "blank check," practical instructors would purchase equipment to match what students will use when they enter the industrial world as employees.

Student participation or teacher demonstration

Even when setting up new labs, budget constraints often force instructors to make difficult choices — for example, the choice between a piece of quality test equipment and a multi-function trainer for each student. Because most students learn best by performing experiments and lab exercises, the instructor often chooses the all-purpose trainer. As a result, students miss the opportunity to use modern, industry-standard test equipment and end up performing experiments and lab exercises which do not closely relate to the real world of measurements.

Purchase by low bid

Although institutional purchasing agents are seldom trained to select quality equipment, they are responsible to taxpayers to stay within fixed budgets. Formal training for electronics instructors does not always include practical instruction in specification writing and the "politics" of successful equipment bids.

As many instructors can attest, the low bid is not always the item best suited to the classroom application. However, when equipment specifications are vague or incomplete, the instructor gets what the purchasing agent considers the best value. Too often, this results in a lab with a hodgepodge of equipment from a variety of manufacturers, including equipment that is rarely used in industry. Some equipment may even be unsafe for inexperienced operators.

Sometimes, the equipment is not built to withstand the rough treatment of eager, but inexperienced, hands resulting in early failure. Then, the real problem may begin — where to get service for a piece of equipment that is not distributed or supported locally. This is but one of the problems that lead to additional cost that can result from equipment purchased by lowest bid. Other costs include the need to develop related courseware, lab exercises, and understandable operating instructions for the instruments. And the search for supporting material such as video tapes or primers to teach the basics of measurements can be both time-consuming and frustrating.

A solution to the dilemma — the Tektronix Classroom Series

An ideal solution to this dilemma is found in the new Classroom Series from Tektronix. Of utmost importance is that the Classroom Series presents an industry-standard solution to measurement training — students learn on instruments with the look, the feel, and the performance of instruments used in industry. As a matter of fact, instruments in the Classroom Series packages are already in use in many industrial applications. The result is that students can more easily move from the classroom into industry, having trained on equipment that meets industrial performance standards.

Another important fact for schools is that this performance is available at an affordable cost. The Classroom Series was designed as a total solution including signal stimulus, measuring instruments, and oscilloscopes and are available in instrumentation packages which combine the instruments with supporting literature. A special educational discount is available on Classroom Series instrumentation packages to qualifying educational institutions.

Instruments in the Classroom Series are supported by easy-to-understand instruction manuals, study guides, instructor's aids, video tapes, application notes, optional service manuals, and other material to make the task of the electronics instructor easier.

Finally, with the Classroom Series you only need to make one phone call if service is required. You don't need to spend time determining which instrument is at fault and then try to find local service for the problem instrument. Instead, a call to your local Tektronix Service Center will bring the help you need. But if you would rather maintain your own instruments, the optional service manuals provide detailed instructions so you can perform routine maintenance and repair in your own shop.

The new Classroom Series from Tektronix provides the answer to the instructor's dilemma — low price, industry standard performance, curriculum support material, and after-sales service and support.

EDITOR'S NOTE: John Benson worked for the Tektronix Portable Test Instruments Division Marketing group during the Summer of 1987. His experience in the classroom was influential in design and marketing decisions on the Classroom Series. In addition, John helped write the instruction manuals and much of the support literature for these new products.

Tektronix goes to school

Bob Oblack
Marketing Program Manager
Portable Test Instruments Division
Tektronix, Inc.

Using quality test equipment in school labs is an important training step in preparation for jobs in industry.

Educators in today's electronics field face a real dilemma. As electronics become more pervasive and sophisticated in our everyday lives, a higher skill level is required of the people trained to design and service such equipment. Unfortunately at the same time, availability of the training equipment needed to teach these critical skills is dwindling. And even if the equipment were available, schools face increasingly tighter budgets, making changes and equipment upgrades difficult.

These were the central findings of a study conducted by Tektronix and the National Center for Research in Vocational Education based at Ohio State University. Tektronix used this study to develop a new line of educational packages that provide training help for all skill levels — the Classroom Series.

Caught in the squeeze

The study uncovered two contradictory trends: First, educational institutions find it increasingly difficult to obtain funding for lab equipment from shrinking school budgets. In colleges and universities, electronic test equipment is usually purchased through the general operating budget. Competition for the available funds is heavy, and equipment replacement is often a low priority. Grants also provide funding, but they are limited and difficult to obtain.

In secondary schools and vocational training facilities, the situation is perhaps even more critical. The majority of funding for these schools comes from state and local governments whose budgets are already constricted. Little discretionary income is available to add new equipment and labs.

The second trend is the growing demand on educational facilities at every level to produce "work-ready" technicians and engineers. Many courses are being rewritten to include specific electronics instruction to prepare students for industrial employment.

Simultaneously, more and more students, realizing the future in electronics, are opting for an electronics education. Enrollments are increasing in secondary school, university, and college electronics programs. The researchers found that enrollment in post-secondary electronic programs in six sample states was expected to increase almost 24 percent in the next five years. Seventy percent of the schools surveyed planned to expand their electronics curriculum during that same period.

In addition, vocational training facilities are finding that many displaced workers are choosing electronics as a new career. Many of these students previously worked in older, smoke-stack manufacturing industries that experienced layoffs due to a variety of factors including foreign competition and plant automation.

Being ready for electronics jobs means being up-to-date. According to the study, that means being familiar with digital technology. A student lacking the digital training needed for sophisticated electronics systems cannot be considered truly work-ready.

Answering the needs

These and other findings of the study led to the development of the Tektronix Classroom Series (CRS) — a complete instrumentation package including support materials and instruments designed for the classroom. Oscilloscopes in the CRS packages range from the Tektronix 2205 20 MHz Oscilloscope for beginners to the sophisticated 60 MHz 2220 Digital Storage Oscilloscope for advanced students. Supporting instruments include a digital multimeter, frequency counter, function generator, power supply, and a general signal source. Using the results of the study as a blueprint, all of the support materials and instruments in the Classroom Series are tailored to meet the needs of students.

A major finding of the research was that instruction on sub-industry level "trainer" instruments (instruments that do not meet

the performance demands of industry) is no longer acceptable because it places the burden of additional training on the shoulders of the eventual employer. As a result, all instrumentation in the CRS packages is standard industrial quality — the same quality of instrumentation Tektronix supplies to their commercial customers — giving students the equipment familiarity required to work productively in the industrial sector immediately upon completion of the course.

Another major concern of educators — because of restrictions in funding — is longevity and durability of training equipment. Thus, the Classroom Series includes only instruments designed to be rugged and reliable. Despite their ruggedness and simple operation, the oscilloscopes have the capability to make the broad range of basic tests and measurements necessary for effective training. Extra features that cost more and complicate learning for the beginner are omitted.

For example, the 2205 20 MHz Oscilloscope is equipped with 1X oscilloscope test leads which instructors said they prefer in beginning labs rather than more delicate and expensive attenuator probes. However, options are available to add 10X probes for use by more advanced students.

To offset the heavy, sometimes unpredictable punishment students can inflict on instruments, all of the CRS instruments are designed to withstand the daily wear and tear from many users with varying levels of experience.

Training beyond the basics

For training in the important field of digital measurements, the 2210 50 MHz Digital Storage Oscilloscope provides unique learning features. It combines digital storage with analog capabilities in a single instrument, providing flexibility in classroom instruction. Instructors can use the oscilloscope in analog mode to teach beginning techniques and then move to digital storage mode for more advanced students who are measuring low-repetition rate signals in such fields as mechanical testing and physical science labs. Because one lab setup can be used for all learning levels, costs can be more easily justified.

Demands of the job market also shaped the design of these new educational packages. According to the study, students must have the full complement of test and measurement instrumentation available if they are to graduate with work-ready skills. Tektronix engineers developed the Classroom Series to include power supplies, function generators, digital multimeters, and frequency counters. These instruments make it possible to perform the sophisticated analyses required in modern electronics classrooms.

Safety in the classroom

For safety, Tektronix includes only equipment certified by Underwriters Laboratory and the Canadian Standards Association in its CRS packages. Purchasing third-party certified instruments saves educational institutions the additional cost of having the equipment certified to assure that it's safe for lab use (see **Electrical safety** in this issue). Contrary to popular belief, much of the equipment being used in classrooms today is not safety-certified.

All equipment in the Classroom Series is warranted and backed by the extensive Tektronix service organization located in major cities around the world. This means that schools don't have to pay twice for equipment they buy — first to purchase it and second to keep it working. In addition, optional service manuals are available which include maintenance instructions at a level sufficient to allow schools to maintain their own equipment.

Support materials

Researchers also found that secondary electronics instructors have a more than adequate supply of textbooks and other curriculum materials that teach the theory. But they found a dearth of support materials that help students get hands-on experience with electronic test equipment.

In response, Tektronix developed training and support materials tailored for course work using each of the CRS instrumentation packages (see **Help for your basic electronics curriculum** in this issue). These materials were designed and written by experienced educators and can be easily integrated into typical lesson plans.

