ELECTRONIC Servicing & Technology

AUGUST 1982/$2.25

Shock hazard at the work bench

What is an industrial robot?

The coming age of robotics


Jim Taylor
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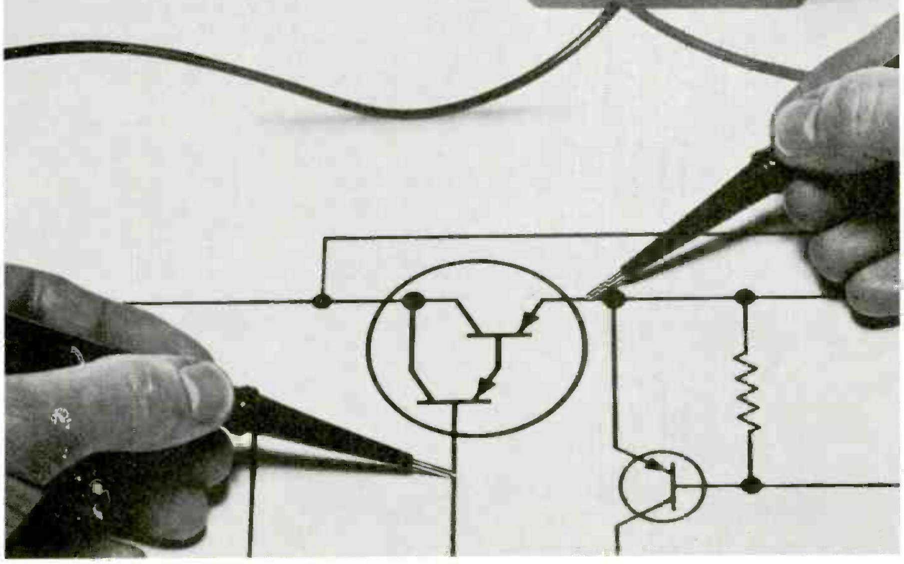


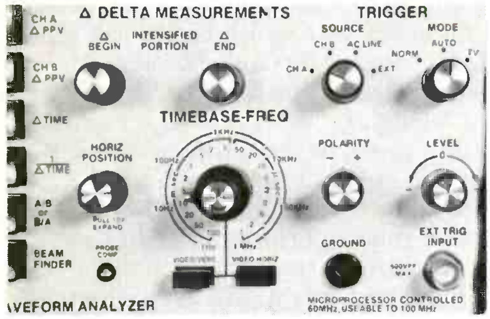
Circle (5) on Reply Card

The how-to magazine of electronics...

ELECTRONIC Servicing & Technology

August 1982
Volume 2, No. 8

The field of robotics is currently revolutionizing industry. See story on page 38. *(Photo courtesy of Thermwood Corporation.)*



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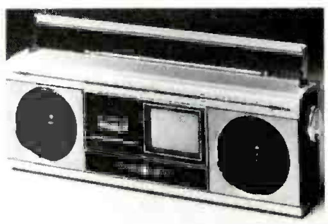
Departments

Next month...



Previewing GE for 1983. Large and small screens, portability and new circuitry are features of General Electric's new line of video and television. This model has a 3-inch television, FM-stereo and AM-radio reception, plus a stereo microcassette recorder/player. A step-up model with similar features permits the microcassette to be removed for headphone listening.

EDITORIAL

Almost every magazine, newspaper article or special issue that discusses robots starts with a mention of the play *R. U. R.* (Rossum's Universal Robots) by Karel Capek. This issue will be no exception.

Actually, the play, and the concept of robot in the play, have almost no applicability to robots as they are developing in the real world today. But mention of the play is important, because it is from *R.U.R.* that our language got the word *robot* in the first place. It comes from Capek's native Czech word *robit,* or *robota,* which literally means *work.*

According to Harry Domin, general manager of *R.U.R.,* Rossum was mad and had wanted to play God and to create real humans. The material for these beings was a substance synthesized by Rossum that behaved like living matter but had a different chemical composition. After his father's death, the young engineer chose to manufacture the beings as cheaply as possible, with the least requirements. He rejected man and made the robot, an entity mechanically more perfect than humans, with highly developed intelligence, but no soul.

In Capek's dark view, these beings, secretly altered in character by one of *R.U.R.*'s scientists, revolted and turned on humans, whom they hated utterly.

The concept of *robot* has since been used extensively in fiction to describe anything from a simple machine to one that can barely be distinguished from a human (and is frequently portrayed as superior in many respects).

The idea of robots tends to instill fear in people. Many see them as monsters, just waiting to run amuck. Others see them as usurpers, being built by the thousands to take the jobs of deserving humans.

It is perhaps unfortunate, if understandable, that industry, the technical/scientific community, commerce and government have chosen to apply the word robot to that class of machine that is capable of performing functions that humans perform (roughly described as manipulation) and that is also programmable; that is, it can be readily readapted, without hardware changes, to perform a new task. It is unfortunate because the term robot conjures up dark visions of our worst fears about automata, into which real-world robots just don't fit. It is understandable because the motion of a sophisticated robot uncannily mimics the motion of a human.

Harry Domin's vision of the ultimate effect of *R.U.R.*'s robots was of a world in which all of humankind would be turned into a kind of aristocracy, with robots performing all of the dirty, messy, dangerous, repetitive, mindless tasks. In the play, that was not to be. Those who today are either manufacturing or applying robots also profess a belief that the ultimate effect of robots will be to free humans from the drudgery and discomfort of the worst of industrial jobs. They foresee that the numbers of people replaced by robots will be more than compensated for by vast numbers of jobs being opened in the robot industry.

We hope that the robot-related articles in this issue will help readers gain some perspective on the current state and possible future direction of the robot industry. *R.U.R.* was fiction. Capek's robots are dead. Today's real-world robots are highly advanced machines that are being developed and applied to industrial production along with other modern technology.

Nils Conrad Persson

ELECTRONIC SCANNER

Anti-scanner law in Philadelphia is declared unconstitutional

The city of Philadelphia recently began enforcing a 1967 ordinance that was actually enacted before the scanner radio was invented in 1968. By interpreting the law to apply to scanners, the city attempted to make it illegal to sell, possess or use a scanner radio – even in a private home – within the city limits. Although the law has been in effect for 15 years, it was not enforced in Philadelphia until last fall, when several owners and employees of retail stores were arrested for selling scanners. It was the only area in the country that had such a restriction.

In dismissing charges against the defendants, Municipal Court Judge J. Earl Simmons Jr. determined that Section 10-817 of the Code of Philadelphia ordinances (anti-police radio receiver case) is unconstitutional as being beyond the permissible scope of the police power of the city council and as being unduly oppressive upon individuals. The judge ruled that the citations charging summary offenses should be dismissed and the defendants discharged.

Summer Consumer Electronics Show reflects industry growth

The increased number of attendees, exhibitors and new product introductions at the 1982 International Summer Consumer Electronics Show (CES) indicates that this industry will remain the most dynamic of the 1980s.

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FEEDBACK

History of ES&T

Your letter* spoke of the time, 30 years ago, when **PF Reporter** was organized and later became **Electronic Servicing.** My time goes back to the late 1930s when we, (RSA), in Chicago, induced Sandy Cowan to organize a magazine for radio service men, which was known as **Service.** We organized enough subscribers to make it worth Sandy's time to publish the magazine. I was the national treasurer of RSA at that time and a board member in Chicago.

Later on, Sandy sold **Service** to **PF Reporter,** which in time became **Electronic Servicing.**

I have enjoyed all three magazines since about 1939 or 1940, so I predate you a bit.

H.W. Cunningham
Port St. Lucie, FL

P.S. I have been retired in Florida for the past nine years but like to keep up on the latest techniques anyway.

*Letter to subscribers about the merge of **ES&T** and **ET/D**.

Building an air compressor

Regarding page 56 of the May 1982 issue, "Building an Air Compressor"–you **NEVER** set up an air compressor without a safety (or relief) valve in the system to protect against control failure and explosion!

This is an essential part–in fact, an acceptable system could incorporate a safety valve without a pressure control. Some commercial units are sold that way.

Regarding the "about $100"–if one hunts, and particularly if he looks for sales, commercial units can be bought for about this amount.

If blowing dust in electronic equipment is the objective, there should be cleanliness advantage in buying one of the oil-less 30 to 40psi spray paint units, which will deliver adequate pressure and oil-vapor-free air. In fact, if duct blowing is the objective, pressures on the blast nozzle should be limited to some 30psi by a pressure control valve or OSHA-type nozzles, which reduce blast velocity to "safe" levels, should be used.

One other condition–I do not know the internal design of the York-Ford air conditioning compressor. But freon is completely miscible in oil and these compressors are designed with the fact that oil will be circulating with the gas being pumped. One should worry about lack of lubrication, or the "pumping of oil into the air discharge," or both.

Compressors designed to pump air are designed to handle the lubrication and low oil content in the air discharge problems.

Harry Kottas
K-Service
Steelville, IL

Stereo amplifier repair

After reading Carl Babcoke's article on repairing the Marantz 2325 receiver (April 1982), I must disagree with the conclusions drawn. I learned many years ago that you do yourself and your customer a disservice by attempting to repair a product that you are not familiar with, that is very complex and that you cannot obtain original parts for. He seems to draw the opposite conclusion; that is, you can attempt repairs on anything as long as you use proper techniques and are careful.

Let us look at a few points in the article that dramatize my point. From the initial inspection, he concludes that each channel could produce approximately 100W, yet he connects to this unit two speakers in small baffles. Later on he states that he ruined two speakers while testing the unit. This certainly cost him money and reduced his profit margin. My test speakers are capable of handling high power levels. I have serviced 2325s with the same problem as his. The noises they make sound like a major explosion, yet, I have never damaged a speaker. In case the relay protection of the circuit amplifier fails, I also have a protection circuit built into my test panel. Its relay opens if an excessive dc level appears.

Babcoke suspected an intermittent bias adjust control R740. He states that he had to drill the board to make a replacement fit. This has to take extra time and certainly makes an unprofessional-looking job. After all this, R740 was not bad after all. I have not always had the correct part either, but I've found that I can solder something above the board or to the back to use as a check, and then order the correct part if needed. I just do not think that it is fair to the customer to make modifications to the circuit board that are unnecessary. I suspect that the proper control could not be installed now if it were available.

Concerning the slip of the test probe, I am certainly in sympathy with him here. I've done the same thing. A little slip, a little pop, a whisp of smoke, and you know that you have cost yourself another hour or so. A trick that I have learned to minimize these disasters is to put a 100 or 150W light bulb in series with the ac line. This limits the maximum current that the unit can draw, and usually saves the output transistors.

Now let's examine the solution to this problem. Babcoke states that suitable replacement transistors were found. I just can't agree with this, and I'm sure Marantz would be horrified. I have found very few instances in which a unit with a replacement transistor would meet its specifications. I do not mean by this that the unit would sound bad on your small test speakers, but I doubt that it would be within power and distortion specifications at rated output.

Replacement transistors usually cause some ringing or other glitches to a sine wave at rated power. By using replacement parts, he has done a disservice to his customer by returning to him something less than he originally purchased. I noticed also that Babcoke stated he shorted two original outputs. Surely he did not mix two replacements with two original transistors. (Each channel uses

(continued on page 61)

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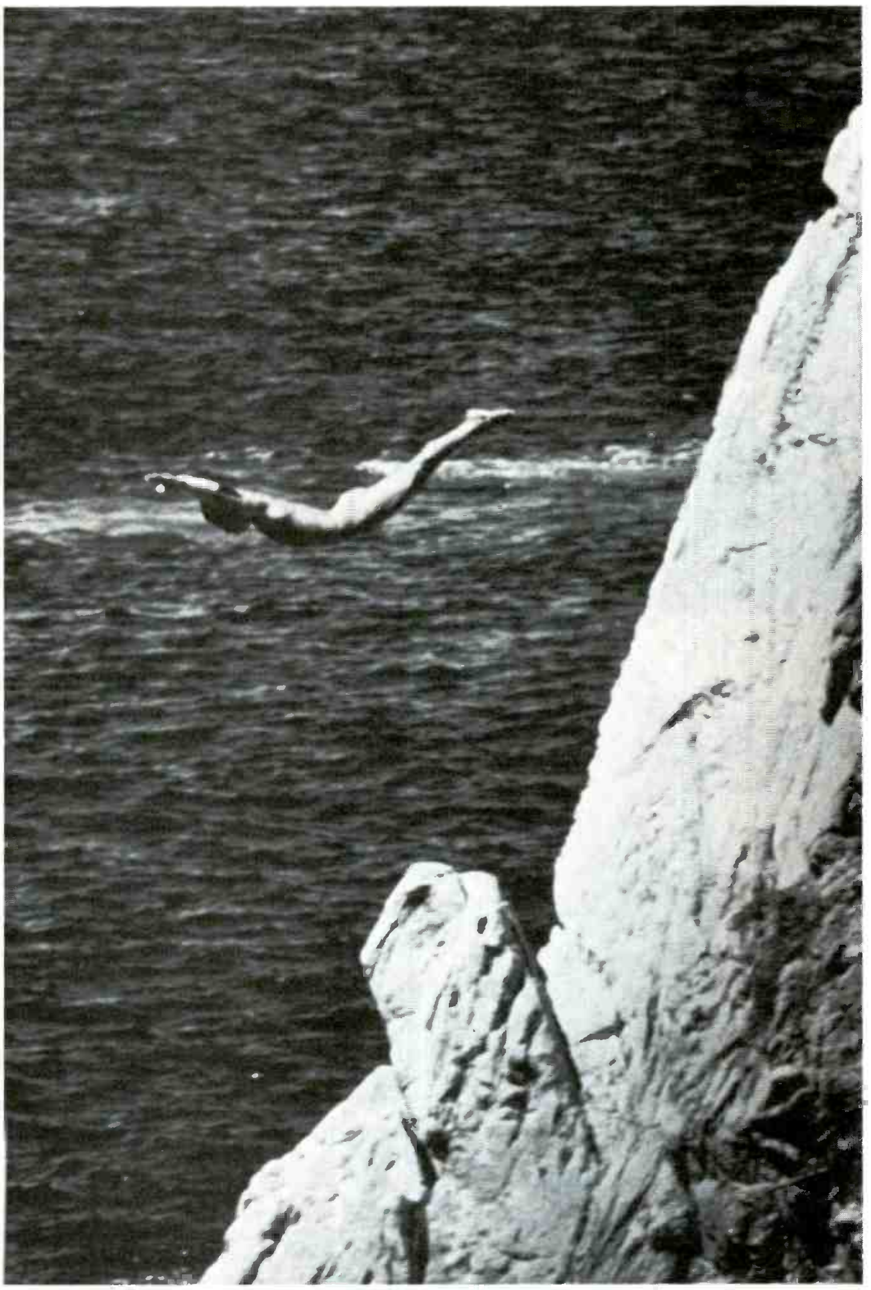