The CRS operators manuals present both the theory of operation and actual measurement techniques at the level of the beginning student. Laboratory exercises, primers, and posters have been developed to assist instructors in daily lesson plan development. An optional video tape library is available which features instructional tapes and workbooks. These video tapes are designed to be used in parallel with the curriculum.

For more information

Additional details on the Classroom Series are given in the following articles. If you would like additional information on any of the packages, instruments, or support materials described in this issue, contact your local Tektronix Field Office or sales representative. In the U.S., information including prices can be obtained from the Tektronix National Marketing Center toll free — 1-800-426-2200. And be sure to tell them you read about the Classroom Series in **HANDSHAKE**.

A total educational package

With the new Classroom Series, Tektronix introduces more than just a series of new instruments. Instead, we are introducing a whole new concept in electronics training. At the core of this new concept are four instrumentation packages covering the learning spectrum from basic analog measurements to advanced digital storage. These packages include everything you need to teach the concepts of making measurements: Instrumentation, instructional support material, and optional video tapes with study guides.

Designed for the classroom

The Classroom Series instrumentation packages have been carefully designed to meet the instructional needs at various levels of training. This design is based upon the advice and recommendations of educators who are familiar with the demands in the classroom.

Instruments in the Classroom Series are designed to work together. This gives you neater, less cluttered lab benches. Also, instructors find it easier to teach when the instruments are "designed" to work together rather than "patched" together.

Another advantage is that Tektronix provides related course material, study guides, and support materials for the Classroom Series.

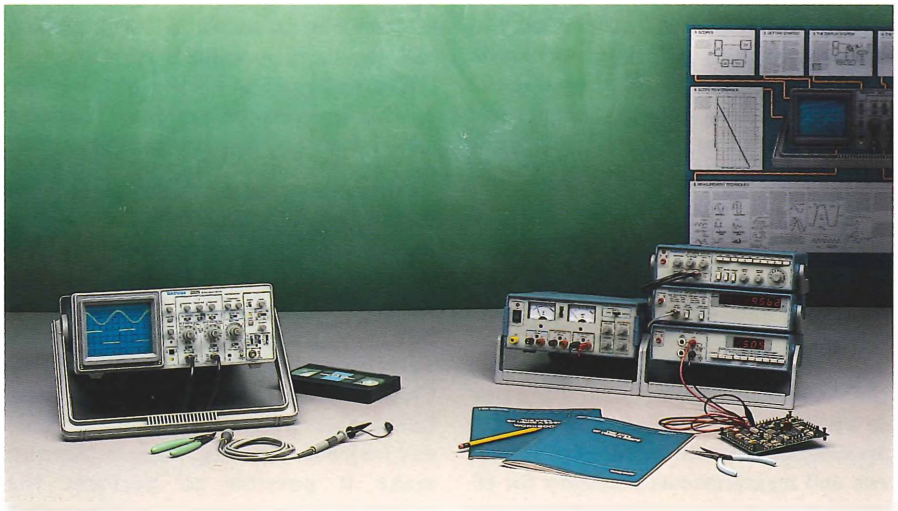
A further benefit of the Classroom Series is better after-sales support due to single-vendor source for your training instruments. Tektronix sales and applications support are available to help with any of your measurement problems. And, you get a single-source warranty from Tektronix Service Centers located in major cities around the world.

The Classroom Series

The following Classroom Series packages are currently available; additional packages are being developed.

The CRS2205 Instrumentation Package is designed for beginning students. It includes:

- 2205 dual-channel 20 MHz Oscilloscope
- CDM250 Digital Multimeter
- CFG250 Function Generator
- CPS250 Power Supply
- Instructional material credit for training material of your choice from the Instructional Material Catalog



Classroom Series instrumentation packages provide everything you need for teaching the basics of making measurements. CRS2225 Instrumentation Package shown.

The CRS2225 Instrumentation Package is similar to the CRS2205 with additional capabilities for the more advanced student. This package includes:

- 2225 dual-channel 50 MHz Oscilloscope
- CDM250 Digital Multimeter
- CFC250 Frequency Counter
- CFG250 Function Generator
- CPS250 Power Supply
- Instructional material credit for training material of your choice

The CRS2210 Instrumentation Package, designed to teach both analog and digital measurement concepts, includes:

- 2210 50 MHz Digital Storage Oscilloscope
- CDM250 Digital Multimeter
- CFC250 Frequency Counter
- CFG250 Function Generator
- CPS250 Power Supply
- Instructional material credit for training material of your choice.

The CRS2220 Instrumentation Package is similar to the CRS2210 with higher performance and the capability to add a GPIB or RS-232-C interface to teach automated testing concepts. Instruments included:

- 2220 60 MHz Digital Storage Oscilloscope
- CDM250 Digital Multimeter
- CFC250 Frequency Counter
- CFG250 Function Generator
- CPS250 Power Supply
- Instructional material credit for training material of your choice

Qualifying educational institutions receive a special educational package discount on these instrumentation packages. In addition, each package includes an instructional material credit which allows you to choose support material from an extensive list available from Tektronix.

Details of individual components in these packages are given in the sidebar **A close-up look at the Classroom Series**. For additional information on the supporting instructional material, see the sidebar **Help for your basic electronics curriculum**.

Contact your local Tektronix Field Office or sales representative for prices or additional information on these or other instrumentation packages, individual instruments in the packages, supporting instructional material, or educational package discounts. U.S. customers can call the Tektronix National Marketing Center toll free for information or to place an order — 1-800-426-2200.

Help for your basic electronics curriculum

An important part of teaching at any level is having good support material to supplement the classroom instruction. Recognizing this as an essential aspect of any training material, Tektronix supports the Classroom Series with easy to understand instruction manuals, lab exercises and workbooks to provide practical examples of measurement techniques, video tapes, and primers on a variety of measurement concepts.

Understandable instruction manuals

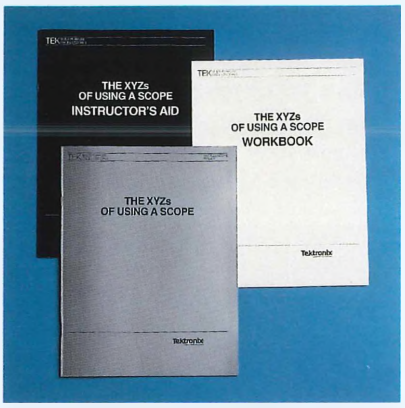
Support for the classroom begins with instruction manuals that are understandable at the student level. The Classroom Series manuals were written by educators so they can be used in the classroom. In addition they were tested for clarity and understandability by students.

Manuals for the Classroom Series are written at the beginning student level, with careful consideration to vocabulary and technical detail. These manuals serve not only as a guide to operation, but also as a training aid in learning measurement concepts. Optional service manuals are available which provide adequate information so you can maintain your own instruments.

Primers

Tektronix has a series of primers which help students understand the concepts behind measurement instruments and techniques. For example, **The XYZs Of Using A Scope** provides tutorial information which is supported by an instructor's aid as well as a student workbook. Other available primers cover topics such as probes and digital storage.

A few of the primers available from Tektronix.



The XYZs primer set provides a tutorial, an instructor's guide, and a student workbook.

Another primer available is **Laboratory Experiments Using The Tektronix 2225 50-MHz Oscilloscope ....** This primer provides a series of learning exercises using the Tektronix 2225 Oscilloscope. The first few exercises provide detailed instructions to carefully guide the student through the learning process. Later modules require the student to apply earlier lessons in order to obtain correct results. After completion of the primer, the student will understand operation of the 2225 and typical measurements that it can make.

Video tapes

Video tapes to support classroom instruction or individualized learning are also available from Tektronix. These tapes span a wide variety of topics from the beginning student level all the way through advanced topics. Tapes are classified in the **Instructional Material Catalog** as to difficulty level.

Other material

Tektronix application notes describe many basic as well as advanced measurement concepts and procedures. The

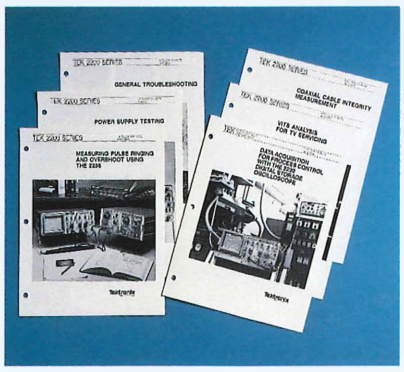
Video tapes are available on a variety of topics to enhance classroom instruction or for individualized learning.

Instructional Material Catalog provides a list of available application notes. In addition, new application notes are introduced on an on-going basis; check with your local Tektronix Field Office or sales representative for additional topics.

Subscriptions to **HANDSHAKE** are available upon request. **HANDSHAKE** is published quarterly and will help to keep you informed on new instruments and measurement techniques available from Tektronix.

A free catalog

A complete catalog of instructional material for use in the classroom is available from Tektronix. For a copy, check the **Instructional Material Catalog/Ordering Guide** box on the **HANDSHAKE** reply card in this issue.



Tektronix application notes describe measurement concepts and procedures.

A close-up look at the Classroom Series

The Classroom Series instrumentation packages include industrial-quality instruments with performance suitable for industry but priced for education. While designed with the educational customer in mind, individual instruments can be purchased for non-educational use as well.

Each instrument is supported by an instruction manual written at a basic level. Optional service manuals are available for each instrument.

All instruments in the Classroom Series (except the CRS101) have third-party safety certification and are listed by UL and CSA (Canada).

Signal sources and measuring instruments

Signal sources include a function generator, a triple-output power supply, and a general signal source. Measuring instruments include a digital multimeter and a frequency counter.

These instruments are designed to stand alone or to stack with other instruments in the series (except for the CRS101). A locking, multi-position handle allows the instruments to sit at a slant for ease of operation.

The CRS signal sources and measuring instruments are warranted for one year. Optional service plans are available to maintain your equipment investment at minimum cost after the warranty period.

The **CDM250 Digital Multimeter** measures analog quantities and displays them in digital form. The CDM250 measures direct and alternating current from 200 microamps to 10 amps in six ranges; AC and DC voltage from 200 millivolts to 500 volts in five ranges; and resistance from zero to 20 Megohms in six ranges. All values are displayed on a 3.5-digit LED display. Sine wave alternating voltages and currents are displayed in RMS values.

The **CFC250 Frequency Counter** counts the signal frequency of sine, square, and sawtooth (triangle) waves from 5 Hz to 100 MHz at input levels from 30 millivolts to 42 volts peak. A low-pass filter prevents high-frequency interference for signals below 100 kHz.

The CFC250 Frequency Counter.

The **CFG250 2 MHz Function Generator** produces sine, square, and sawtooth waves and TTL signals. Applications include testing and calibration of audio, ultrasound, and servo systems. The sweep function can be internally or externally controlled. Duty cycle, DC offset, sweep rate, sweep width, and amplitude are individually controllable by the operator. The CFG250 has an output frequency range of 0.2 Hz to 2 MHz in seven decades.

The **CPS250 Triple Output Power Supply** is a multi-function bench or portable instrument. It has an integral analog voltage and current meter. Voltage available on the 5-volt supply is 5.0 volts DC at 2.0 amps maximum. Voltage available on the two 0 to 20-volt supplies is 0-20 volts DC at 0.5 Amps maximum.

The CPS250 Triple Output Power Supply.

The fixed 5-volt output can be used in transistor-transistor-logic (TTL) applications. The two 0 to 20-volt variable outputs can be used in either independent or tracking mode to meet the needs of most semiconductor test or experimental applications. The two variable outputs can be switched to operate in series or parallel to increase voltage or current.

The **CRS101 Basic Training Lab** provides a convenient source of signals to demonstrate concepts such as risetime, pulse width, frequency, digital troubleshooting, and video measurements. It's suitable for beginning through advanc-

The CDM250 Digital Multimeter.

The CFG250 Function Generator.

The CRS101 Basic Training Lab.

ed courses in electrical engineering, electronics, engineering technology, or physics. The CRS101 can also be an invaluable tool for both laboratory demonstrations and student lab stations. For more information, see **A signal for all reasons** in the Spring 1987 **HANDSHAKE**.

Oscilloscopes

Oscilloscopes available in the Classroom Series are all industrial-quality and combine ruggedness, reliability, and ease of use. Front-panel layout is similar on all oscilloscopes in the Classroom Series, allowing easy transfer from one instrument type to another. In addition, controls and functions are similar to other Tektronix oscilloscopes, allowing easy transfer of learning from the classroom into industry.

All oscilloscopes in the Classroom Series except the 2205 are warranted for three years; the 2205 is warranted for one year. Optional service plans are available to provide continued service and maintenance after the warranty ends.

The **2205 20 MHz Oscilloscope** sets the standard for low-cost, industry-standard measurements. It is a dual-channel portable oscilloscope with DC to 20 MHz bandwidth. The vertical channels have calibrated deflection factors from 5 millivolts to 5 volts/division. Sweep speeds range from 0.5 seconds to 100 nanoseconds/division with a magnifier that expands the trace by a factor of 10 for a maximum sweep speed of 10 nanoseconds/division. Triggering modes include peak-to-peak auto, TV line, TV field, and single sweep.

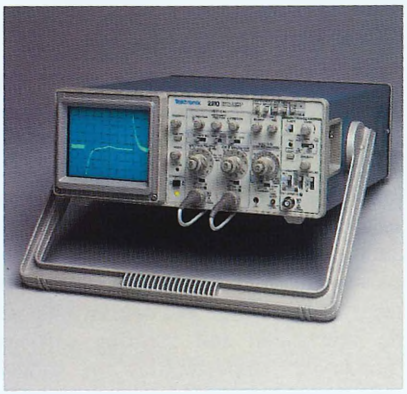
The 2205 20 MHz Oscilloscope.

The **2225 50 MHz Oscilloscope** is a full-function analog oscilloscope at an affordable price. It features a dual-channel vertical with 50-MHz bandwidth. The channels can be displayed in an X-Y mode with the flip of a switch.

The 2225 50 MHz Oscilloscope.

Trigger capabilities equal those found on more expensive scopes. TV field/line triggering is also available. A unique alternate-horizontal magnification feature provides the power of a delaying time base without the operational complexity. See **Tek goes under $1000 with new portable scope** in the Summer 1987 **HANDSHAKE** for further details on the 2225.

The **2210 50 MHz Digital Storage Oscilloscope** provides both analog and digital storage operation in a single, full-function oscilloscope. It features a 50 MHz analog bandwidth as well as one-button digital storage at 20 megasamples/second on each channel. Record length of 4K/channel at 8-bit vertical resolution allows high-resolution measurements. Other features include pre- and post-triggering, roll mode for viewing slowly changing signals, external clock input (DC to 10 MHz), and full triggering capability.



The 2210 50 MHz Digital Storage Oscilloscope.

The **2220 60 MHz Digital Storage Oscilloscope** is a higher-performance version of the 2210. In addition to the features of the 2210, the 2220 provides X-Y drive signals for an X-Y plotter, equivalent-time sampling to the full bandwidth, and a peak detection mode. GPIB or RS-232-C interface capability is available as an option. For more details on the 2220, see **Digital storage at an affordable price** in the Fall 1987 **HANDSHAKE.**

The 2220 60 MHz Digital Storage Oscilloscope.

For information or prices on these or other industry-standard instruments for the classroom or the lab, contact your local Tektronix Field Office or sales representative. In the U.S., call toll-free for information or to place a purchase order — 1-800-426-2200. And be sure to tell them you read about it in **HANDSHAKE.**

Teaching automatic test equipment concepts at Purdue University

Tom Pfaffenbach
Supervisor of Materials Management Test Engineering
Delco Electronics Corporation
Kokomo, IN 46902

The ATE lab setup at Purdue University — Kokomo, Indiana. Photo courtesy of Purdue University — Kokomo.

Industry's needs, education's challenge

Their mission, "service through instruction," requires institutions such as Purdue University to include practical, real-world approaches in their curriculum so that graduates are prepared to move into industry. However at the same time, it's essential to provide the technology student a fundamental education rather than merely "application" training for a specific job. The rate of technological change quickly obscures application-specific training. The future employee's ability to "bootstrap" to new capabilities as the inevitable changes occur is based upon a thorough understanding of the basic principles. This is also key to remaining competitive, both as an individual and as an industry, as innovation obsoletes older processes and technologies.

Automatic test equipment (ATE) systems have become major tools in many companies, particularly in engineering and manufacturing organizations seeking to support customers involved in "model year" or "model change" oriented businesses such as the automotive industry. Response to competitive pressures and external regulation has required the automotive-industry supplier to be able to test, confirm, and document specific parametric qualities of their products.

At the present time, American industry is involved in a "quality revolution." Current concepts favor control of processes and design parameters rather than testing output in order to develop higher yields — "build" the quality in rather than "test" it in. This might seem to cast serious doubt on the wisdom of developing expertise in the field of applications engineering over the long term. However, industry has found large scale (or grand scale) ATE systems to be cost-effective and has committed substantial capital investments into developing this capability over the past ten or more years. Applications engineering skills are required to support this investment, both now and in the future.

Accepting the challenge

The challenge set before the Purdue University — Kokomo administration and electrical engineering technology (EET) faculty was how to provide a basic education in preparation for a career which will continue to change and develop over a lifetime. Establishing the proper investment basis with limited funding, being sure the faculty is up-to-date and comfortable with the new tools, and assuring sufficient "hands-on" opportunities for students were some of the major goals that had to be met in setting up the curriculum for teaching automated test equipment concepts.

A normal 16-week semester allows 75-90 contact hours between faculty, facilities, and students (at Purdue — Kokomo, this is divided between 45 class hours and 30 - 45 in the laboratory). That amount of time doesn't provide enough exposure to a typical large-scale ATE system for proper learning.