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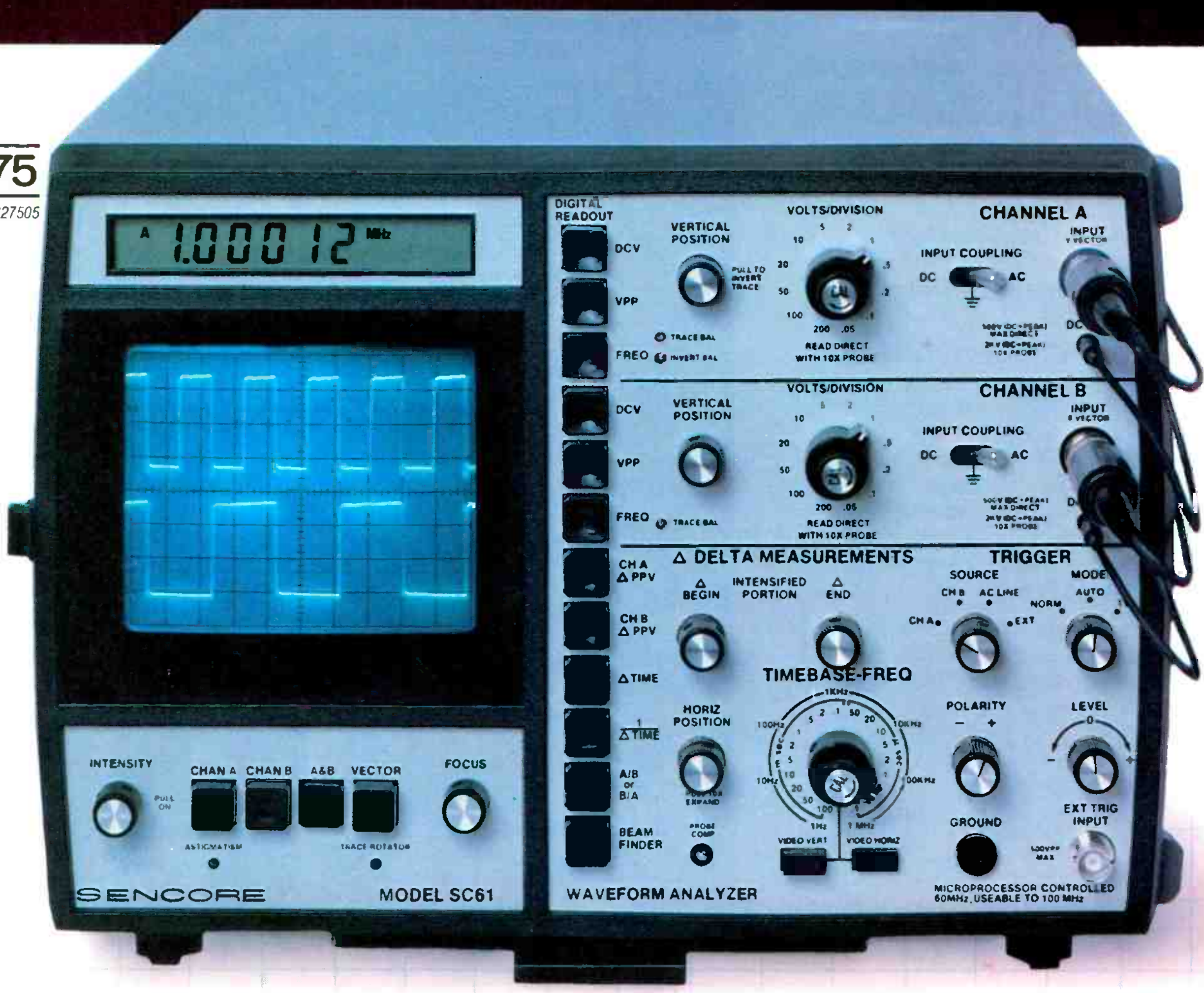

Sencore SC61 60 MHz Waveform Analyzer.

The intelligent-machines industries

The state of the art

By Carl Helmers, editor, **Robotics Age**

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The intelligent-machines industries are new. This newness is not tied to an exact date of birth, but rather to the growing realization of their importance. Recent developments in the history of technology have helped spur their birth as a body of thought and practices.

In electronics we think of the progression from the first transistor to today's large scale integration of 64Kbit chips, or the 16bit microcomputer's processor that is contained on a single chip. In mechanical fields, we think of the continuing improvements in areas ranging from materials engineering and manufacturing arts to the interfaces of electronic and mechanical systems. In the aerospace field, the use and design of intelligent machines are universal. At one end of the spectrum, we think of the modern digital autopilot in its commercial and experimental forms; at the other end, we think of the autonomous robot cruise missiles and their peaceful counterparts in interplanetary space probes. In the world of consumer goods, we see wonders ranging from electronic games to self-diagnosing automobiles, intelligent kitchen and household appliances to personal computers and calculators.

There is a common thread that binds all these technological trends together – the use of computers to implement the artificial approximations of intelligent behavior

The "robot" pictured here is one of several seen at such conventions as the National Association of Broadcasters convention in Dallas. This model is actually remotely controlled by a human operator, as well as equipped with a radio so the operator may make it seem to speak. It is intended as a showstopper. Most robots in development today do not look like this and serve to perform repetitive rudimentary production tasks. ES&T.

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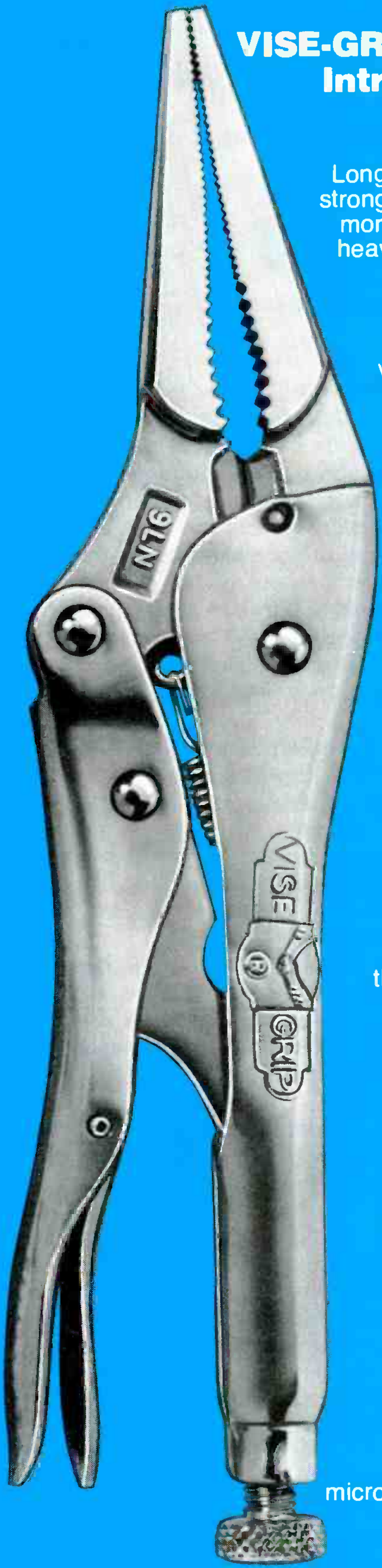

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*U.S. patent D261,096.
Other U.S. and foreign patents issued and pending.

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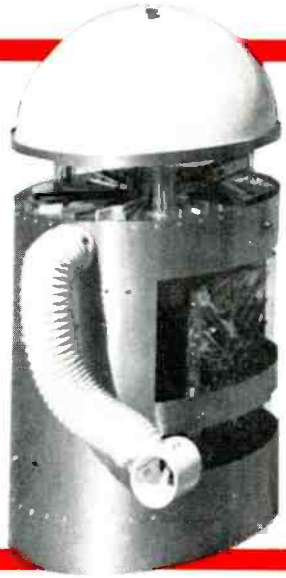

The word robot has become a recent code word for manufacturing automation that uses flexible, reprogrammable manipulators.

demanded by these real-world systems. Computers and their applications are at the heart of these new industries. The challenge is to utilize inexpensive modern computer powers in cost-effective and innovative ways. Computers have rapidly broken out of the conventional mold of blithe and innocuous data processor. They have entered the real world of designs once confined to science fiction dreams.

An informal survey

The intelligent-machines industries are really a collection of tools, practices and design approaches involving application of computer systems techniques. The industries we include in this area of computer application are several. All involve automation. All involve use of computers and software techniques to achieve specific applications of general-purpose computing elements.

Manufacturing

Machine intelligence is becoming essential in the manufacturing industries. There the word *robot* has become a recent code word for manufacturing automation that uses flexible, reprogrammable manipulators. But intelligent machines in manufacturing are hardly limited to manipulators and the automated production line: the whole area of computer-aided design and sophisticated computer-aided manufacturing requires the application of intelligent machine engineering disciplines.

The products that result from the manufacturing uses of machine intelligence vary. The purpose, improving and enhancing manufacturing productivity, remains the same in all cases. The computer-aided design installation provides software and tools that enhance the ability to create manufacturable designs. The numerically controlled machine tool can take the instructions from that design facility and build the tooling necessary to produce parts from the design. The robot arm manipulator can then be employed in numerous tasks that use the tooling in a production process. At all levels of the process, machine intelligence in the form of software for computer systems is a key element.

The economic justifications of manufacturing automation developments are obvious and unassailable: The newer techniques can result in real productivity and cost improvements with very short payback periods. The inherent charisma of such automation is the tantalizing prospect of the totally automated factory, the ultimate capital good. The results impact on all other areas of human endeavor.

Consumer products

It's one thing to apply the intelligent-machine concept to the process of manufacturing. Going one step further, we begin to see more and more use of machine intelligence in the objects being manufactured.

In the late 1970s, we saw microprocessor-controlled sewing machines, microprocessor controllers for microwave ovens and all manner of intelligent toys. In the 1980s, the first big orders were made for microprocessors as intelligent system controllers in automobiles. And toys have certainly become much more sophisticated.

The ultimate consumer application of intelligent machines is the domestic-servant robot. The more "practical" skeptics would rightly respond "show me." We can't predict when, but with a past record of turning science fiction into technology fact, it must happen. A whole cottage industry of tinkerers and experimenters is already at work trying to perfect prototypes of this ultimate appliance.

Civilian and military aerospace products

Intelligent machine concepts have been part of the aerospace electronics design field for the past several decades, sometimes evolving with the technology, and sometimes being forced to evolve by aerospace applications of the technology. The latest in flight instrumentation for military and civilian aircraft epitomizes the use of contemporary intelligent machine design.

An airline pilot once described to me the sensation of flying in the cockpit of a Boeing 747, a design that is more than a decade old. In

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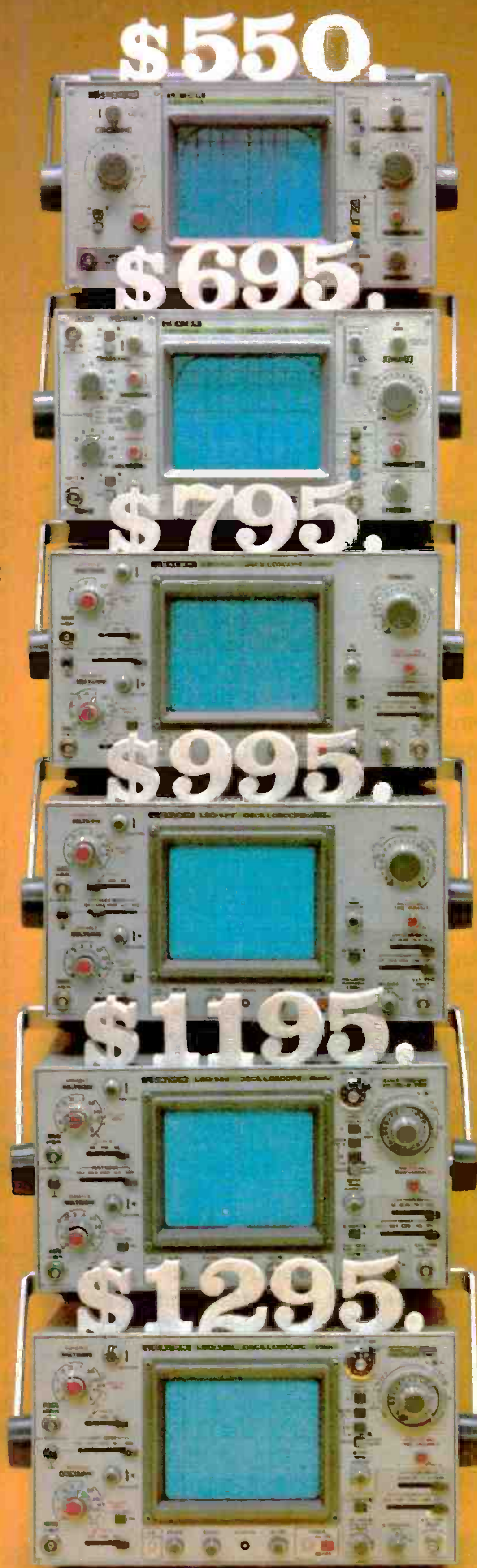

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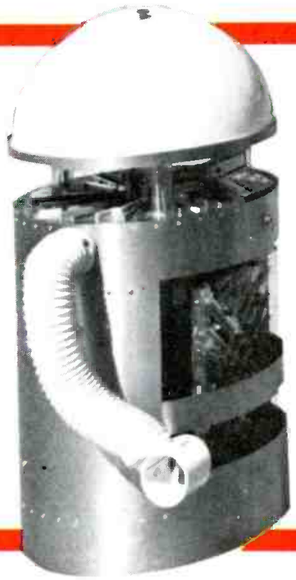

The intelligent machine is a major factor in the recovery of increasingly scarce resources from our planet's mineral trove.

effect, he said that "you dial in the numbers, sit back and relax while the plane flies itself from New York to London."

Although that statement is somewhat exaggerated, the trend is quite real. There are inertial navigators and satellite navigation systems of unprecedented accuracy. Cockpit automation computer systems planned for the next generation of planes allow use of 2-man crews. And there are existing instrument landing systems and projected collision avoidance systems that will greatly improve the safety aspects of flying.

Then there's the defense industry's latest – the cruise missile – a much-improved version of the World War II German "buzz bomb" system. This autonomous flying robot has but one purpose – reaching its target under active, self-generated guidance to deliver a bomb. But the same class of algorithms that makes this weapon so effective in the face of hazardous terrain has peaceful uses as well. We will eventually be able to teach an automobile to drive from point A to point B, saving lives that would otherwise be lost.

Natural resource recovery

The intelligent machine is a major factor in the recovery of increasingly scarce resources from our planet's mineral trove. We can save lives and lower costs by using a sort of intelligent teleoperator for mining activities. This, however, is only an immediate and obvious use.

The abstract field of artificial intelligence seems far removed from the physical reality of such projects, yet it has already entered into the field of resource recovery. Significant work is under way in the area of "expert systems," specifically as underwritten by oil exploration budgets. The analysis of a complex spectrum of data taken from seismic prospecting is ripe for automation, and "expert" analysis of oil field data could greatly improve the process of exploration.

Analysis of earth resources data with software that employs scene recognition, image enhancement and other techniques of computer-aided analysis is still another area. Expert systems research in artificial intelligence is not confined to one field of expertise. It borders on the general theory of knowledge representation and the act of getting to information in databases.

Research

All of this leads up to an important "application area" of the intelligent machine engineering culture – research into the limits. As with all frontier activities, the border between generally accepted engineering practices and the wild land of new techniques is continually being pushed back. Research into the use of computer sensing, planning and controls is one of the most important areas of future applications of the technology.

Research into the limits of intelligent machine design can take many forms. At one level, it is the amply funded research of the professional working in the context of a manufacturer, an industrial research organization, academic institution or a government agency. At the other end, it is the scantly funded innovation of the imaginative tinkerer with a personal computer, a knowledge of electronics and a willingness to experiment with a particular application.

Everyone has had the opportunity to read science fiction. Few have had a chance to implement it. The exploration of new functions in a research environment is a major source of the excitement of the field. Getting a computer program to play at grand-master chess levels is a feat of machine intelligence. Having a mobile robot map its environment and feed itself is an act of machine intelligence that marks a great accomplishment for the machine's designer.