Since the typical ATE system can represent an investment of several hundred-thousand dollars, a single system must serve many students, further complicating the opportunity for hands-on experience. As a result of this heavy investment, practical ATE experience on industrial-quality equipment is often out-of-reach or impractical for many institutions. Finally, the typical ATE system is very complex due to the diverse configuration required to permit demonstration of the various types of applications, making learning both time consuming and difficult.

Optimizing learning value

A program designed to develop attitudes which result in future top performers for industry must not over-burden the student. To avoid excessive requirements for self study and to minimize difficult-to-schedule appointments for use of available ATE equipment and systems, maximum use of laboratory time is necessary.

To keep course objectives in focus, the functionality of the measurement system must be clearly understood by the student. The ability to manually set up the instrument is key to demonstrating the problems that can occur between the syntax requirements of the instrument and the software program developed by the programmer.

To spark and keep student interest, "hands-on" success must come quickly. The ease with which a measurement can be made must lead the student through a thought process which establishes ATE as a capable tool, rather than a difficult process which provides incomplete evaluation for the sake of "thruput."

One of the tasks of a test engineer is to create a test which executes efficiently while correctly making the required measurements. In order to learn this, the system must be easy to reconfigure and it must be accessible in order to allow easy verification of results as various "trial" programs are run.

Defining the system, planning the course

The EET faculty, with assistance from Delco Electronics Corporation and Tektronix Sales and Applications Engineers from the Indianapolis and Detroit Field Offices, enhanced an existing course (EET 365) at the Kokomo Campus which is a true prototype for providing hands-on training for the technology student. This course provides practical knowledge for a smooth transition into industry using tools that will be available after graduation.

The Tektronix TM 5000-Series Programmable Modular Test Instruments, the Tektronix 4041 System Controller with GURU and TEK EZ-TEST software, and the Tektronix 7D20 Programmable Digitizer were chosen as the building blocks for establishing a curriculum in the field of automated test and measurement.

The course, EET 365 — Electrical Measurements, begins by equating modern measurement instruments with historic developments. Lecture sessions stress why there is a "need to know" the exact boundaries of circuit conditions in quantifiable terms as new designs are developed. Limitations of simulation and analysis are also discussed. Somewhat suprisingly, these considerations are not self-apparent to students.

Also, the student needs to recognize that they are part of a continuum of technical development, looking toward their future position in industry. Much of the knowledge they need to apply to the task is readily available. An overall understanding of sources, resources, and services available to them is stressed. In particular, the services available from the technical marketing personnel associated with test and measurement instrumentation companies are discussed.

Then, the student is introduced to the Tektronix TM 5000-Series Programmable Modular Test Instruments. The first assignment is to characterize a simple audio amplifier circuit using only the manual mode of the test instruments. Through this exercise, the student becomes aware that a great deal of time is required for the many iterative measurements required for full characterization. In short, the purpose of this exercise is to help students discover for themselves the need for a better method — specifically instrumentation directed by the power of a computer.

Next the student is introduced to the Tektronix 4041 System Controller and TEK EZ-TEST Software. At this point, the student begins to detect the differences that exist between the theoretical and the practical — not everything in the real world "works by the book."

The educational value of this approach to "enlightenment" derives from the fact that the differences are at a manageable level. The student has used the measurement instruments in a manual mode and learns that ATE errors come from such things as inexperience in application of the program commands and necessary "escapes" or "fixes" that the programmer couldn't foresee and thus did not provide. However, the intent is to help them realize that ATE programming is not an overwhelming impossibility of dealing with a monstrous system!

During the semester, learning is reinforced by class work on measurement applications using the text Elements of Electronic Instrumentation and Measurement by Joseph Carr. The student is challenged to use the ATE lab instrumentation to fully characterize an automatic gain-controlled preamplifier — an enhanced version of the previous amplifier. First step is to develop a specification to characterize the original design criteria of the module. Then, the student defines a procedure to test the module against that specification. As students discover the value of automating the tests, they must determine the level to which automation is justified, plan the test process, and write the test program. Through this "hands-on" approach, they learn the basics of ATE measurements and, through practical experience, the choices that must be made as well as some of the pitfalls to be avoided.

Instrumenting the lab

The EET department at Kokomo has an extremely well designed, multi-functional laboratory for instruction in BASIC language programming, IC design, microprocessor systems design, and automatic test. An IBM-PC compatible personal computer, connected to an RS-232-C bus that runs around the laboratory, is available at each student station. Funding was available for two Tektronix 4041 System Controllers, one 7D20 Programmable Digitizer with a 7603 Mainframe, and 3 each Tektronix DM 5010 Programmable Multimeter, FG 5010 Programmable Function Generator, and PS 5004 Programmable Power Supply.

The 4041 System Controllers are connected to the RS-232-C lab bus via the communication port. This allows test instructions to be down-loaded from the individual student PCs using a special transfer program developed for this purpose by Tektronix. The TM 5000 test instruments are controlled from the 4041 via GPIB. This set up is extremely important to good learning through practical experience since many students have access to PCs outside of class. They can work independently on programs with minimum inconvenience and stress. Also, this increases access to the ATE equipment and maximizes available lab time.

The 7D20/7603 Digitizer is shared between test systems or can be used in a stand-alone mode. The third set of TM 5000 test equipment is used as a stand-alone test system. This makes more test equipment available to all students early in the semester when they have very little experiential background and need to get "hands on" to develop understanding.

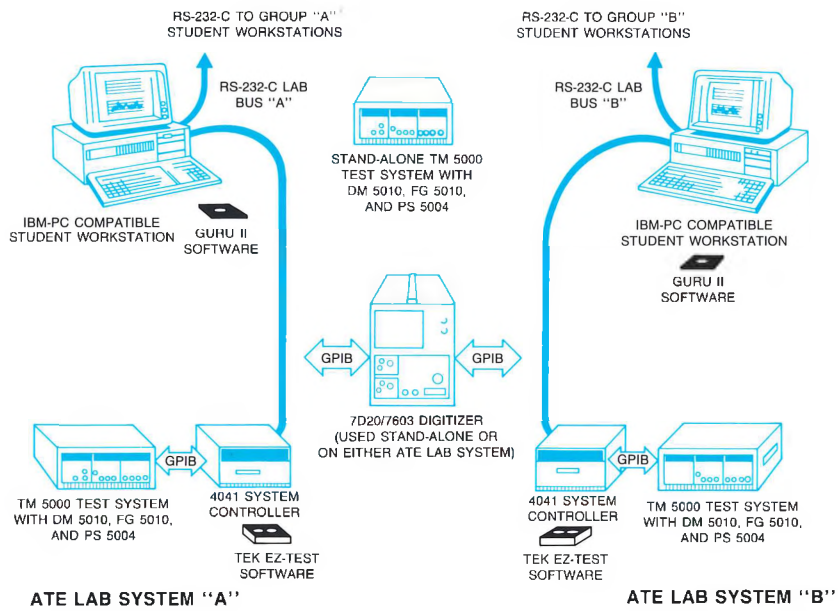


Figure 1. *Block diagram of equipment setup in ATE lab at Purdue University — Kokomo. Programs developed on the student workstations are downloaded to the GPIB-based test system via RS-232-C.*

Summary

Funding and installation of the ATE lab were barely complete before the first students arrived seeking to complete their degree requirements. Tektronix and local industry came to the aid of the University to minimize the impact of start-up problems and to "debug" the various interactions between students, text, facilities, and faculty to bring off the first semester of EET 365 without a hitch.

The requirements of a high-technology industrial base and the mission of universities to serve this base through industry-specific instruction are finding focus in the conferences and committees where industry and the academic community can make plans and take action together. Their mutual goal must be to insure competitive survival in a world where past performance does not insure the future. This process at Purdue University — Kokomo, is a prime example of what can be achieved.

Acknowledgements

Bill Gatheridge, Tektronix Sales Engineer, Indianapolis, was instrumental in helping to define the original ATE lab system. Scott Falconberry, Tektronix Applications Engineer, Detroit, wrote a special module for GURU to simulate the screens of TEK EZ-TEST on the students' PCs and allow transfer to the 4041 System Controller. Delco Electronics Corporation allowed Tom Pfaffenbach to participate first on the advisory committee chaired by Professor Bill Hubbard, EET coordinator at the Purdue University — Kokomo Campus, and then to teach the first semester of the course. This cooperative approach was important in tying the specific curricula requirements to the needs of industry.

Last call for U.S. HANDSHAKE mail list update

We're nearing completion on our current effort to update the U.S. **HANDSHAKE** mail list. If you have not returned a survey from the Summer or Fall 1987 issues of **HANDSHAKE** (U.S. copies only) or have not been in contact with us for other reasons within the past two years, we need to know if you want to continue receiving **HANDSHAKE**. While our goal is to provide **HANDSHAKE** to everyone who wants to receive it, we don't want to waste copies by sending it to those who are no longer interested or have moved.

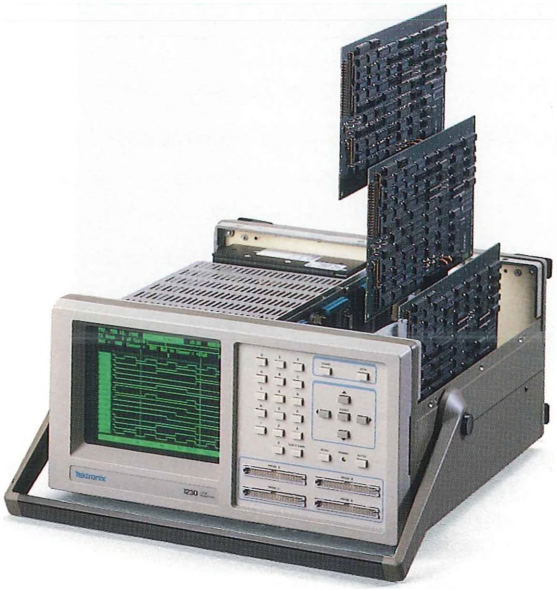
After we receive the response from this issue, we will begin the process of removing names from our list. To insure that you continue receiving **HANDSHAKE**, check the Yes, continue my subscription box on the reply card in this issue and return today. Please attach the peel-off address label from the back of this issue as it contains some important codes to help us process your response faster.

If for some reason you no longer want to receive **HANDSHAKE**, we'd appreciate if you let us know using the reply card so we can keep our mail list accurate and up to date.

Thank You!

Logic analyzers in education

Garrick West
Education Market Program Manager
Logic Analyzer Division
Tektronix, Inc.



The Tektronix 1230 Logic Analyzer can be expanded to grow with your logic analysis needs by adding additional data acquisition cards.

Why logic analyzers in education?

Would you use a hand saw to fall a large tree? Would you use a Crescent wrench to remove spark plugs? Would you use a broom to clean a carpet? Hand saws, Crescent wrenches, and brooms are examples of general purpose tools that provide excellent functionality for a wide variety of tasks. However, certain specific tasks require more specialized tools such as a chain saw, spark plug wrench, and vacuum cleaner in the above examples.

The same principle applies to digital circuit design and troubleshooting. The oscilloscope, for example, is an excellent, general purpose electrical test and measurement tool. However, for certain types of tests and measurements, a logic analyzer will do the job more efficiently and effectively. To be adequately prepared for industrial jobs, students need to learn that a broad array of specialized tools exist to work on complex electronic products.

What is a logic analyzer?

The logic analyzer is an excellent tool for locating and identifying digital hardware and software problems. It's very useful, for example, in designing and troubleshooting microprocessor-based circuits in computer systems. The logic analyzer selectively samples information from many different parts of an electrical circuit at once, stores it in memory, and displays it in a variety of different formats. A logic analyzer samples input waveforms to determine whether they are high or low in relation to a specified voltage level (threshold). If the signal is above the threshold when it is sampled, the logic analyzer stores it as a one or high. If the signal is below the threshold, it's stored as a zero or low.

Many tools have more than one purpose. The claw hammer, for example, was designed to pound nails and also to pull nails. Similarly, the logic analyzer is a multi-functional tool. One function, called either synchronous or state analysis, captures information from circuits under direction of a clock in the system being tested (analysis synchronized to the system clock). State analysis can be used, for example, to trace execution of software instructions in a computer's processing system. A typical state information display is shown in Figure 1.

Another function of the logic analyzer is called asynchronous or timing analysis. Timing analysis samples information under direction of an internal clock (analysis not synchronized to system clock). Timing information is useful when looking at time relationships on multiple digital circuits (commonly termed a bus). A typical timing information display is shown in Figure 2.

A typical application is troubleshooting circuit boards. The logic analyzer can readily compare circuits on a problem board to a known good board. State and timing analysis will help the user pinpoint problem circuits quickly and accurately.

Unique features of a logic analyzer

Students will find that Tektronix logic analyzers have unique features that are useful in designing, debugging, and troubleshooting digital-based systems.

Simultaneous multiple-channel acquisition. The number of channels may vary depending on needs of the system being tested. With the Tektronix 1230 Logic Analyzer, for example, 16, 32, 48, or 64 channels can be selected to fit the application.

Selective data capture. Selected data can be chosen for storage, allowing easier analysis and faster problem identification. A student, when looking at information on a number of circuits, may only want to see information that is written into the memory of a computer system. In this example the student can solve a problem more quickly by studying a particular class of data.

Data storage memory. This important feature provides the capability of con-

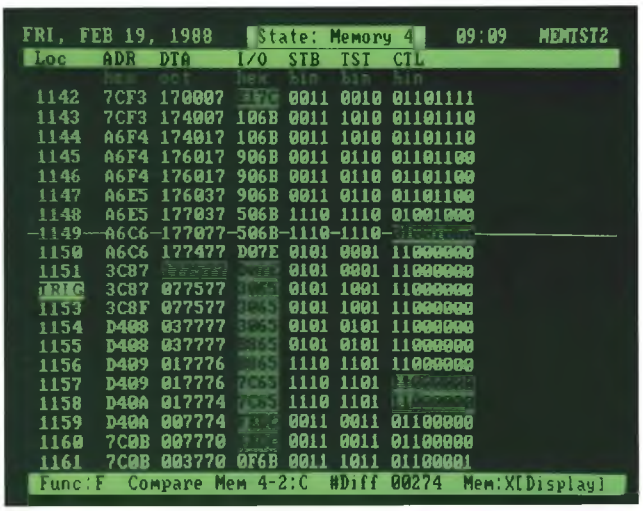


Figure 1. *Typical state information display.*

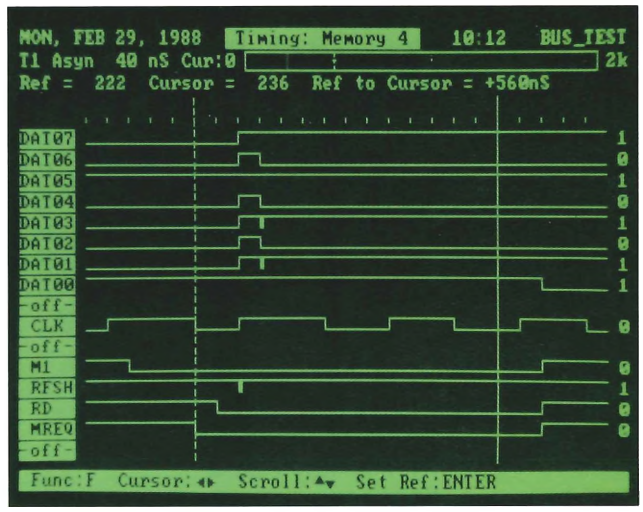


Figure 2. *Typical timing information display.*

tinuously sampling data and examining data history around a predetermined point or after a particular problem occurs. Students can look backward to see what caused a problem in a circuit and look forward in time from the problem area to see what other effects that problem caused.

Reference memory for comparison. Tek logic analyzers can compare previously acquired data to newly acquired data. This allows easy detection of changes in large blocks of data or comparison of specific rows and columns of data captured from a digital bus.

Data capture based upon predetermined digital conditions. The logic analyzer captures data surrounding a particular problem, condition, or sequence of conditions. The student can specify the conditions which "trigger" the logic analyzer to capture data.

Multiple display formats. Logic analyzer data can be displayed in easy to understand formats such as binary, hexidecimal, octal, and ASCII radices or timing diagram waveforms.

The Tektronix 1230 — the right tool for the classroom

Tektronix has recently advanced the state-of-the-art in logic analyzers with the introduction of the Tektronix 1230 Logic Analyzer. The 1230 has some key features that make it the right tool for the classroom.

Low price. A high degree of functionality at an affordable price makes this unit ideal for the price-conscious education market.

Expandable. Start with 16 data acquisition channels and easily expand to 32, 48, or 64 channels right in the classroom. Expansion cards can be shared among several lab systems to save money while providing the performance needed for more demanding exercises.

Portable, rugged, quiet, and safe. Portable for varying classroom locations, rugged for extensive student use and, since it has no fan, quiet so students can concentrate undisturbed. And the 1230 is UL approved for student safety.

Wide range of applications. Students can learn general-purpose timing and state analysis, bus analysis, and 8- or 16-bit microprocessor analysis.

Extensive microprocessor support. Students can work with a variety of microprocessors including Z80, 6502/C02/C802, STD Bus, Intel 8085 and 8086/8088, and Motorola 6800/6802, 6809/6809E, 68000/010.

Easy to use. The Tektronix 1230 was designed for easy learning and usage. For example, students can call instructional notes onto the logic analyzer screen to help them use the instrument. In addition, the 1230 has a video port to attach a large-screen monitor for classroom viewing.

Logic analyzers have rapidly become an essential tool in industry for designing and troubleshooting digital hardware and software. With the proliferation of computer-based products, it is essential that students interested in electrical and electronic technology become familiar with the capabilities of a logic analyzer. The 1230 comes with a training video tape, two training workbooks, and a training test circuit. A series of workbooks on the fundamental concepts of logic analysis with beginning and advanced logic analyzer application examples is under development.