Exploring new uses of robotics in factory, laboratory or even domestic projects is a reward unto itself. The designers and innovators of the industries that are just now in the early stages of existence recognize the opportunities, as intelligent machines become an ever more important part of every day existence.

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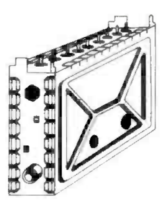

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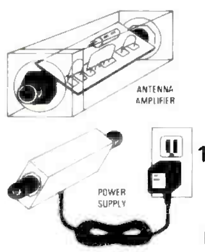

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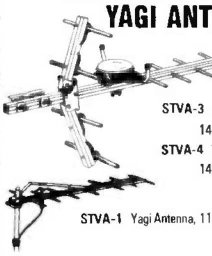

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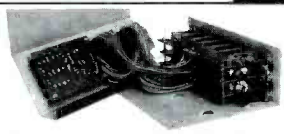

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Reports from the test lab: the Sencore SC61 Waveform Analyzer

Each report about an item of electronic test equipment is based on examination and operation of the device in the **ES&T** *laboratory. Personal observations about the performance of new and useful features are highlighted, along with tips about using the equipment for best results.*

By Carl Babcoke, CET

Figure 1 In addition to many wideband scope features, the Sencore model SC61 has an LCD digital readout that provides two general classes of measurements. Most digital readouts are obtained by pressing one button for each, following the normal scope-waveform adjustments.

Although it has a family resemblance to its predecessor, the model SC60 scope, the Sencore SC61 (Figure 1) has several new features that can shorten diagnostic time significantly, while providing improved accuracy of readings.

The external evidence of these unusual features is the LCD readout, located above the CRT screen. Some other scopes have digital-multimeter (DMM) functions added to them, sometimes as a piggyback but separate unit with its own test leads. That is not true with the SC61. The LCD readout displays some DMM functions (without current or resistance measurements), but the signals come through the scope probes.

Two types of measurements are displayed on the LCD digital readout. Push-buttons for each A and B vertical channel select the *Auto-Tracking Digital Tests.* These are dc voltage, ac peak-to-peak voltage, repetition frequency, and the ratio of signal frequencies in channels A and B. All ranges of these functions are selected automatically by the scope (autoranging).

In addition, another four push-buttons select *Delta Digital Tests,* which involve measurements of time (and calculated repetition frequency) between operator-selected points on various waveforms.

General specifications

Basic features and specifications of the SC61 functions will be condensed here, since they are similar to the SC60, which previously has been described in detail.

The rectangular CRT has the usual 8x10 graticule lines of about 0.9cm/div. plus numbers and dotted lines marking the 0, 10, 90 and 100% points for rise-time measurements (Figure 2). These graticule lines are between the CRT glass faceplate and the phosphor coating. This internal graticule is an excellent feature that completely eliminates parallax errors in visual readings.

CRT acceleration voltage is 6kV regulated. No noticeable blooming occurs at high screen brightness, and trace sharpness and brightness are very good.

A beamfinder push-button reduces both horizontal and vertical gains to make visible any waveforms that cannot be seen because of incorrect centering or when the waveform is difficult to see (such as fast-rise-time pulses).

The two vertical-amplifier channels are identical, except the Channel A waveform can be inverted by pulling out the vertical-position knob (a helpful feature in many cases). Frequency response is specified at 60MHz at ±3dB but useable to 100MHz. With ac coupling, the low response is −3dB at 10Hz; but with dc coupling, the low response is flat to dc.

The 12 calibrated sensitivity ranges in a 1-2-5 sequence (plus a variable control) provide tests from 5mV/div to 20V/div when an optional direct probe is used (Figure 3 shows the panel). Probes supplied with the instrument are non-switchable 10X-loss types, and the panel calibrations match the probes by showing maximum sensitivity of 0.05V/div to 200V/div. This is a convenience because it is

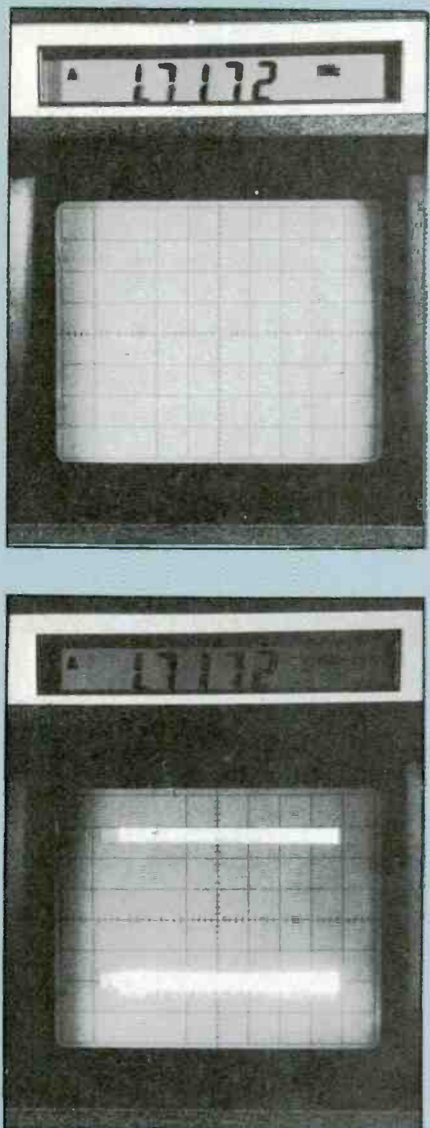


Figure 2 Figures used for rise-time measurements are placed along the left edge of the CRT screen, which has an internal graticule. Although the top picture shows no scope waveform, the LCD readout shows a 1.7172kHz signal of some type. When the beamfinder button is pushed (above), the signal is revealed as square waves or pulses of excessive amplitude. Because the rise time is so fast, the faint vertical rise and fall lines are invisible in the top picture.

not necessary to multiply each scope measurement by 10. Seldom is more sensitivity needed for video or TV machines, but the full 1600VPP, full-scale capability produced by the 200V/div range is needed vitally for testing HV pulses in solid-state color televisions or the vertical output pulses in older tube-type receivers.

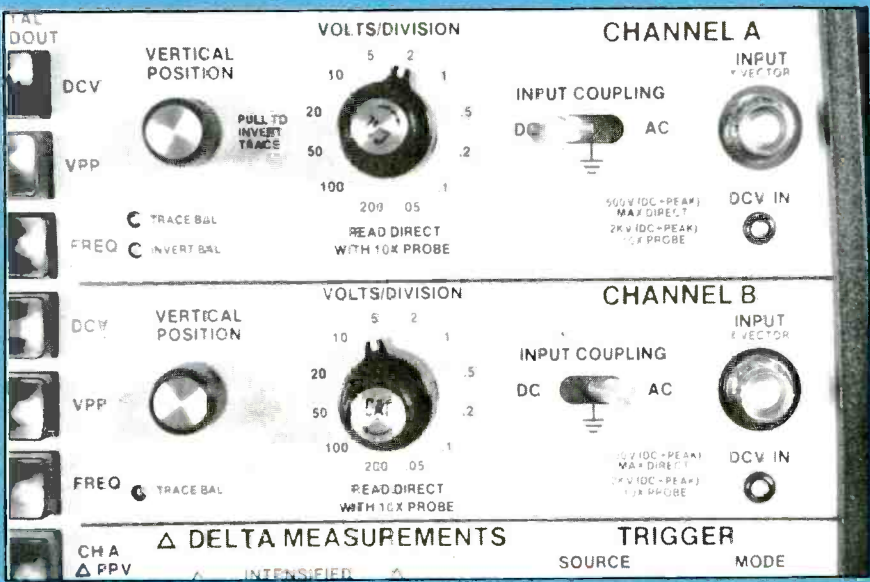


Figure 3 Layout of the vertical-channel controls is shown in this photograph.

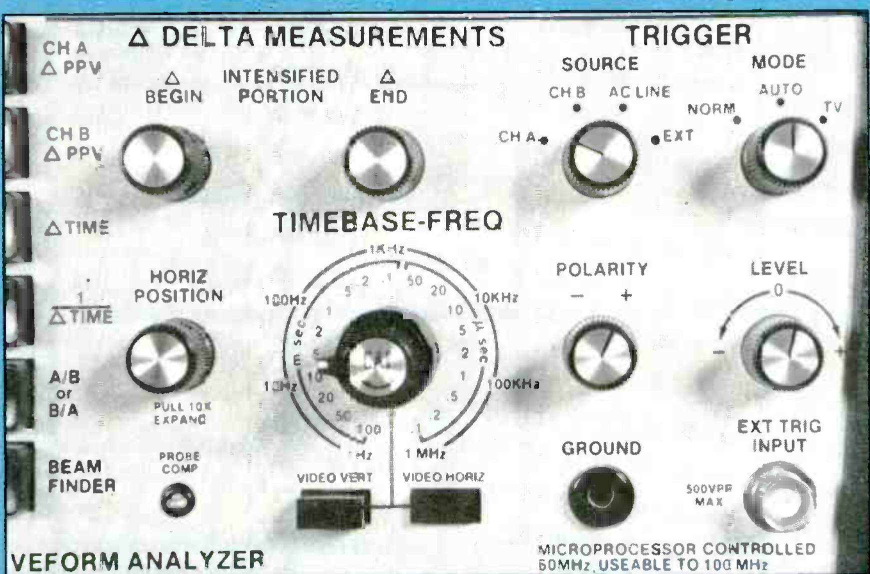


Figure 4 Horizontal-sweep time and triggering controls on the SC61 panel are grouped for easy access.

A 70nS delay line is included following the dual-channel diode switching. This delays the vertical to the CRT, while allowing the undelayed previous-stage signal to trigger the sweep. Therefore, the triggering edges of pulses are not cut off, but can be seen. Remember, the correct name of this feature is *signal delay*, which is completely different from *delayed sweep*, a feature found in some lab scopes.

Either or both vertical channels can be selected by push-buttons located below the CRT screen. Pressing the A&B button gives dual-trace operation in chopped or alternate mode (according to sweep-time selected). There is a method of forcing the sweep into alternate mode when desired. Signal waveforms of both channels are added together algebraically when Channel A and Channel B buttons are pressed simultaneously. The *addition* changes to *subtraction* when the Channel A signal is inverted by pulling out the vertical-positioning knob.

When the standard 10X probes are used, the vertical channels are protected to a 2000V total of dc voltage plus ac peak voltage. Pressing the *vector* button provides vector-type X and Y displays.

Horizontal sweep has 19 calibrated ranges (plus an uncalibrated variable control), giving sweep times between 0.1μS/div and 100mS/div (Figure 4). Pulling out the horizontal-positioning control gives the effect of a 10X decrease of sweep time, but at the price of reduced trace brightness.

The video-preset position (with the timebase-frequency knob pointing straight down) provides several cycles of vertical or horizontal video (selected by two buttons). These cycles can be reduced to the usual two by rotation of the variable time control. The internal sync separator (which is indispensible for video signals) is activated by this video-preset position (also by one position of the mode switch).

Triggering can be obtained from any of four selected sources, including the internal sync separator. When the TV or video mode (with sync separator) is selected, internal blanking removes the vertical-retrace section of composite video, thus removing the confusing blanking and equalizing pulses found in most scope waveforms (Figure 5).

According to Sencore information, special ECL-logic and differential-coupled stages provide stable triggering of all signals, including digital wavetrains that usually are difficult to lock. During our tests, the triggering was rock-steady at all times.

Auto-tracking operation

Any of four functions can be selected by the A/B or B/A button (one above the bottom in Figure 6) or the three buttons for each vertical channel. These are the four auto-trace functions: dcV; acV peak-to-peak; repetition frequency and the frequency ratio of the A and B channel signals. All these functions are autoranging; no adjustments (except the usual scope locking) are needed or possible.

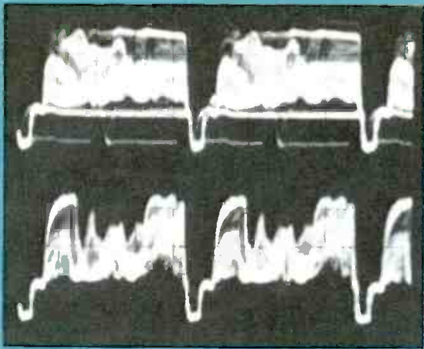


Figure 5 The video waveform at the top was photographed from the SC61 when the TV/video sync separator feature was not used for triggering. Notice the faint ghost-like lines from the vertical blanking and equalizing sync pulses in the waveform. When the same signal was triggered from the internal sync separator, those obscuring lines were eliminated, giving a clearer waveform.

Peak-to-peak acV. These readings cover the entire waveform, including any overshoot or ringing. Sometimes technicians ignore these unwanted sections of waveforms, knowing they do not affect the circuit operation. Remember that the LCD readout includes them, and thus make any needed mental allowances or observe the scope waveform and disregard the LCD readout. Except for these few exceptions, the PP readings on the LCD display are many times more accurate than readings obtained by conventional visual methods from the CRT screen.

Ranges of 0-8V, 8-80V, 80-800V and 800-2000V peak-to-peak are direct reading with the 10X standard probe. Also, they are autoranged to give best resolution.

Bandwidth of the peak-to-peak conversion circuit is said to equal or exceed the vertical-channel bandwidth, and these tests appear to verify that statement. I don't know of any other digital-readout, peak-to-peak instrument that can cover this 60MHz range.

Signals for the peak-to-peak converter are taken from each vertical channel before attenuation by the range switches. One precaution: The signal level must be high enough to give a stable scope pattern, or adjustments of the scope-waveform controls have no effects on the PP digital readouts.

Dc voltages. Inputs for the four automatically selected, LCD-dis-

Figure 6 A vertical line of push-buttons is located at about the horizontal center of the front panel. The top six allow digital Vdc, PPac and frequency readouts from the two vertical channels. Four of the lower six buttons are for the Delta-time measurements, one is the frequency-ratio button and the bottom one activates the beamfinder.

Figure 7 Below each probe socket on the SC61 front panel is a small banana plug that receives dc voltages from the probe. An optional dc-voltage probe can be plugged in, if the scope probe is not desired (for lower-loading measurements).

played dc-voltage ranges are obtained from the same 10x scope probe. However, they are not obtained from the vertical-channel preamplifiers as is done with the PP signals. Instead, separate plugs and sockets at the scope end of the probe cables (Figure 7) bring in dc voltage from the probe, after capacitance isolation by a resistor inside the probe, to another multiplier resistor inside the scope. When DMM-type dc-voltage readings are desired without the scope probe, a 39G157 probe (supplied with the scope) can be plugged in either small banana plug.

For signals that enter the 10x scope probe, the ac/dc impedance of the scope function is 10MΩ, and the dc resistance of the dc-voltage LCD readout is 15MΩ. The total impedance with both functions is about 6MΩ. Either of these functions can be operated alone when higher input impedance (lower loading) is needed. Fortunately, the LCD-circuit dc-voltage wiring does not add any significant capacitance (that would cause a smeared waveform) to the scope's input signal.

Adjustments to the scope-waveform controls have no effect on the dc-voltage readings.

Frequency measurements. The third push-button of each vertical channel connects a special type of frequency counter (actually two separate counters so the ratio function can operate). The main counter takes a signal from the CRT-signal triggers. Therefore, the counter is not confused by video signals and others that have many frequencies present simultaneously.