Designed for industry too!

While we've looked at the 1230 Logic Analyzer primarily from the educational viewpoint, these same features — expandibility, portability, flexibility, ease of use, etc. — make it the ideal logic analyzer for industry as well. The performance required for your complex industrial applications are built into the 1230.

For more information

For more information on Tektronix logic analyzers, contact your local Tektronix Field Office or sales representative U.S. customers can call 1-800-426-2200 toll free for information. And be sure to tell them you saw it in **HANDSHAKE.**

For a data sheet on the 1230 and information on other Tektronix logic analyzers, check the box on the enclosed **HANDSHAKE** reply card.

The Engineering Bench Series — a better way to purchase TM 500/TM 5000 instruments

The Tektronix TM 500 and TM 5000 Modular Instruments offer functionality, configurability, and ease of use to address a broad range of test-and-measurement applications. You can choose from over fifty ready-to-go, compact plug-ins to create multifunction packages for a wide range of applications or to solve unique measurement problems.

Modular test instruments available include digital counters, digital multimeters, a digital delay unit, function generators, pulse generators, signal generators, an arbitrary/function waveform generator, signal amplifiers, audio oscillators, an audio-distortion analyzer, oscilloscopes, oscilloscope-calibration instruments, power supplies, programmable scanners, D/A and A/D converters, a user-configurable development card, and blank plug-in kits for developing your own custom functions. Power for the modular instruments is provided by a variety of TM 500/TM 5000 mainframes — from single to six compartment, manual or programmable — which can be matched to your application and need (see Figure 1).

The TM 5000 Modular Instruments are programmable over the IEEE Standard 488 Interface Bus (GPIB); TM 500 instruments are manual only. Based on a standard form and fit, these modular instruments can be inter-mixed to build the test and measurement system that best fits your application (NOTE: TM 5000 programmable units can only be used in TM 5000 mainframes).

EBS packages for added value

TM 500 and TM 5000 instruments are now available in standard Engineering Bench Series (EBS) packages which provide basic instrumentation for the electronics bench, whether for the R&D lab, production test station, or the classroom. But we also realize that no single solution is the correct answer in every situation. As a result, we offer a variety of packages as well as a flexible "option" plan to allow easy substitution or addition of other TM 500/TM 5000 instruments or Tektronix oscilloscopes.

Why buy an EBS package rather than the individual instruments? One reason is ease of ordering. It's usually easier to write purchase orders and gain funding for a single package than for four or five individual instruments. In addition, you're guaranteed a system with instruments that work together when ordering as a package. Individual instruments may get substituted in the single instrument approach, resulting in a system that isn't designed to work together.

Second is price. Standard EBS packages are offered at up to a 10% cost savings over the same individual instruments when ordered from the catalog.

Another reason for ordering an EBS package is a function of the basic TM 500/TM 5000 Family concept; future expandibility and easy reconfiguration. You can update or expand any EBS package by simply plugging in a new modular instrument. Because of that, your system is never outdated.

Finally, since the EBS packages are based upon the TM 500/TM 5000 Family of modular instruments, they result in neat compact work benches, leaving plenty of room for your projects or experiments. A single connection provides power for up to six modular instruments via the mainframe. With the TM 5000 programmable instruments, up to three individual instruments can be controlled using a single GPIB cable.

Package detail

The following EBS packages are currently available. Additional packages are planned; contact your local Tektronix Field Office or sales representative for the latest listing.

The EBS 501 basic package includes a DM 501A Digital Multimeter, FG 503 Function Generator, PS 503A Power Supply, TM 503A Mainframe, and 2225 Oscilloscope.

The EBS 502 intermediate package includes all of the instruments in the EBS 501 Package plus a DC 504A Counter/Timer. A TM 504 Mainframe is substituted for the TM 503A.

The EBS 503 advanced package adds a PG 501 Pulse Generator in a TM 506 Mainframe to the standard EBS 502 package.

Figure 1. *The TM 500/TM 5000 Family of test and measurement instruments. Even this picture is incomplete as new instruments are being added to the family on a regular basis.*

The EBS 5001 programmable package is designed for applications where GPIB programmability is required. It includes a DM 5010 Programmable Digital Multimeter, FG 5010 Programmable Function Generator, PS 5010 Programmable Triple Power Supply, TM 5006 Mainframe, and a 2430A Digital Oscilloscope.

The EBS 5002 programmable arbitrary stimulus/measurement package includes an AFG 5101 Programmable Arbitrary/Function Generator, DC 5009 Programmable Universal Counter/Timer, DM 5010 Programmable Digital Multimeter, and a TM 5006 Mainframe.

Figure 2. *Electronic Bench Series (EBS) packages offer an easy and convenient way to purchase Tektronix TM 500/TM 5000 Modular Test Instruments. EBS 5001 package shown.*

Want more information?

For more information on these EBS packages or TM 500/TM 5000 Modular Test Instruments, contact your local Tektronix Field Office or sales representative. U.S. customers can call 1-800-426-2200 toll free for information or prices. And be sure to tell them you read about it in **HANDSHAKE.**

Q&A

Q There are so many different GPIB cables available. Is it all right to use the least expensive ones available?

A Initially, these cables might provide satisfactory results. However, the differences between GPIB cables are the result of things which often don't become obvious until you've used them for some time. Typical problems you can encounter with cheaper cables include poor strain relief leading to premature breakage of the shield or signal conductors and poor EMI radiation shielding. To prevent loss of data from your measurements, we recommend use of the following GPIB cables: 1-meter, Tektronix Part No. 012-0991-01; 2-meter, Tektronix Part No. 012-0991-00; 4-meter, Tektronix Part No. 012-0991-02.

Douglas Howard
Measurement Systems Division

Q I found the articles on the PEP 301 Systems Controller in the Winter 1987/88 **HANDSHAKE** very interesting but have a question. Why wouldn't one of the many 386-based personal computers be just as effective?

A You probably could use many of the available 386-based personal computers to perform most of the functions of the PEP 301. However, the result is an upgraded personal computer and not necessarily an instrument controller. To get equal performance you would have to add features that are standard with the PEP 301 (some of these features are only available on the PEP 301): High-resolution, multisynching, VGA-compatible monitor; 80387 co-processor chip; zero-wait state memory; GPIB card with GURU II software; and EZ-BUS Software to assist in writing instrument control software. Even after you add as many of these features as are available, you're still missing one important ingredient for a good systems controller — single-source applications and warranty support. With the PEP 301 you get a toll-free 800 number staffed by test and measurement experts to help with even your most difficult problems. When all of these things are taken into account, a 386-based PC used as a controller may be more expensive than the PEP 301 when you include the time and labor spent configuring and debugging a self-built solution. The PEP 301 is designed to start working via GURU and EZ-BUS with Tektronix instruments right out of the box!

Dave Barnard
Measurement Systems Division

Q I would like to use EZ-BUS with my existing PC-based instrument controller. How can I order it?

A As described in the article **EZ-BUS — converting standard languages into GPIB controller languages** in the Winter 1987/88 **HANDSHAKE**, EZ-BUS is available only as an integral part of the PEP 301 Systems Controller and is not available separately. This is due to the specific system requirements for use of EZ-BUS.

Dave Barnard
Measurement Systems Division

Questions?

Do you have a question on signal measurements? Send it to **HANDSHAKE** Q&A, M/S 02-382, P.O. Box 500, Beaverton, OR 97077, or use the Comments section of the reply card to send in your question. We'll get a personal answer to you as soon as possible and print questions of general interest in future Q&A columns. Your name and name of your company will be used with the printed question unless you specifically request that it be withheld.

Electrical safety

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Safety is important whenever you use electrical equipment — whether in the classroom, in the laboratory, or in the home. In this article we look at some basic safety considerations, particularly as they relate to the safe use of measurement equipment. The accompanying sidebar on ***Third-party safety certification*** *explains why safety certification should be an important consideration when choosing electrical equipment.*

Safety is everyone's responsibility. Nowhere is this truer than when using electricity.

Using electricity is like swimming, in that novices and experts can both enjoy its benefits provided they follow the rules at all times. None of us can fully depend on others to provide a safe working or playing environment. You have more control than anyone else over your activities and the caution you use when participating in those activities.

Practice safety

Tektronix encourages you to learn and follow these general precautions, and to read and follow instructions specific to circuits or equipment you work with.

- Never work alone.
- Learn first aid, especially cardiopulmonary resuscitation (CPR), for electrical accident victims.
- Except when absolutely necessary, turn off power or disconnect power source before working on electrical or electronic circuits. Consider all wires and terminals to be live until proven otherwise by a safe test method.
- Be sure your test equipment is operating properly before using it.
- Do not work on electronic circuits or equipment while standing on a wet floor, or when touching plumbing or metal objects that may provide a hazardous earth-ground path.
- Remove metal jewelry, watches, rings, chains, etc., before working on electrical circuits or equipment.
- Whenever possible, make current and voltage measurements with one hand in your pocket or behind you.
- Resist the temptation to throw a switch "to see what happens."
- Turn off power and unplug equipment before checking or replacing fuses. Locate and correct the cause of a blown fuse or tripped circuit breaker before replacing the fuse or resetting the breaker.
- Replace defective cords and plugs. Form a habit of inspecting for defects such as frayed wires, loose connections, and cracked insulation.
- Always check the electrical ratings of equipment you use, and be sure you use that equipment within its ratings.
- In general, treat all circuits as if high voltage or high current is present.

Safety measures

A primary safety measure is grounding the equipment chassis through a wire in the power cord. This practice is variously referred to as "green-wire ground" (because of the color of the insulation on the chassis ground wire) or "third-wire ground" (because a ground wire is a third wire).

If an internal electrical fault should somehow apply a dangerous voltage to the chassis of an instrument with a grounded chassis, the chassis ground wire would safely conduct the fault current to ground. In the process, the current might trip a circuit breaker or blow a fuse, which would alert the user that the instrument has a problem. But the main reason for the ground wire is to provide a path for any fault current. No fault current will then flow through the user if he/she touches the chassis.

For the reasons just explained, do not cut off the ground terminals of power cords in order to make "floating measurements" — doing so defeats ground protection. (Floating measurements are referenced to a voltage other than ground potential.) Use safety-approved equipment or procedures for such measurements.

The market offers various products, such as the Tektronix A6901 Ground Isolation Monitor and the A6902B Voltage Isolator, that permit floating measurements.

One technique of making floating measurements is to use a buffer to isolate the device being tested from the measurement portion of the test instrument. The Tektronix A6902B Voltage Isolator uses this buffer technique, which extends the range of the test instrument to 3000 volts (DC + peak AC) or 500 volts (DC + peak AC), depending upon the type of probe used.

Another way of making floating measurements is to isolate the power supply of the test instrument from the AC power-line ground reference. The Tektronix A6901 Ground Isolation Monitor uses this method, which allows an instrument's chassis to float up to ±40 volts (28 volts rms) from ground.

Safety symbols as marked on equipment

⚡ DANGER — high voltage.

⏚ Protective ground (earth) terminal.

⚠ ATTENTION — see operator's manual.

Safety symbols in manuals

⚠ ATTENTION — This symbol indicates the location of applicable cautionary or other information in Tektronix operator's and service manuals.

What is electric shock?

According to Stedman's Medical Dictionary, electric shock is "a sudden violent impression caused by the passage of a current of electricity through any part of the body." This says nothing about the magnitude of that current.

The human body is electrically controlled; that is, it operates in response to its own minute electrical signals. Different persons have different resistances and sensitivities to electricity.

We recognize that electric shock is voltage dependent. One does not expect to get a shock from a battery or other low-voltage source. Sources below 30 volts are usually no problem. When voltages above 30 volts are present, precautions to prevent electric shock are appropriate. We must guard against any shock that could be fatal itself, or cause a severe reaction. We even want to prevent perception of the current.

The threshold of current perception is about 0.5 milliamps for 99.9% of the population, according to Charles F. Dalziel.[1] In other words, 999 persons out of a thousand will perceive a current of 0.5 milliamps; one will not.

Cord-connected appliances and equipment usually comply with this 0.5 milliamps leakage current limit. Some industrial equipment may exceed this value. Equipment with greater leakage current is usually marked "Warning — the protective grounding conductor provides protection from electric shock; this equipment must be earth grounded for adequate protection."

The "let-go current" is the maximum current a person can tolerate and still release the conductor by using the muscles directly stimulated by the current[1] — the average is 9 milliamps for men and 6 milliamps for women. The "conductor" is the source of current that the person has grasped.

"Further increase in current up to values that are not well-defined but thought to be on the order of 100 milliamps may cause a fibrillation of the heart," according to K. S. Geiges.[2] He specifies five important parameters, as follows:

Lowest resistance of the body	
Wet skin, outdoors	500 ohms
Dry skin, indoors	1500 ohms
Let-go current for adults	6 to 20 milliamps, AC, depending upon the person
Safe current, adults	
AC (rms)	5 milliamps at 30 volts
DC	5 milliamps at 20 volts

"Current caused by ordinary household voltage (120 V, North America; and 240 V, Europe) will be 240 milliamps (120 V/500 ohms) and 480 milliamps (240 V/500 ohms), showing that lethal shock can occur in the home."[2] Or, we add, in any place where standard electricity is available.

Fuses and circuit breakers will open the circuit under fault conditions. The time it takes these protective devices to open is rather long compared to body reaction times and, as a result, electric shock can result. Ground Fault Interrupters (GFI) are devices that sense current in the hot and neutral AC power lines. If currents are unequal, the difference must be a ground current, which causes the GFI to open the circuit. A GFI can be used to prevent severe electric shock when line current is diverted into a fault. With a GFI installed in the power circuit, a reaction will occur but fibrillation should not result.

"Currents above those possible from ordinary household voltage across a body impedance of 500 ohms (usually in the ampere range) can affect the nerve centers, causing paralysis. The most common effect of paralysis is respiratory failure. (Power linemen are subject to this.) Such current passing through the body causes hemorrhages and burns."[2]

Summary of electric shock effects[1]

Following is a summary of the effects of electrical shock. Also refer to Figure 1.

- Currents above the reaction-current level may cause involuntary movement and trigger a serious accident.
- If long continued, currents in excess of the "let-go current" passing through the chest may produce collapse, unconsciousness, asphyxia, and death.
- An alternating current as small as 20 microamps may produce ventricular fibrillation if injected directly into the human heart.
- Currents in the order of milliamperes flowing through nerve centers controlling breathing may produce respiratory inhibition that may last for a considerable period, even after interruption of the current.
- Cardiac arrest may be caused by relatively low currents flowing in the region of the heart.
- Current in the order of amperes may produce fatal damage to the central nervous system.
- Electric currents may produce deep burns, and currents sufficient to substantially raise body temperature produce immediate death.
- Delayed death may result from serious burns or other complications resulting from severe electrical shock.
- Capacitor discharges in excess of 20 joules (watt-seconds) are likely to be hazardous.[3]

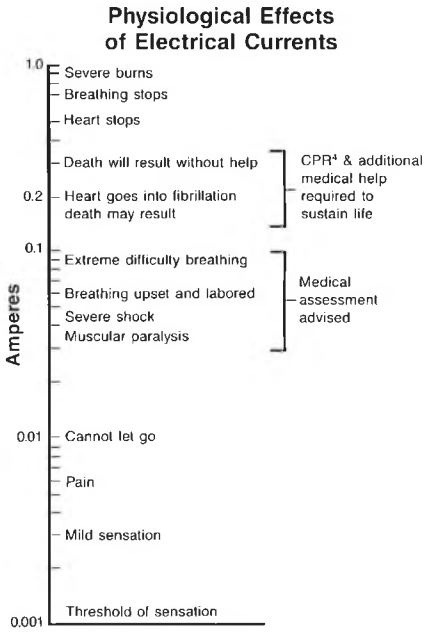

Figure 1. *Physiological effects of electrical currents.*

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1. Charles F. Dalziel, "Electric Shock Hazard," **IEEE Spectrum**, February 1972.

2. K. S. Geiges, "Electric Shock Hazard Analysis," **AIEE Transactions**, Part III-Power Apparatus and Systems, Volume 75, 1956.

3. Canadian Standards Association C22.2 No. 154-M1983.

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J. E. Bridges, G. L. Ford, I. A. Sherman, M. Vainberg, **"Electrical Shock Safety Criteria,"** Pergamon, New York, 1985.

International Electrotechnical Commission (IEC), IEC Publication 479, **"Effects of Current Passing through the Human Body,"** 2nd edition.

Adapted from Tektronix Safety Note 40W-6687 and Third-Party Certification Note 40W-6837. Tektronix encourages you to reproduce this document for student use. Contact your local Tektronix Field Office or sales representative for copies of the above safety notes.

Third-party safety certification

In today's market, with its profusion of competing products and product claims, how is one to decide which products are the safest to buy? Products with a high degree of safety are almost mandatory nowadays. Certain cities have safety codes and regulations stating that only equipment that has been approved can be sold, offered for sale, or used within the city.

Regulations, planning, and effort notwithstanding, individuals still sustain personal injury and property damage still results from the use of products that, in some way, fail to perform as expected. We may well ask, "Why?" Manufacturers claim that their products comply with all standards. But product failures still occur, injuries result, and product failures are often measured in liability dollars.

How can you protect yourself and your organization or school from legal liability for personal injury and property damage?

One way to assure yourself that you are doing all you can to prevent accidents to those who use equipment, and minimize your risk of liability exposure, is to purchase and use equipment that has been tested by an independent, technically expert laboratory and certified to comply with industry and/or regulatory-agency product safety standards.

Equipment tested and certified to comply with industry or regulatory standards by an independent certifying and testing laboratory is said to be "third-party certified." A third-party certifying laboratory is independent and is not associated with either the purchaser or the equipment manufacturer.