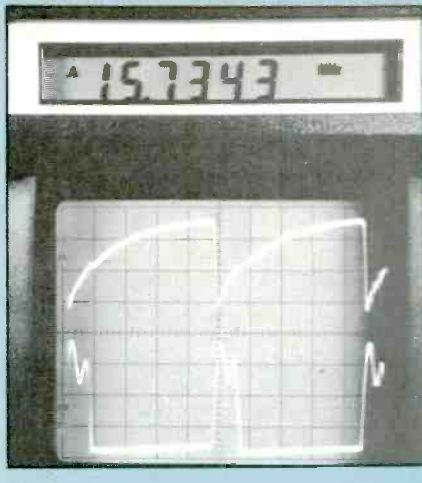
There are no controls to adjust for either frequency counter because of the autoranging and other automatic circuits, and the stability and convenience of these frequency measurements were outstanding.

Frequency coverage of each counter is 1Hz to 99.9MHz, in seven ranges. As many as six digits are provided by the readout when needed, and digits are blanked when not needed. Resolution of 0.01Hz is provided up to 99.9Hz, 0.1Hz to 99.9kHz, 1Hz to 999.9kHz, 10Hz to 9.99MHz and 100Hz to 99.9MHz.

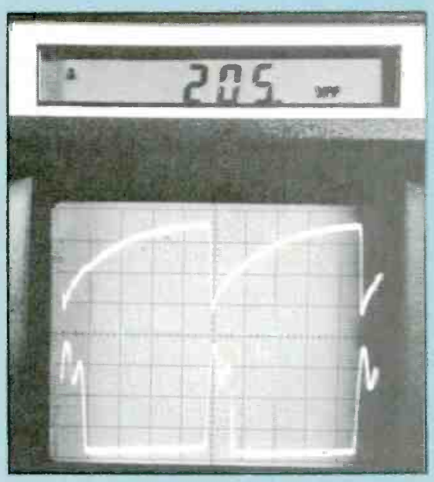
Rated accuracy of the SC61 frequency counters is 0.001% at room temperatures. This is sufficient for measuring or adjusting all oscillators except oven-temperature-control crystal types used in communications or broadcasting under FCC rules.

The SC61 counters are compensated by video blanking to give accurate readings of interlaced-scanning composite video and sync from such video. Small errors are produced when non-interlaced signals are tested. The Sencore operation manual explains these few exceptions.

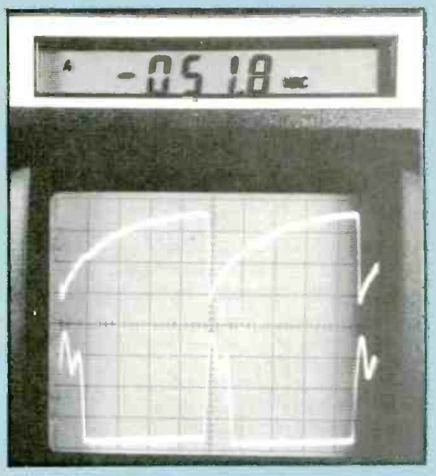
Voltage and frequency readings illustrated. Figure 8 shows the same waveform during consecutive LCD readouts of frequency, peak-to-peak voltages and dc voltages. The readings are from a 6JE6 horizontal-output-tube grid drive (top waveform; horizontal pulses below are for comparison).



A



B



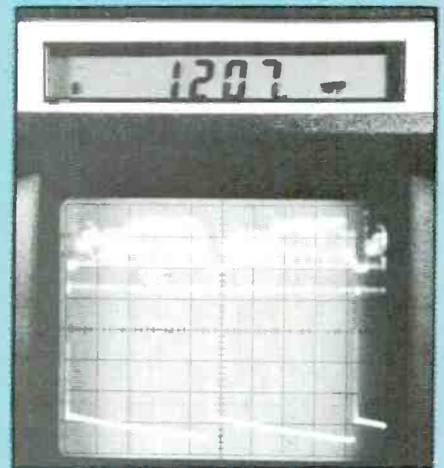
C

Figure 8 The top waveform shows the grid waveform of a 6JE6 horizontal-output tube, while the lower trace shows high-voltage pulses for comparison of phase. All LCD readouts were for scope channel A (the grid-drive signal). (A) The frequency-counter function showed 15.7343kHz (sometimes 15.7344kHz). Notice the A (for channel A) and the kHz annunciators in the readout. (B) Without any change except pressing the channel A VPP button, the display read 205VPP. (C) Pressing the DCV button gave a -51.8Vdc reading. This performance was convenient and highly accurate.

No probes were moved. The three readings were obtained by activating the three push-buttons in sequence.

Also, notice the small capital A in the upper left corners of the LCD readings, indicating the reading was for Channel A. Annunciator readouts at right of the digits show the frequency reading was in kHz, the ac reading was in VPP and the minus reading was in volts dc.

A



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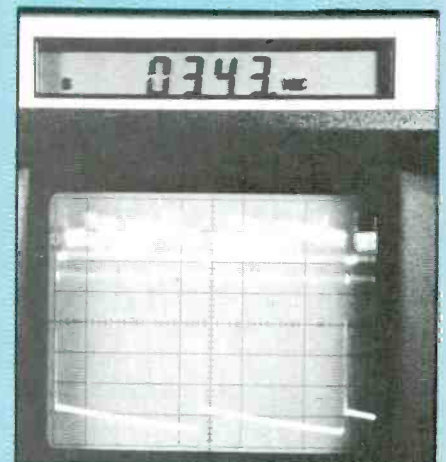


C

Figure 9 Digital readouts were made of the bottom-trace vertical-output-tube plate waveform. (A) Vertical repetition rate measured 59.94Hz (a reading that is difficult to obtain with some frequency counters). (B) The amplitude measured 1207VPP. (C) The plate voltage measured +343Vdc. No higher accuracy should ever be needed for these circuits.

Figure 9 illustrations are similar except the Channel B waveform is measured (plate waveform of a vertical-output tube; the Channel

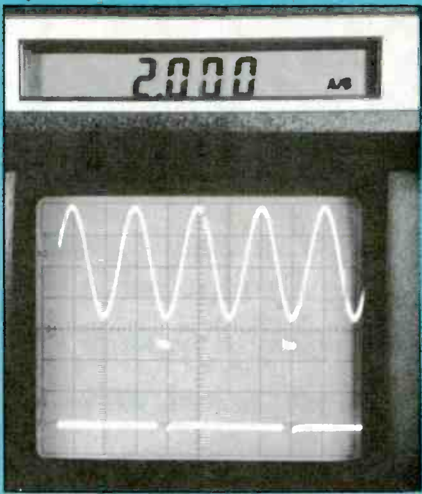


Figure 10 A 2:1 frequency ratio was measured for these two signals. Two separate generators were adjusted carefully to obtain this condition.

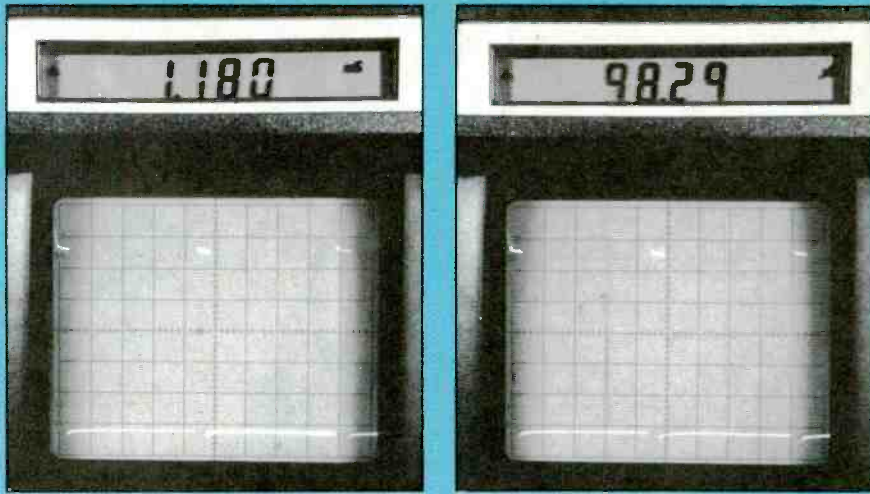


Figure 11 Computed repetition rate and duty cycle were obtained easily by two Delta-time measurements. Left, one pulse tip (at center of trace) and one space between pulses measured 1.180mS (or 1180μS). Right, the pulse tip alone tested 98.29μS, making the calculated cycle 8.3%. Also the one-cycle time of 1.180mS translated to 847.46Hz when the 1/Delta-time button was pressed. These intensified waveforms have low contrast in the photographs because the LCD display required bright floodlamps. With average room lighting, the waveforms were easy to analyze.

A video waveform was varying too much to be photographed properly). Again, no probes were moved; one button was pushed for each reading.

These results were outstanding, especially the PP and frequency functions.

Frequency-ratio tests. When signals of different repetition rates are present in vertical Channels A and B, the ratio of these repetition frequencies is displayed on the LCD readout after the *A/B or B/A* push-button is pressed (second from the bottom of the 12).

Waveforms and LCD readout of Figure 10 show the outputs of two generators. One signal (top trace) was a sinewave, while a 10% duty-cycle pulse train was the second signal (bottom trace). The pulse-generator frequency was varied manually until the screen showed two sinewave cycles for each positive-going pulse. Some normal drift was present, but when the waveforms moved to the position shown, it was obvious the signals represented a 2:1 frequency ratio. Notice the 2.000 A/B ratio on the readout. This was chosen to show the principle, although any ratio can be displayed between 1 to 999,999. This ratio feature has many applications, including checking the repetition rates of fixed or programmable dividers.

Also, the annunciator shows which channel signal has the highest frequency. *A/B* is shown when the Channel A signal has the higher frequency, while *B/A* is displayed when the Channel B frequency is higher.

Delta-time measurements

The previous Auto-Tracking tests involved the entire waveform. Delta-time tests, in comparison, can measure some things in a waveform or between two waveforms. Possible measurements include the duty cycle of pulses, the time between two events on one waveform, the time or phase between two events on two waveforms, the rise time of pulses or square waves, the Delta peak-to-peak amplitude of any section in a waveform and the repetition rate.

Delta-time measurements require operation of four push-buttons and two controls. However, before these measurements are made, the CRT must show a stable waveform of appropriate amplitude, because the measurements are made on that particular section of the signal, and any waveform motion will affect the readings.

On the SC61 panel, delta is represented by the Greek letter Δ, an equilateral triangle.

When the Delta-time button is pressed, an area of the waveform (or waveforms, if comparison between channel waveforms is needed) is made brighter. Right-to-left location and width of the brighter area are determined by rotation of two multiturn controls called *Delta begin* and *Delta end*.

In actual operation, the *Delta-time* push-button is activated, the *begin* control is rotated CW or CCW as needed to place the left edge of the intensified area at the waveform's left point to be measured, and the *end* control is rotated to place the right edge of the brighter area at the desired right-side point of the waveform. The time in microseconds or milliseconds for the duration (width) of the intensified area is then displayed on the LCD readout.

The repetition frequency can be obtained by using the *begin* and *end* controls to intensify one complete cycle of the waveform. This gives the time of one cycle, and the frequency can be obtained by pressing the *1/Delta-time* (one divided by Delta-time) button. The LCD readout displays the frequency. Of course, this is the old method for calculating the repetition frequency by taking the reciprocal of the time of one cycle, but the microcomputer in the SC61 does the mathematics automatically.

The Figure 11 waveforms show how the duty cycle and repetition frequency of positive-going pulses were measured. The Delta-time mode was selected to intensify one cycle (one pulse and one space between pulses). Pressing the 1/Delta-time button gave the calculated repetition frequency, which was compared with that ob-

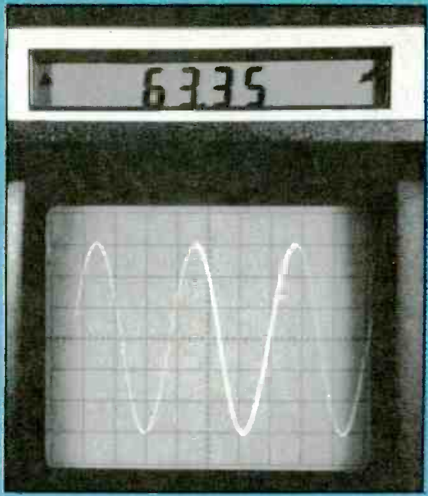


Figure 12 A sinewave having approximately the frequency of horizontal sweep measured 63.35μS by Delta-time reading. The 1/Delta-time button then gave the calculated frequency as 15,770Hz, which compared favorably with the counter direct reading of 15,737Hz.

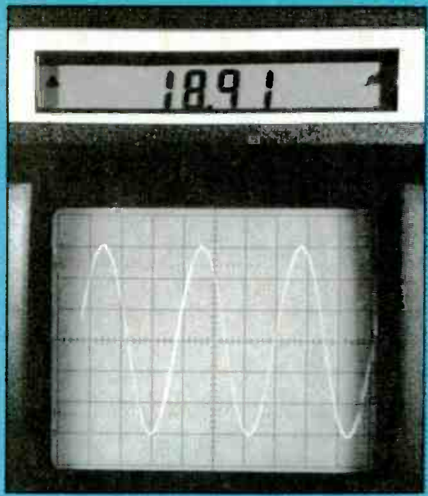


Figure 13 A sinewave was used (rather than square waves or pulses) to make more clear the process of measuring rise time by Delta-time mode. The amplitude of a locked waveform is adjusted to the 0% and 100% graticule lines, the waveform rise time is horizontally expanded, then the Delta-time mode is selected and the 10% to 90% slope is covered by rotation of the begin and end controls that make this slope brighter. The LCD readout shows a time that needs no processing or calculations.

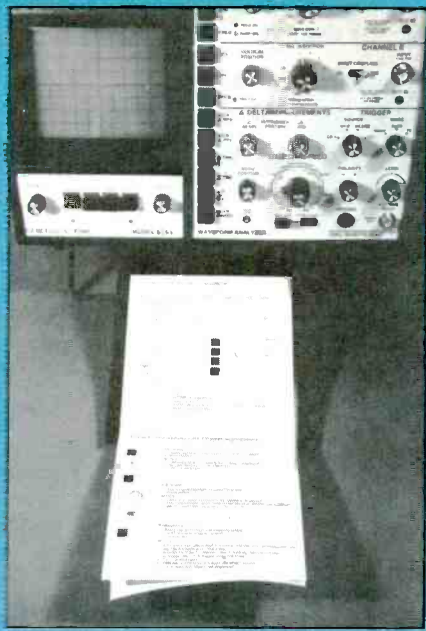


Figure 14 A mini operating manual is mounted under the scope. It can be pulled out and opened when a refresher is needed.

tained by the Channel A counter. Finally, the pulse time was measured by the same Delta-time operation with the pulse tip intensified. In this case, the pulse time was 98.3μS, and the complete cycle time checked 1180μS. By dividing the pulse time by the cycle time, the duty cycle was determined to be 8.3%, while the repetition rate was calculated as 847Hz. In comparison, the Channel A frequency counter gave a reading of 839.2Hz (which is believed to be very accurate). The difference between 847Hz and 839.2Hz probably was caused by visual difficulties in reading the intensified area, and it illustrates the errors that are inherent in measuring time or amplitude by a scope.

Scopes probably have time and amplitude accuracy of about ± 4%. When visual errors and operator sloppiness are added, some scope-screen measurements might have no better than ± 10% accuracy. That is reason enough to use the digital-readout measurements when highest accuracy is needed.

Frequency measurement of the sinewave in Figure 12 by the Delta-time method was more accurate. Frequency-counter reading was 15,737Hz versus 15,770Hz by Delta time.

Rise time is checked by adjusting the waveform height to equal the 0% and 100% lines on the graticule. Then the sweep is locked solidly and the sweep time varied until the leading edge has sufficient slope to permit measurement. Finally, the Delta-time mode is selected and the *begin* and *end* controls are rotated to intensify the rise time between the 10% and 90% points. The LCD display shows the rise time in microseconds or milliseconds. In Figure 13, a sinewave, rather than a pulse, was used to make the rising edge more visible in the photograph.