Probably the best-known such testing and certifying laboratory is Underwriters' Laboratories, Inc. (UL). Among many other independent testing and certifying laboratories are: Factory Mutual (FM), ETL Testing Laboratories, Inc., and the Canadian Standards Association (CSA), which tests consumer and industrial goods to ensure compliance with Canadian Safety Standards.

What third-party certification means to customers

Equipment that has been third-party certified offers several advantages over noncertified equipment:

Level of safety. Users are assured that third-party certified equipment has a reasonable level of safety because it has been planned, designed, manufactured, and tested to ensure that it complies, and will continue to comply, throughout its useful lifetime with industry product-safety standards. Using third-party certified equipment should reduce the possibility of personal injury to equipment users.

Compliance with regulatory requirements. Because of its certification (usually indicated by a label displayed on the product), third-party certified equipment normally complies with applicable regulatory requirements. An important implication of such compliance is that users are not likely to be deprived of the use of needed equipment due to the lack of proof of compliance with applicable regulations.

Users of third-party certified equipment do not need to have products independently prequalified before purchase; this can reduce costs substantially.

High quality and reliability. Third-party certified equipment can also mean improved product quality and reliability, because its components and design must meet stringent test standards.

Lower insurance costs. Also important in our increasingly cost-sensitive market, use of third-party certified equipment may mean lower insurance costs. Insurance companies are sensitive to liability exposure, and are familiar with third-party agencies and their role in lessening personal injury and property damage by assuring that products comply with applicable standards.

Meet OSHA requirements. Third-party certified equipment should meet OSHA requirements for safety in the workplace for employees.

What could be wrong with equipment that is not third-party certified?

Equipment that has not undergone the planning, designing, manufacturing, and testing that goes into products intended to meet safety standards from the outset may present such safety hazards as:

Electric shock. This is always a concern with electrical equipment. Internal breakdown during use could cause electrical equipment to become "live" and expose the user to electric shock.

Fire. Is the product flammable, or is it likely to catch fire during normal or extended use? Electrical equipment is often left unattended for extended periods, sometimes overnight. During unattended operation, internal breakdown could cause fire inside the equipment. Equipment that is not properly designed or internally protected could allow the fire to escape the equipment and cause a larger, more damaging fire.

Third party certified equipment label

Equipment that has not been tested or certified by a third-party testing facility may well comply with applicable standards and be perfectly safe. But the customer must take the manufacturer's word for such compliance. Verbal assurance may be insufficient for regulatory agencies. Products displaying a third-party certified equipment label assure the purchaser and its insurance company that they comply with applicable product safety standards and regulations. Purchasing third-party certified equipment should result in peace of mind and may result in lower insurance costs.

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For copies of any of these back issues, please use the **HANDSHAKE** reply card included in this issue.

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Climbing the learning curve faster with operation training

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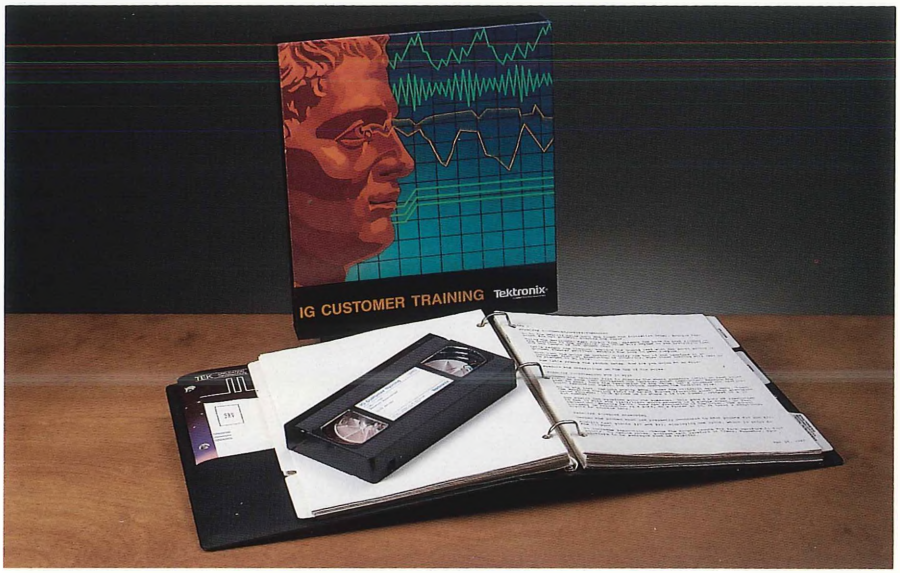

Self-study training packages from Tektronix provide video-based operator training so you can learn at your pace and at your convenience.

Training new instrument operators is an important, yet time consuming, task. Now, Tektronix offers several forms of operation training to help the instrument user gain more competence in less time than learning by trial and error. Operation training is available in a variety of formats to match your needs — video-based self-study packages, on-site workshops at your company, or group workshops in major U.S. cities.

A self-study package has the advantage of being completely time flexible. You can go through it in sections as it fits into your schedule. Want to see a demonstration again? Just reverse the tape and play it again. Want to try that control? Do it in one of the labs that come with the self-study packages.

Workshops add the advantage of a knowledgeable instructor to direct the learning process, answer your questions, or help with a lab. A complete list of regularly scheduled workshops is provided in each issue of **HANDSHAKE**. On-site workshops can be scheduled at a site and time most convenient for you.

For further information, call IG Customer Training: 1-800-835-9433, ext. 430.

On-site workshops provide the advantage of a knowledgeable instructor to direct the learning process, answer your questions, or help with a lab.

Tektronix Self-Study Training Packages

Sixteen self-study programs are available on Tek measurement instrument operation and concepts:

Title	Part Number
Operating the 2225	068-9196-22
Operating the 2213A/2215A	068-9197-22
Operating the 2235	068-9198-22
Operating the 2236	068-9199-22
Operating the 2245/2246A	068-9200-22
Operating the 2210	068-9203-22
Operating the 2220	068-9204-22
Operating the 2221	068-9205-22
Operating the 2230	068-9206-22
Fundamentals of Analog Scopes	068-9195-00
Fundamentals of Probes	068-9201-22
Fundamentals of Digital Scopes	068-9202-22
Using the PC as a Controller	068-0225-22
11301/11302 Measurement and Analysis	068-0232-22
11401/11402 Waveform Measurement	068-0233-22
11401/11402 Waveform Measurement and Advanced Waveform Measurement	068-0234-22

CLASSES AND SEMINARS

Tektronix offers classes and workshops for the convenience of Tektronix customers with application, operational, or service training needs. Here's the schedule of classes and workshops to be offered in the near future.

Product Service Training Classes

Tektronix Service Training provides new technicians the skills and techniques required for effective maintenance of Tektronix products. In addition, it brings experienced technicians up-to-date on maintenance of new products. Call Tektronix Service Training, 1-800-835-9433, ext. WR1407 to register for the following classes.

CLASS	LOCATION	DATES
465B/475A Portable Oscilloscope	Atlanta, GA Irvine, CA	July 25-29 Nov 7-11
2215/35/36 Portable Oscilloscopes	Atlanta, GA Irvine, CA	Aug 1-5 Nov 14-18
2465A Portable Oscilloscope	Atlanta, GA Santa Clara, CA	June 6-17 Sept 26-Oct 7
7904/7633 Laboratory Storage Oscilloscopes	Irvine, CA Atlanta, GA	July 11-22 Dec 5-17
7912HB Programmable Digitizer	Beaverton, OR	Oct 3-14
7854 Waveform Processing Oscilloscope	Beaverton, OR	Oct 24-Nov 11
TM500 Calibration Package	Boston, MA	Sept 12-23
113XX Programmable Oscilloscopes	Beaverton, OR	Aug 15-19
114XX Programmable Oscilloscopes	Beaverton, OR	Aug 22-26

In addition to classroom instruction, Tektronix Service Training has a variety of training packages and video tapes available for self-study. Classes are also available for maintenance of other Tektronix products. Call for further information.

Workshop and class sizes are limited. We recommend that you enroll early. Other classes are planned beyond this schedule. For more information or to register, call the numbers listed above.

IG Customer Training Workshops

Call Tektronix IG Customer Training, 1-800-835-9433, ext. 430 to register for the following workshops.

CLASS	LOCATION	DATES
2230 Digital Storage Measurements	Irvine, CA Dallas, TX	July 12 Sept 13
2430A Advanced Digital Measurements	Irvine, CA Dallas, TX	July 13-14 Sept 14-15
11401/11402 Waveform Measurements	Essex Jct, VT Wash. DC Irvine, CA	June 8 Aug 10 Sept 28
11401/11402 Advanced Waveform Measurements	Essex Jct, VT Wash. DC Irvine, CA	June 8-9 Aug 10-11 Sept 28-29
11301/11302 Measurement and Analysis	Wash. DC Irvine, CA	Aug 12 Sept 30

Most of the above workshops are available in a self-study format. On-site training is also available. For information call 1-800-835-9433, ext 430.

We retain the option to cancel or reschedule classes or workshops.

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