Directions for making peak-to-peak measurements of waveform segments and other applications of Delta-time tests are covered in the Sencore operation book.

Miscellaneous features

Simplified operating instructions for the SC61 are contained in a four-page booklet that can be pulled out from under the front panel (Figure 14). However, before these instructions are used, the technician should read the 52-page operating manual packed with each instrument. After all details have been committed to memory, an occasional refresher from the small pull-out booklet will be very helpful.

Comments

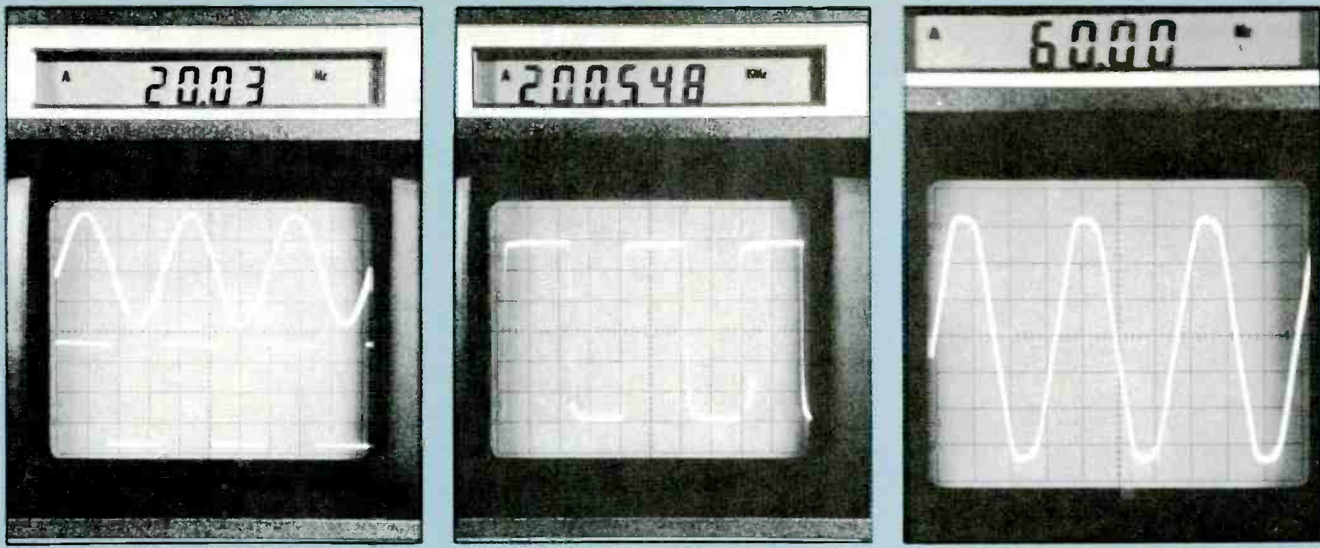
Before giving personal observations about the performance and operation of the SC61, I should discuss features the machines does not have.

The SC61 does not have delayed horizontal sweep, which gives the effect of expanding waveforms horizontally without adding jitter. There is no waveform storage (either CRT or digital), no RF detector and no single-sweep mode. It is clear that Sencore intends the SC61 for the video, TV and digital fields and therefore has provided the features most beneficial to them. Few users will notice the missing functions.

The internal graticule has no provision for lighting the grid lines, and this caused some minor problems during the photographing of various waveforms along with the LCD readout. However, no problems were encountered with viewing the LCD readout, the graticule lines and the waveforms *in actual operation.*

A review of the tests and measurements made with the Sencore SC61 brings no disappointments or compromises. All measurements and procedures operated without any failures or limitations.

When operated as a conventional wide-band scope, the performance was excellent, with stable locking and bright sharp traces. None of the performance tests



A B C

Figure 15 Some frequency counters cannot measure these waveforms accurately and stably. (A) Sine and square waves of 20Hz were counted by the SC61 without any problems. (B) Square waves of 200kHz were counted easily. Notice that the rising edge of the first square wave is complete; that was made possible by the signal-delay line in the common vertical channel. (C) Here is a perfect 60Hz readout of a 6.3V RMS tube-heater voltage in an operating color-TV receiver. This is the first time such a signal has been counted successfully in the **ES&T** Test Lab.

showed any lack of bandwidth or sweep times. The Delta-time measurements were simple to perform, giving accurate results without complications.

Some technicians may not appreciate having the equivalent of a wide-band scope, a good digital multimeter and a frequency counter all in one case. After all, most well-equipped shops have all these items of equipment that can be connected when needed. But a technician who actually operates the SC61 soon will discover several levels of advantages. First of all, there is the simplicity and convenience of having those three LCD-readout functions without the complications of connecting separate power and signal cables to three instruments.

However, the SC61 advantages are much greater than convenience. These internal test functions operate better than can be obtained from most separate instruments. For dc-voltages, of course, the only improvement comes from not being compelled to connect another set of test probes, although in crowded chassis and circuit boards, this has considerable value. The dc-voltage readings are autoranging but otherwise are little different than those from digital multimeters.

A tremendous advantage comes from the circuit design of the internal peak-to-peak conversion system. Few DMMs have ac-voltage frequency response that is flat, even over the audio band. DMMs with peak-to-peak action are also rare. Compare that with the SC61 peak-to-peak function with both wide frequency response and extreme accuracy. All PP tests showed more than adequate bandwidth. Also, conventional DMMs always smear TV pictures and video waveforms when video ac voltages are measured, because of the capacitances added. The SC61 PP readings are taken from the scope vertical amplifiers so no additional capacitances are added to the tested circuit.

The frequency-counting functions also performed better than most separate instruments. All frequency counters perform adequately on RF signals that are confined to a protected environment. When applied to measuring audio signals (even sinewaves), most models fell far short of the specs. In fact, before the SC61, I never have tested one that would measure accurately the 60Hz heater voltage in a color-TV receiver. Readings on these specialized counters wandered from 100Hz to several thousand, regardless of control adjustments. The SC61 performed this and other audio measurements without problems.

Figure 15 shows the readouts and waveforms obtained when testing various frequencies with the SC61. Of course, it might be expected that any good counter could measure the 200kHz square waves. But in the past, many counters failed to measure 20Hz. Another factor that makes counters unstable around color-TV receivers is the strongly radiated horizontal-sweep pulses. Notice that the last photograh shows a stable 60Hz reading for the 6.3V RMS heater supply in an operating tube-type color receiver. No adjustments were made, except to lock the scope waveform. This is exceptional performance for a scope.

While the test sample SC61 was in the test lab, a Sony color receiver was brought in for diagnosis of a defect causing absence of high voltage. This model has all solid-state active components, so the first measurement with the SC61 was the drive signal at the gate of the output device (which resembled an SCR). The waveform did not have the conventional ringing and overshoot lines, but rather was nearer a pure wide pulse. Usually this is proof that the output device is not operating because the input junction is open. However, there is always the possibility that the horizontal-oscillator frequency might be too high, perhaps double or triple the desired 15,734.4Hz of locked sweep.

With the SC61, only pressure on one button (frequency of Channel A signal) showed a repetition rate of about 19kHz. Of course, this was not correct, but the discrepancy was not sufficient to indicate an oscillator defect; the loss of sweep could have changed it that much.

Pressure on another button showed a negative dc voltage reading that was lower than the schematic value. However, the presence of a negative voltage indicated the input junction was not open; the low reading, again, might be caused by the loss of horizontal sweep.

The probe was changed to the anode (with a transistor, it would be the collector). No waveform was there, but the dc-voltage pushbutton showed +159.8V, which is too high because the supply is supposed to be regulated.

The preliminary diagnosis is that the output device was open between anode and cathode. Also, the regulator transistor probably was shorted, thus increasing the supply voltage. In fact, the defective regulator likely caused the output problem. The regulator transistor and sweep-output device were checked out of circuit and found to be defective, as suspected. Replacement restored normal performance.

The waveforms, dc voltages and PP drive amplitude were checked again with the SC61, and were in tolerance. For example, the horizontal-drive frequency measured 15,734.4Hz.

A separate scope, DMM and frequency-counter instruments were available, along with the SC61, on the same test bench. Therefore, the same procedure *could* have been followed without the SC61, but considerable testing time was saved by using the SC61.

However, my memory of the repair is not about testing time, but of the freedom and lack of strain it gave me to perform all desired tests without being concerned that the test equipment *might* be giving false answers.

In conclusion, Sencore SC61 scope/Waveform Analyzer performed all measurements attempted flawlessly. It seems clear that technicians who take full advantage of the features will save diagnostic time. ES&T

BOOK REVIEWS

***Editor's note:** Periodically **Electronic Servicing & Technology** presents reviews of books dealing with subjects of interest to our readers. Please direct inquiries and orders to the publisher at the address given in each review rather than to us.*

Microcomputer Dictionary, by Charles J. Sippl; Radio Shack; $7.95.

This dictionary covers more than 5000 terms and is cross-referenced to help locate definitions. It includes several appendices with useful information on microprocessors, microcomputers and their applications. The volume is designed to familiarize both the beginner and professional with terms associated with the use of a computer.

Published by Radio Shack, 1800 One Tandy Center, Fort Worth, TX 76102.

How to Measure Anything with Electronic Instruments, by John A. Kuecken; Tab Books; 336 pages; $15.95 hardbound, $8.95 paperback.

Today's electronic test equipment is more sensitive, more sophisticated, more specialized and more expensive than ever before. So how can hobbyists and experimenters afford to buy all the measuring devices needed for hobby experiments or for troubleshooting everyday household electronic equipment problems? They do what growing numbers of amateurs *and* professionals are doing: *make their own!* Now this handbook shows how to do it easily and inexpensively!

This guide covers designing, building and using devices for measuring almost anything, for any purpose. It's for anyone involved in any phase of electronics: students who want to learn the theory and practice of measurement, technicians or engineers who need specific test equipment that isn't commercially available, or the hobbyist who wants the challenge and enjoyment of creating something on his own. There are step-by-step directions, diagrams and schematics to make the going easy, even for those who've never tried building electronic equipment before.

Starting with a look at units of measure (force, mass acceleration, work and power, and electrical units), the author goes into the basic techniques of measuring and the electronic devices used for each type of job.

Published by Tab Books, Blue Ridge Summit, PA 17214.

Electronics Pocket Handbook, by Daniel L. Metzger; Prentice-Hall; 284 pages; $3.95.

This book measures 3 inches by 5¾ inches, yet contains hundreds of bits of information on electronics. The book includes definitions, formulas, charts and component data and characteristics. Topics such as simplified circuit analysis and design, unit conversions, constants, standards, symbols, codes and test procedures are also covered. A 28-page glossary in the back of the book explains more than 400 terms.

Published by Prentice-Hall, Englewood Cliffs, NJ 07632.

Revised and Enlarged Handbook of Oscilloscopes, Theory and Application, by John D. Lenk; Prentice-Hall; 340 pages; $19.95 hardbound.

The guide is designed for technicians, engineers and for the training of hobbyists. The information has been revised and expanded to include changes in oscilloscope technology, especially the extensive use of curve tracers.

Topics include probes, accessories and the use of scopes with sweep generators. The author describes methods of measuring voltage, current, time, frequency and phase, and of checking individual components, amplifiers, amplifier circuits, communications equipment, industrial devices and TV receivers.

Published by Prentice-Hall, Englewood Cliffs, NJ 07632.

ES&T

READERS' EXCHANGE

#800-668 for clock radio, model F472 W3. Please state price. *Able TV and Electronics, Rt. 4, Box 764, Panama City, FL 32405.*

Needed: New or good used Admiral flyback transformer, part #79A166-4, for model 12B618M, chassis T3-L6-2A. Also need broken B&K tube tester, model 707, for parts. *Stanley Budzinski, 821 Randolph Drive, Aberdeen, MD 21001.*

Needed: Tuner for Emerson model 19P92, chassis #120963A – tuner #471871. *M. Seligsohn, 1455 55th St., Brooklyn, NY 11291.*

Needed: EMC model 802 signal tracer and generator, B&K 415 sweep/marker generator, VIZ model WP-26A isolation transformer or similar models. *Caswell Davis Jr., 601 Delmar, Apt. 2, San Antonio, TX 78210.*

Needed: Front panel dial tuning mechanism for Zenith radio, model F 474, with AM/FM clock radio. Part number may be 812-684. Also Zenith clock #800-668 for clock radio, model F472 W3. Please state price. *Able TV and Electronics, Rt. 4, Box 764, Panama City, FL 32405.*

Needed: Akai X1800SD or GX1900D tape transport for salvage; need not be operable. Also schematic and parts list (Sams 348) for Philco model E2006-11 b&w TV; will copy and return. *Vernon Tiger, P.O. Box 392, Casselton, ND 58012.*

Needed: Rider radio manuals 1, 2, 3, 14 and 15. Pages Misc. 6-9 and 6-10 for manual 6, index for volumes 1 through 15, Also operating manuals for Precision E490 stereo generator, RCA 150 signal generator and Supreme 339 radio analyzer. *Gregory J. Kulp, 1115 Lilac Lane, West Lawn, PA 19609.*

Needed: Type J speaker (two coils in series, resistance in each coil about 275Ω) for Atwater Kent Q chassis. Would like information from anyone who has one of these for sale. *Ken Wagner, Rt. 4, Box 580, Gresham, OR 97030.*

Needed: RCA service data, 1973-75, color and b&w. Also 1974 and 1975 radio phono. *Calvin S. Logue, Jr., 923 Washington Road, Westminster, MD 21157.*

Needed: Schematic and information about scope from the Precision Apparatus Company, Elmhurst, NY, model 318. *Joseph Vaccarella, 15 Laidlaw Ave., Jersey City, NJ 07306.*

Needed: Sams Photofact TR-82 and Supremes Vol. R-2 and 3 and TV-1 through 4. *C. T. Huth, 146 Schonhardt St., Tiffin, OH 44883.*

Needed: High-voltage transformer for RCA television (chassis #CTC-4, model 21CT661U), part #100409 listed in Sams 314. Will accept new or used. State price. *Joseph V. Bowie, 4120 Alton St., SE, Bradbury Heights, MD 20743.*

For sale: Sencore PS148 oscilloscope with probes and manual, $150; Eico 460 oscilloscope, brand new in carton, $225; B&K 1074 and 1075 Analyst with probes and manuals, $100 each. *Niver's Inc., 801 Columbia St., Hudson, NY 1-518-828-0616.*

For Sale: Sams Photofacts from 20 to 600, best offer plus back issues of Electronic Servicing and ET/D. *Lewis Radio & TV, Rt. 1, Central City, NE 68826.*

For sale: Processor Technology SOL-20 terminal computer with 16K memory plug-in; several program tapes; Basic, electric pencil by Shrayer and etc. Electrohome 14-inch b&w TV monitor. Anderson Jacobson (IBM) AJ841 Selectronic terminal printer that gives letter copy print-out; complete set-up price $1600. For details phone 1-318-445-0262 or 1-318-640-1466 after 6 p.m. *Bob Goodman, P.O. Box 452, Alexandria, LA 71301.*

For sale: Complete electronic shop of repair and test equipment, all like new with accessories and service manuals – retiring. Also TV manuals, Photofacts, symcures and Tekfax. *Clarence Gillow, P.O. Box 177, Springer, NM 87747, 1-505-483-2363.*

For sale: Simpson model 311 VTVM; high 22MΩ impedence; $100. Macrotronics ham interface for TRS-80; model TM-800 factory wired includes M80-M800-FSD1 and AFSK; complete with manuals and software; $200. Bird model 4351 RF wattmeter; $70. *William D. Shevtchuk, 1 Lois Ave., Clifton, NJ 07014.*

For sale: Tekfax volume #8 (1966), #111 (1973), #112 (1975), #115 (1979). Make an offer. *Benjamin Halfin TV, 603 Ivey Ave., Colonial Heights, VA 23834.*

For sale: BK-alignment generator, television; excellent condition, all cables, probe; $300 firm. *Jerry Martin, Box 1, 105 E. Pine, Bloomfield, NM 87413.*

TROUBLE-SHOOTING TIPS

Intermittent vertical deflection
General Electric AC-C and AC-CAA versions
(Photofact 1979-1)

Preliminary tests for intermittent problems involve jarring the circuit board and all suspected components, in addition to applying heating and cooling alternately. When these were performed on the General Electric AC chassis, the temperature-cycling tests gave no results, but the physical manipulation of the circuit board sometimes would start or stop the loss of picture height.

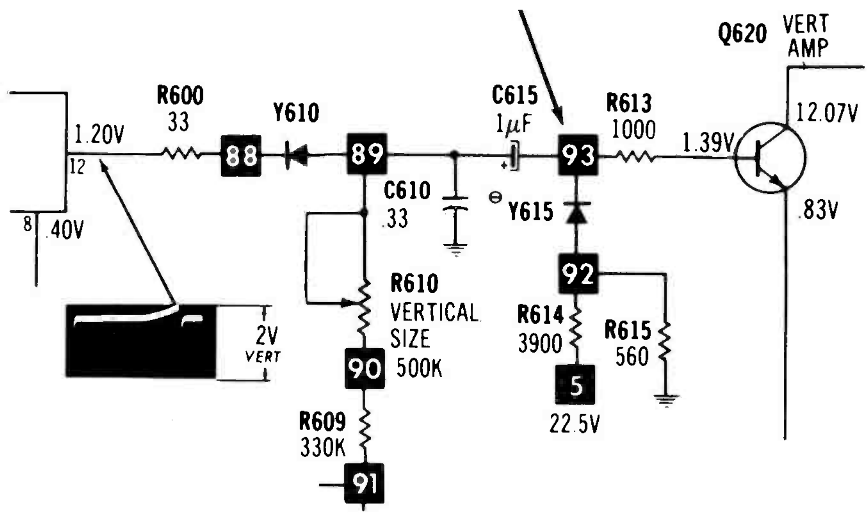
Scope waveform and dc-voltage tests at the vertical-signal output (emitter of Q640 and collector of Q645) showed a loss of waveform and a huge shift of dc voltage when the height collapsed. Scope waveforms can locate the precise stage where the problem originates. However, this vertical circuit had a type of linearity correction that fed a sample of the output waveform back to the Q620 emitter. A loss of signal inside this loop would distort the waveforms that remained. So, additional tests by flexing and moving the circuit board seemed wise.

Finally, an intermittent open was found on the board's top side between feedthroughs W1A and W1B. Rather than attempt a repair that might prove to be ineffective or temporary, I made a jumper of hook-up wire and soldered it to the two points. That eliminated the erratic vertical height.

Since that first repair, I have found several other AC chassis with the same defect. Of course, these were easier to find because I remembered the original repair.

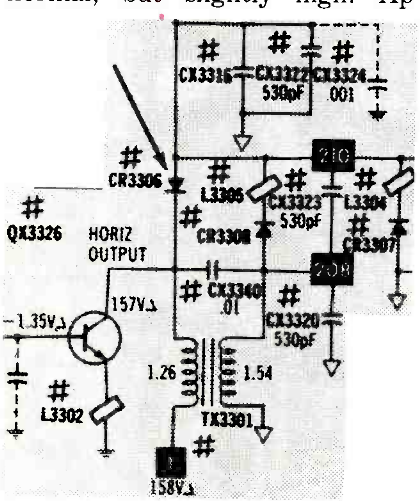
In some chassis, resistors R650 (4.7Ω) and R640 (100Ω) were found to be out of tolerance, probably because of overloads during the loss of sweep times. Therefore, it is wise to replace them each time intermittent sweep has occurred.

Bruce R. Youmans, CET
West Covina, CA



No sound or raster
Zenith L1990W9
(Photofact 1920-2)

When first turned on in the shop, the Zenith had no picture or sound. A few quick tests showed that the output of the bridge rectifier was normal, but slightly high. Apparently, the shutdown circuit was operating to eliminate all scan-rectified power, or there was no horizontal drive to the output transistor.



I find the easiest approach to shutdown problems is to reduce the receiver line voltage using a variable transformer, such as a Variac. Starting at zero voltage, I increased the voltage until the receiver came to life at about 80Vac. However, further increases reached shutdown at about 92Vac.

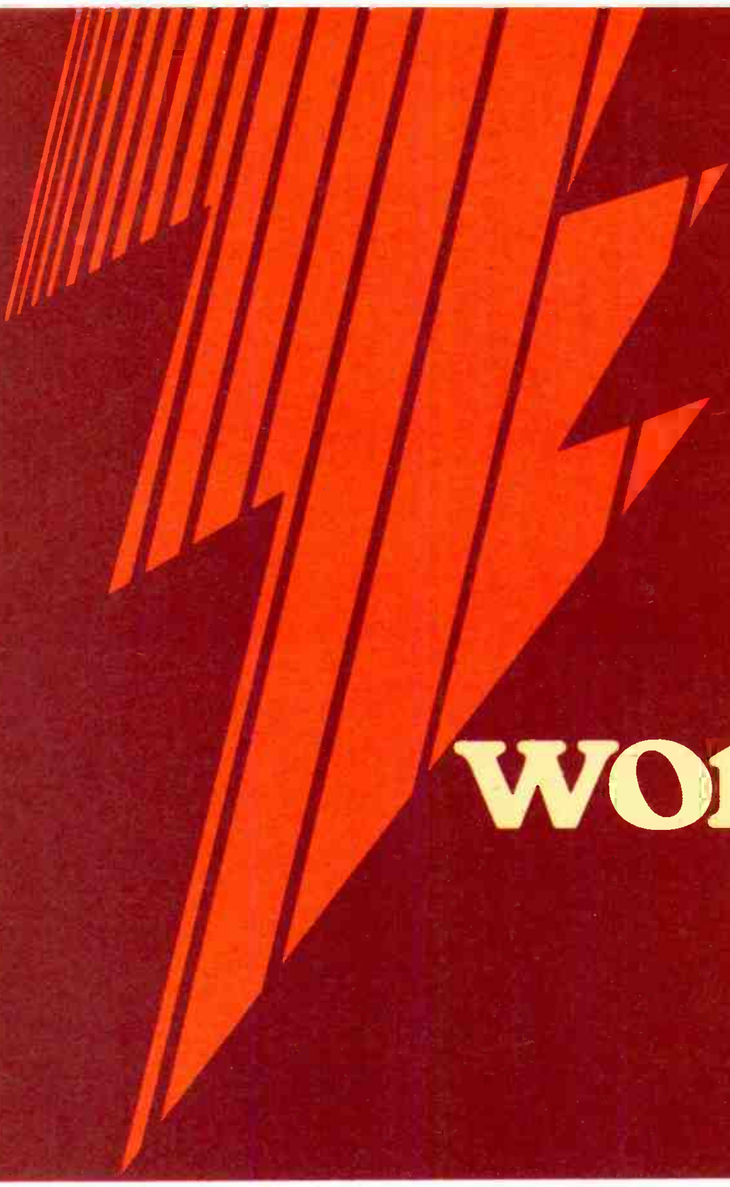
These symptoms suggested an open in one of the retrace-tuning capacitors (CX3316, CX3317, CX3318, CX3320, CX3322 and CX3324) or perhaps an open in diodes CR3307 or CR3308. However, after these were replaced, the shut-down continued unchanged.

Addition of a 0.025μF capacitor in parallel with all other retrace-tuning capacitors permitted operation at 120Vac, but the picture width was stretched tremendously. Obviously, this was not a solution.

While the receiver operated at 85Vac, the horizontal-output transistor collector measured about +80Vdc, but the high voltage at the picture tube tested a whopping 30kV. How could an output transistor with only about half the normal dc voltage produce such high voltage?

One of the few untested components was CRX3306, a diode in the collector circuit. Replacing this diode with the correct Zenith replacement cured the problem, bringing normal operation at 120Vac line voltage.

M. B. Gembala
Maywood, NJ



Shock hazard at the workbench

By Robert K. Benson

Most of us who have spent much time at the workbench designing, building kits and servicing electronic equipment have experienced a teeth-rattling jolt from high voltage at least once.

Such shocks usually come about in one of two ways. Either we consciously expose ourselves to the possibility of shock by working a circuit "hot" and get careless, or it strikes unexpectedly when we're handling test equipment or the device being serviced.

Although most modern electronic equipment is solid state and operates on low voltage, there are still many designs that require tube circuitry using 100V or more. Also, most test equipment still derives operating power from the 110V, 60Hz power line.

Some circuit problems are difficult to diagnose with the aid of an ohmmeter, and hot circuit measurements are often necessary. The possibility of lethal shock when troubleshooting and using high-voltage equipment is obvious, so we naturally tend to be a bit cautious. Frequently, however, the shocks come when least expected, such as when shifting test equipment around the bench or connecting for a test. This latter situation is generally caused by leakage currents.

The heart can experience what is called ventricular fibrillation (the fibers of the heart muscle twitch with little contraction of the heart) when subjected to only about 10 or 20μA of current. This condition is usually fatal unless skilled help and special equipment are immediately available. About 100μA of current flowing through the chest area may cause 10μA in the heart. Obviously, current will take a chest path if a hand-to-hand or hand-to-foot contact is completed across a voltage source. The resistance of the body between these extremities can vary from many thousands of ohms, under normal dry conditions, to about 1000Ω under conditions of stress, sweat or work in a damp environment. This evidence, fortified by a simple exercise in ohms law, helps us to understand why people are electrocuted by 110Vac power sources.

We can also understand why we must take particular care to avoid such hazards because many workshops are not located in as dry an environment as we might prefer. Dampness can increase the shock current through the body because of lowered skin contact resistance, and dampness can also increase leakage current in the equipment.

The technician who must work a circuit hot to diagnose his problem, may be exposing himself to 110 or 220Vac power or tube circuit dc voltages from about 100 to 500V or more, or possibly to the high dc voltage of the TV picture-tube power supply. If you are un-

The hazards of electrical leakage

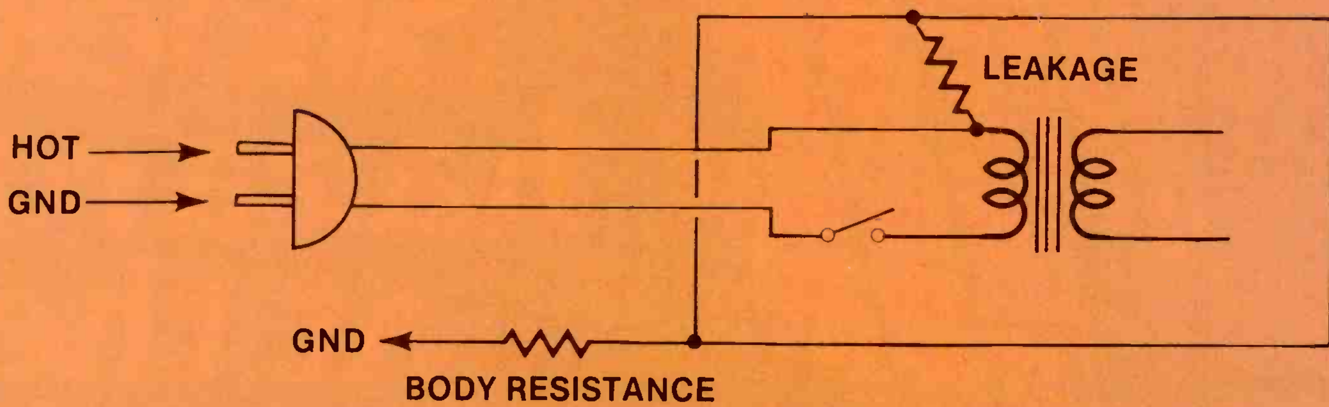


Figure 1. In a 2-wire device with leakage problems, the switch is in the neutral leg; the leakage hazard will exist even if the switch is turned off.

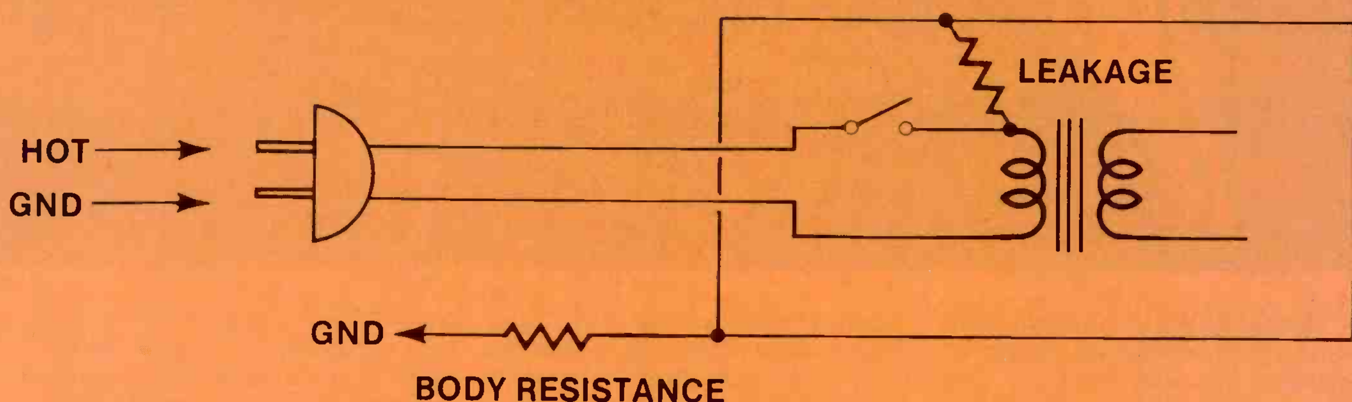


Figure 2. If the switch is in the hot leg, the leakage hazard is removed when the switch is opened.

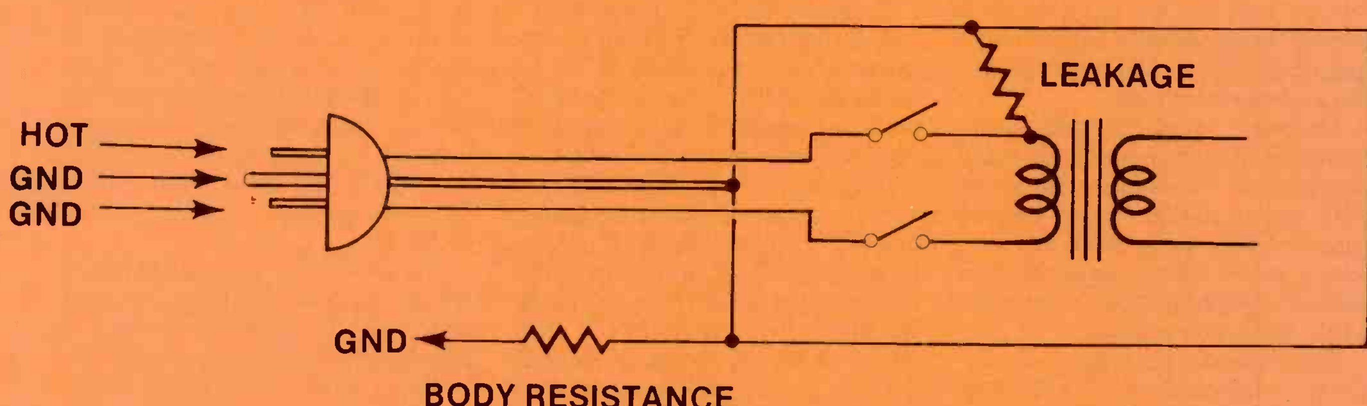


Figure 3. The 3-wire grounding system allows plugging into the receptacle only one way, and provides a grounding path for leakage current.

fortunate enough to come in contact with such voltages, the effect will depend upon such factors as skin contact resistance, general physical condition, amount and type of voltage (ac or dc), duration of contact, frequency, pulse shape and impedance of the voltage source.

Even voltages that may be too small to be lethal can be damaging in a secondary way. The reaction of the body to dc shock is often a violent jerk. Although this could be lifesaving as far as the interruption of the contact is concerned, it could also result in a bump on the head, lacerations or other injury. The reaction to ac shock is somewhat different. If you have a hand grip on the hot circuit, it can be difficult to release due to muscle reaction.

Avoiding these hot circuits when making a direct measurement requires care in handling; but what about the leakage currents that occur when touching two presumably grounded metal instrument cases?

These currents exist because of resistance and reactance paths from the hot side of the power line to ground. This can result from poor transformer insulation or damp wiring, combined with inadequate grounding of the chassis and cabinets. All that is required to receive a shock is to bridge a part of this line-to-ground leakage path with a part of your body. This may involve one or more pieces of equipment, typically a faulty one with an ungrounded chassis or cabinet and a good one that provides the ground.

Figure 1 shows a circuit consisting of a simple, single-pole, single-throw (SPST) line switch in series with the 110V supply to a leaky transformer. When the plug is inserted in the power receptacle so that the switch is on the ground side of the line, leakage current will pass from the transformer winding through and over the dielectric of its insulation, to the metal chassis and cabinet. From this point, it flows by way of any convenient resistance path (such as the human body) back to the line ground. Note that the hazard exists regardless of whether the equipment is turned on or off because the switch is in the ground side of the line.

Figure 2 illustrates a slight improvement made by reversing the plug in the receptacle to put the switch on the hot side of the line. In this case, leakage current only flows when the equipment is switched on. The use of a double-pole, single-throw (DPST) switch to break both sides of the line would assure that the chassis would not be hot with the switch off, regardless of how the plug is inserted.

A more acceptable arrangement is shown in Figure 3. A three-terminal plug and receptacle is used, with the advantage of a one-way-only connection plus a separate ground return. The ground wire should be bonded to the chassis and metal cabinet. In this case, the normal load current flows in the two wires connected to the transformer primary and the third wire conducts leakage currents harmlessly off to ground. This system is safe as long as the ground wire remains intact. This can be assured by visual inspection and continuity measurements with an ohmmeter. Molded three-terminal plugs with connections that cannot be inspected may be risky to use, however, because some cannot be visually inspected and an ohmmeter test alone can be misleading. Suppose, for example, that the wire connected to the ground pin within the molded plug is frayed down to a single strand of wire. The ground circuit could then be interrupted the next time the plug is used.

A GFI is a circuit breaker capable of disconnecting the load from the power.

There are other components, such as line filters, that can be sources of leakage current, but the examples given here are sufficient to illustrate the principle.

In recent years, ground fault interruption (GFI) devices have become available for home and shop use. The GFI is a fast-response, circuit-breaker device that is capable of disconnecting the load from the power when a small unbalance in load current occurs (when the current in each power lead differs by more than just a few milliamperes). A leakage condition or body contact from either side of the line to ground will cause this unbalance in current and trip the high-speed circuit breaker – an obvious lifesaver.

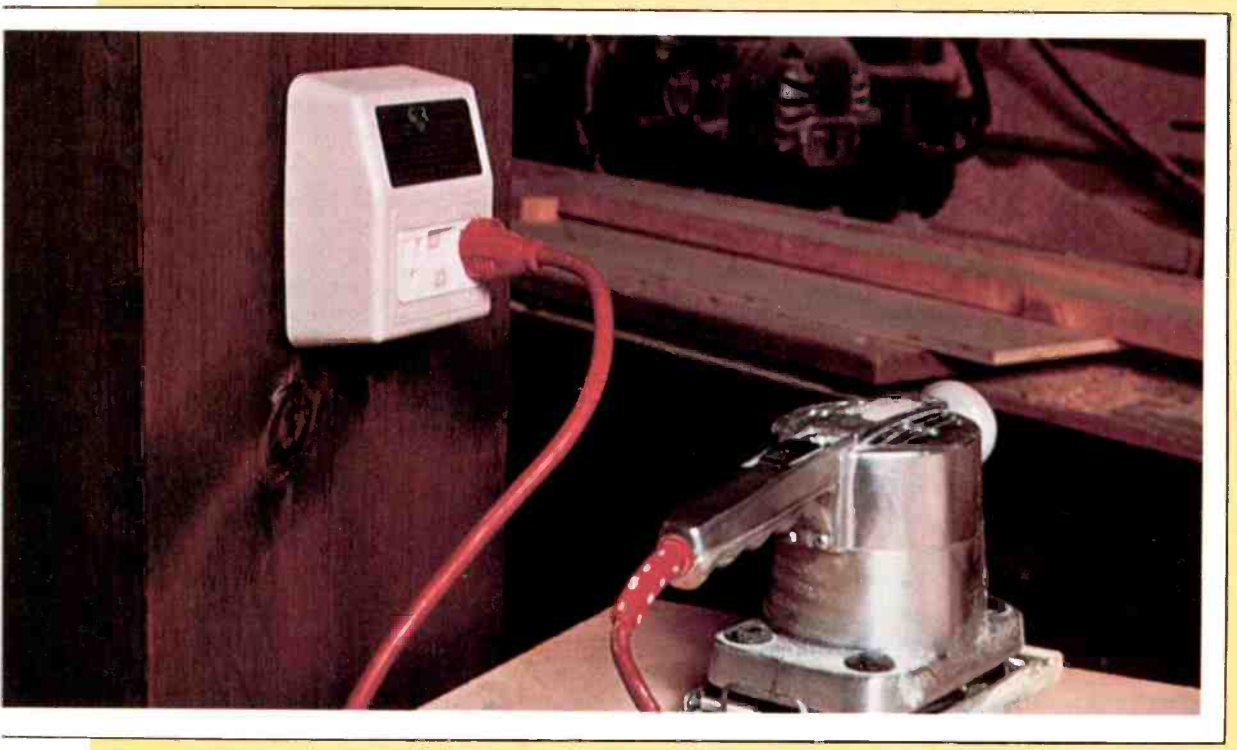
The varieties of GFIs include an outdoor type with built-in circuit breaker, an indoor circuit-breaker type, some that replace existing wall outlets and portable types that can be moved from one outlet to another.

These devices will not protect you if you work a circuit hot and get across the 110V output from the GFI to the load, or the high dc voltage from the internal power supply of the device that you are servicing. In this case, the circuit-breaker current capacity (15 or 20A) dictates the interruption current. The GFI is, however, effective in protecting against those leakage currents that attempt to flow from the device connected to the output of the GFI back to ground. The GFI can find service in places throughout the home, as well as at the shop workbench. In particular, it offers protection to the users of such equipment as toasters, power tools and hedge trimmers, where protection is especially needed.

Ideally the workbench should have its own GFI device. This could be mounted in the circuit-breaker box or an outdoor-type GFI could be installed leading to the workbench outlets. It is not advisable to include the room lighting on the GFI circuit, or the room will be plunged into darkness if the GFI is tripped.

Shocks at the workbench can be minimized in a number of ways. The use of GFI devices will protect you from the sneak attack of circuit-to-ground leakage, whether introduced by faulty equipment, poor design or excessive moisture. When working hot circuits, techniques such as circuit probing with one hand behind the back, wearing rubber gloves and turning the equipment off before connecting clip-type probes, are effective. The key to survival is to keep the hands and body insulated from hot circuits and from ground. Work slowly and think out each step before making your move. Avoid potentially dangerous servicing if any way below par either mentally or physically.

More about GFCI



A **plug-in GFCI** gives portable current leakage protection.

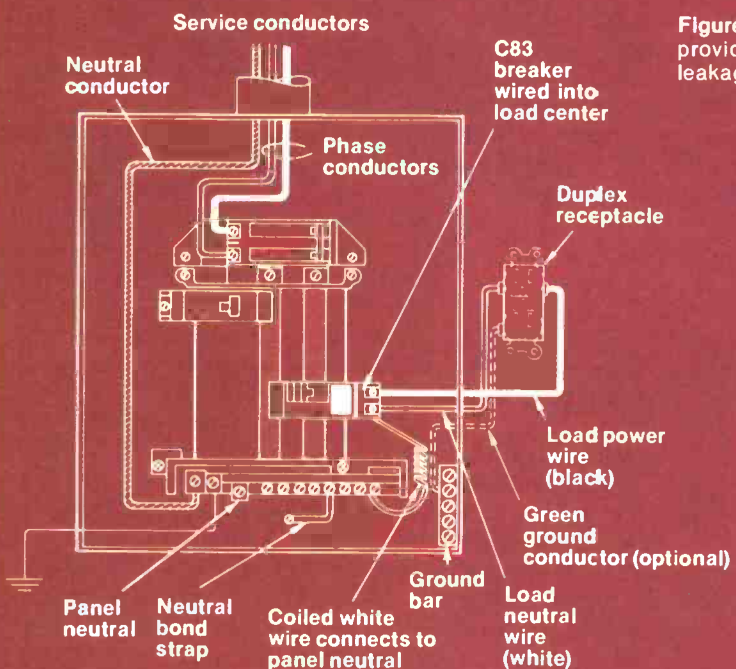
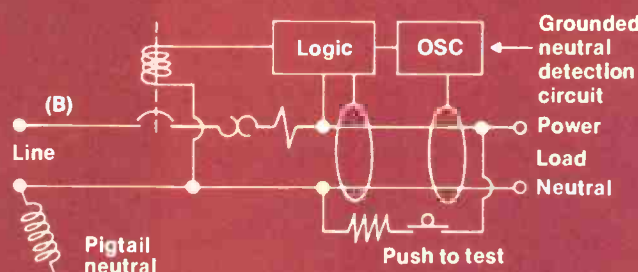


Figure 1a. A ground-fault circuit breaker provides overcurrent protection and leakage current hazard protection.

(Drawings and photos courtesy of General Electric Company.)

Figure 1b. A ground-fault circuit breaker is installed in the circuit breaker panel, and conductors are brought out to the receptacle to be protected.



Electrical equipment manufacturers provide a number of ways to achieve ground-fault protection.

A ground-fault circuit interrupter (GFCI) is a device that consists basically of a sensing unit and a circuit trip device.

Figure 1a is a schematic of a ground-fault circuit breaker, designed to be installed in a conventional circuit-breaker cabinet.

The "hot" and neutral wires carrying the line current pass through a sensing transformer. As long as everything is normal, the circuit breaker remains in its *closed* position, and the circuit protected by the unit continues to deliver current as required by the load.

If an overcurrent condition occurs, such as caused by a stalled motor or a short circuit, the circuit-breaker portion of the device will trip, just as would any other circuit breaker without ground-fault sensing.

The ground-fault protection comes into play when there is ground-fault leakage current. The sensing transformer is coiled around both the hot and the neutral wire. As long as the currents in both conductors are equal, the sensor detects nothing and the circuit continues to operate normally. If a ground fault occurs, part of the current leaks from the hot conductor to ground. This leakage current fails to return through the neutral conductor, setting up an unbalanced current condition that is sensed by the transformer. If the unbalanced current exceeds the preset value for which the GFCI was designed (originally 5mA), a solenoid is activated that trips the circuit breaker and opens the circuit. Figure 1b illustrates how the GFCI breaker is wired into the breaker panel.

Another way to provide GFCI protection is to install a special ground trip receptacle. These devices are designed to fit into a standard receptacle box. Figure 2a is a schematic of a ground trip receptacle that is designed so that additional receptacles downstream may be afforded GFCI protection by this one device. Note that the ground trip receptacle does not have overload or short-circuit protection. That is provided by the fuse or breaker for that circuit back at the load center (Figure 2b).

A third type of device provides portable GFCI protection. It consists of a plug for plugging it in to any standard 3-wire grounded receptacle, a ground-fault circuit interrupter, and one or more receptacles. A unit such as this can be carried to the work site and plugged in to provide protection from current leakage. ES&T

Figure 2a. This ground-fault receptacle features ground-fault protection in a unit that fits a standard receptacle box.

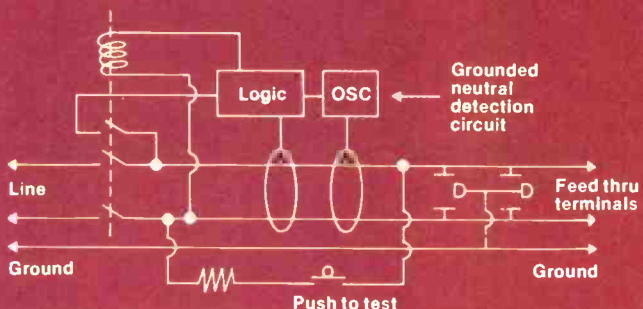
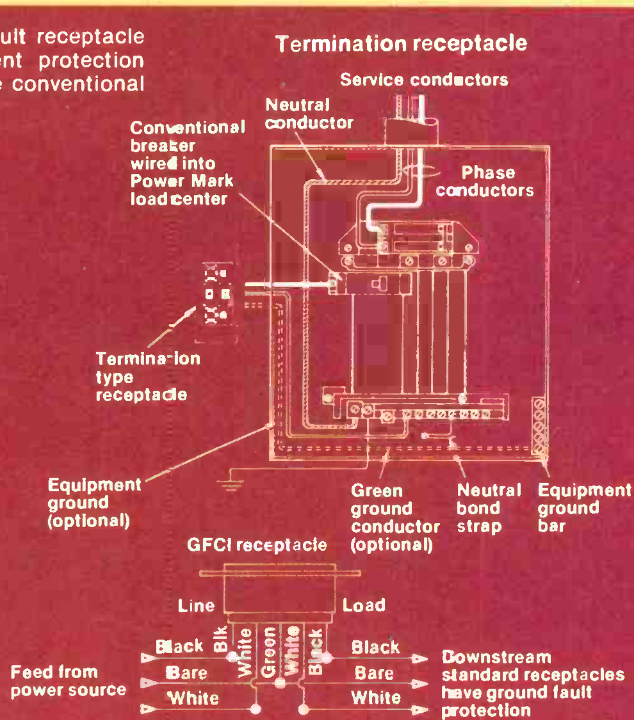
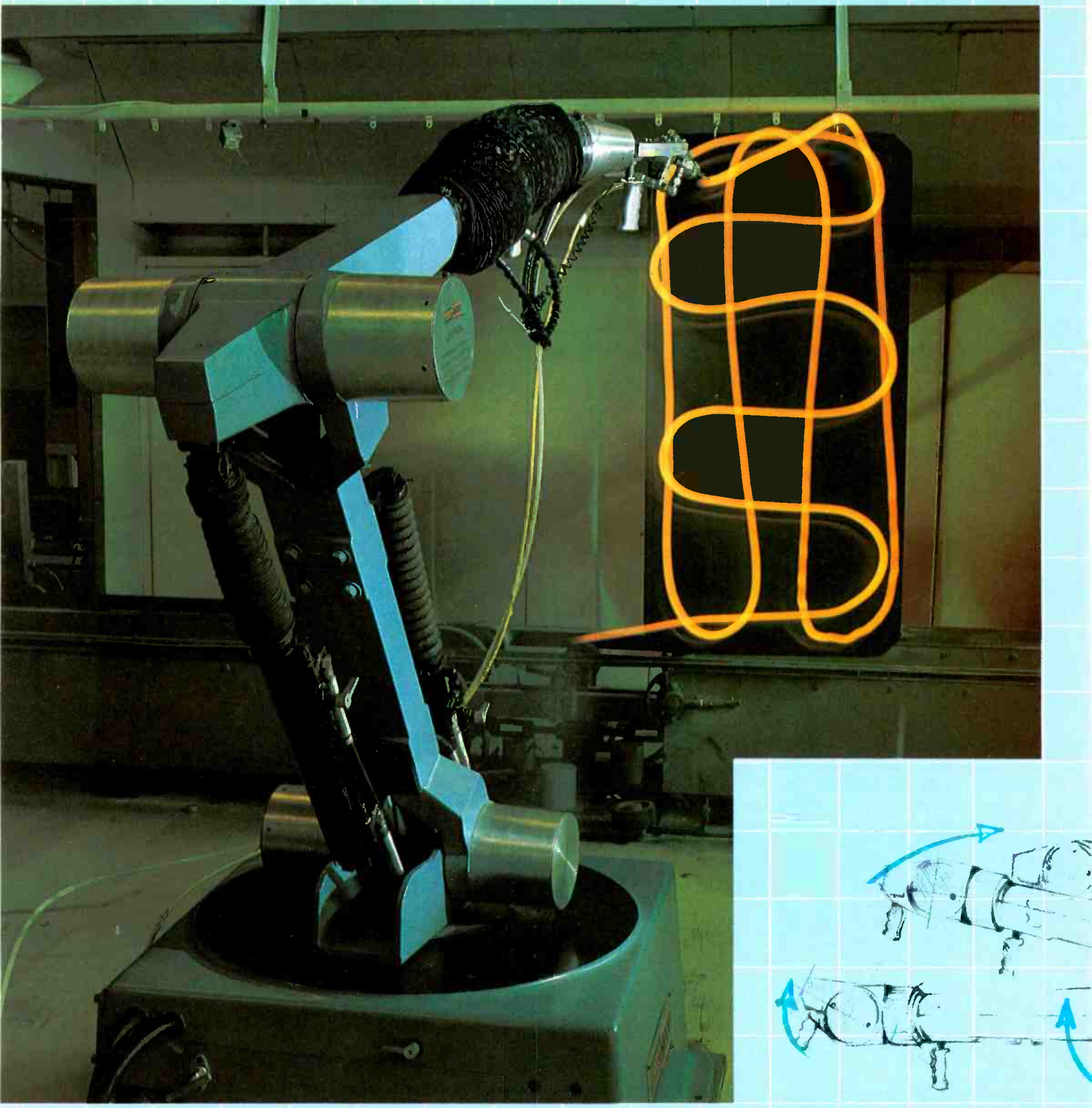


Figure 2b. This ground-fault receptacle does not have overcurrent protection and must be fed from the conventional breaker in the panel.





Robot 1a: a machine that looks like a human being and performs various complex acts (as walking or talking) of a human being; also: a similar but fictional machine whose lack of capacity for human emotions is often emphasized; 2: an automatic apparatus or device that performs functions ordinarily ascribed to human beings or operates with what appears to be almost human intelligence; 3: a mechanism guided by automatic controls.

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What is an industrial robot?

By Ken Susnjara, Thermwood Corporation, Dale, IN,
manufacturer of industrial robots

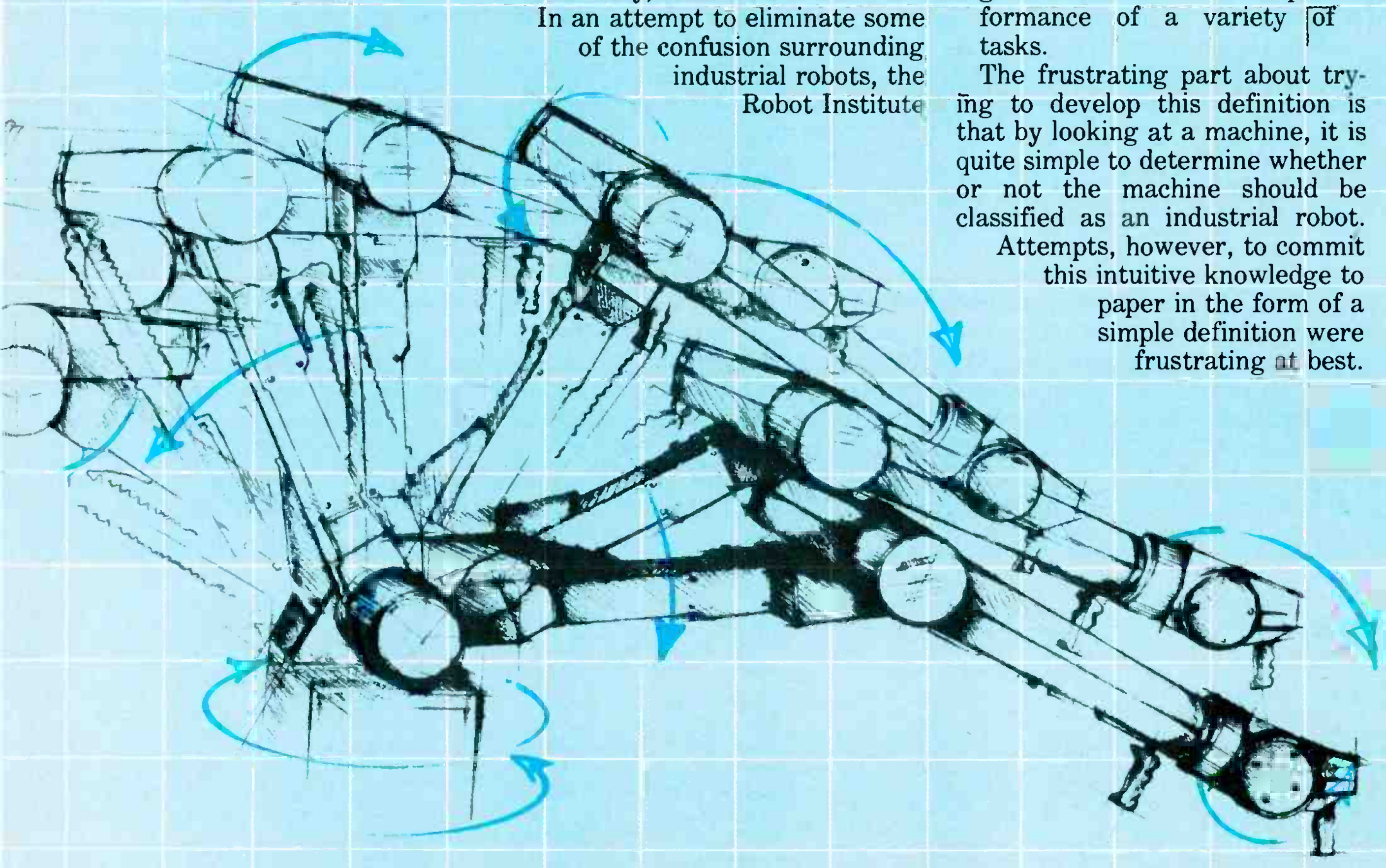
A friend of mine in the investment banking community spent the better part of a day discussing industrial robots with nontechnical investors. All through this discussion, a series of scale models of various industrial robots sat on a desk. As the meeting was breaking up and the conversation turned from industrial robots, one of the visitors picked up one of the scale models, remarked that it was an interesting-looking machine tool and asked what it was.

To the uninitiated, the word robot conjures up visions of mechanical creatures performing almost human feats. It at least conjures up a creature, like R2D2 from the recent movie *Star Wars,* which stands upright and squeaks in an unintelligible electronic voice. While these fantasy images of mechanical workers in industry have undoubtedly helped popularize the concept of industrial robots, they are unfortunately (or fortunately) not correct.

In an attempt to eliminate some of the confusion surrounding industrial robots, the Robot Institute of America (RIA) decided that a common, agreed-upon definition of industrial robots was necessary. Repeated attempts to devise a simple, understandable definition failed before the following, somewhat gingerly worded, definition was adopted:

> A robot is a reprogrammable multifunctional manipulator designed to move material, parts, tools or specialized devices, through variable programmed motions for the performance of a variety of tasks.

The frustrating part about trying to develop this definition is that by looking at a machine, it is quite simple to determine whether or not the machine should be classified as an industrial robot. Attempts, however, to commit this intuitive knowledge to paper in the form of a simple definition were frustrating at best.



The definition finally agreed upon does not, unfortunately, prove enlightening to the uninitiated. A nontechnical manager who has not been exposed to industrial robots will glean little understanding of their looks or capability or functions from a simple definition. In an attempt to properly understand the function of industrial robots in manufacturing businesses today, it's necessary to go back and try to capture that intuitive sense of which machines are really robots.

Robots in the work force

The first fact that must be understood is that an industrial robot is simply a machine. It is not a highly intelligent, mechanical person but is instead a functional machine tool. Industrial robots are today, and will likely remain for sometime in the future, extremely limited in what they can do when compared to even the most unskilled person. Even though some industrial robots are powered by very complex and capable computers, they still perform a limited sequence of motions.

So again let me repeat: *an industrial robot is a machine tool.* However, comparing its performance to that of a person is a unique attribute of industrial robots and brings us to what I feel is the core of the intuitive definition of an industrial robot. Industrial robots are by their very nature, direct replacements for human labor. Their job seems to be performing various tasks that normally would be performed by a person and performing them in essentially the same manner that a person would. These statements concerning the purpose of industrial robots conjure up deep, intense fear on the part of those who manufacture robots. They fear that any mention of robots, i.e., mechanical people, might result in a serious backlash by thousands or millions of workers who fear they will be replaced by these mechanical people. These fears might be well founded except for some realities that are not being considered.

Because a robot is a machine, it requires someone to program it and set it up, someone to keep an eye on it while it is running, even if only indirectly, and someone to fix it when it breaks. Each of these jobs requires some level of skill and special training. However, because the robot is a limited machine, it will need to be placed in a highly regimented environment and perform a fairly simple, repetitive, unskilled task. Because the unthinking, untiring industrial robot can perform its tasks consistently and unchanged day after day, it will provide considerable savings over the unskilled labor it replaces. People do not function well in unthinking, repetitive, monotonous and burdensome tasks. These are in general the only types of jobs industrial robots are capable of performing. It is not surprising then that industrial robots will do a superior job in many of these tasks. At the same time however, installations of industrial robots open up a number of new, exciting and challenging jobs where none existed before.

Engineering principles

Now that you have a conceptual idea of what an industrial robot is and what it does, a common question of the uninitiated is, "What does it look like?"

Industrial robots come in a variety of sizes, shapes, configurations and complexities. In order to understand this area, it is necessary to segment robots into a number of different categories.

Before discussing these categories, it is necessary to understand the meaning of several engineering terms. The first term that must be understood is "axis." You will find that robots are many times specified by the number of degrees of freedom or axes contained. An axis is a degree of freedom or a basic motion allowed by the mechanism. As an example, the bedroom door in your home is considered by engineers as a 1-axis mechanism. The door is capable of pivoting around a line that goes through the center of the door hinges to which it is mounted. The door's swinging open or shut is the one degree of freedom available. It cannot, however, move up and down, tilt, or move in any other direction other than swinging back and forth around the hinge. Another 1-axis mechanism would be a child's electric train riding on a track. The only motion available to the train is either forward or backward along the track. Even though the track may curve or go straight at different points, the fact that the train is restricted to simply moving forward or backward and is guided (it cannot move side to side, up and down, etc.) makes it a single-axis mechanism. Each independent slide or rotary joint within a robot, then, is referred to as an axis. The electric train can serve as an example to explain the difference between a servo-controlled and non-servo-controlled axis.

If you had a spot on a long section of straight track at which you wanted to stop the toy train, there would be two different methods that could be used to accomplish this. The simplest method would be to find a heavy obstacle, such as a concrete block, and place it on the track in such a way that when the train is touching it, it is in the desired position. It is then necessary simply to run the train in the proper direction and wait for it to hit the block. Then it is properly located. This system, with a bit more finesse, is called a non-servo-controlled system.

A second way to locate the train at the desired position would be to turn it on and as you watch it near the proper position, use the electric control to slow it down until it is properly located, then turn off the electric control. If you substitute a sensor that can tell how far the train is from the desired stopping point and allow the sensor to operate the electric control in place of the person, you have a servo-controlled system. The major advantage of a servo-controlled system is that it can stop at any point along the track without having to reposition the block.

Non-servo-controlled robots

Robots are generally separated into either servo or non-servo-controlled types. The non-servo-controlled robots are generally fitted with mechanical stops and are driven into these end point stops, which define the desired positions. Stops between the end points can be cycled into place to provide intermediate positions other than the end points of the axes. It is, however, apparent that the major disadvantage of a non-servo-type industrial robot is the limited number of points at which it can stop.

Non-servo-type robots are generally quite a bit less expensive than their corresponding servo-type systems. Many are capable of using much simpler control systems than the electronic computer control found in most of the servo-controlled machines. Simple air logic controls or electrical sequencing controls perform quite adequately with the non-servo-type robot. These control systems can be obtained at a much lower cost than the servo-type control systems.

Electrical sequencing controls come in many different configurations, however, all have one thing in common. They provide a program signal or signals *to* the robot

Non-servo-type robots are generally less expensive and simpler than servo-type control systems.

and wait for a signal *from* the robot telling the control that some event has occurred. This event can be something as simple as an arm extension or a clamp closing. Once the signal indicating that the event has occurred is returned to the controller, the controller steps to the next preprogrammed combination of signals, which is then sent *to* the robot. Again the controller waits for a signal indicating that the necessary event has occurred, at which time the controller steps to the next set of signals. In this way, the programmer sequentially steps through a series of preprogrammed signals with each new step actuated by a signal from the robot indicating that the last step is complete.

Air logic control works similar to electrical sequencing control except no electrical connections are necessary. All the steps and signals are controlled by the operation of a series of air valves. This type of air logic control has definite advantages when operating in explosive atmosphere. Because no electrical signals are present, the chance of a spark igniting the environment is reduced.

Although non-servo-type robots are generally small and designed to handle small parts at high speed, non-servo machines are available that can handle parts weighing in excess of 100 pounds and moving over a fairly large area.

Non-servo-type robots can provide surprisingly close accuracies at the end points of their travel. Because they generally operate against fixed, mechanical stops, the end accuracy of the robot is dependent on the mechanical give or stop that has developed in the system. This can be kept to a minimum. Small air-operated non-servo robots can easily hold overall accuracies of 0.001 inch, while 0.0001 to 0.002-inch end-point accuracies on some of the larger non-servo robots are possible.

Servo-controlled robots

Servo-controlled machines come in many sizes, shapes and configurations. They are endowed with a variety of working envelopes and weight carrying capabilities.

In general, servo-controlled robots are much more capable than the non-servo-type robots. They are also more expensive, although in recent times, the most expensive non-servo robots and the least expensive servo robots are overlapping in price.

Servo-controlled robots are generally controlled using micro-electronics and a computer-controlled system. These controls provide the robots with a variety of different capabilities that are difficult or impossible to achieve using the non-servo-type control.

In addition to classifying robots by their control system, either servo or non-servo, there are several other classifications of industrial robots in general use today. One of the more common classifications groups industrial robots by their operating methods. In this classification, robots are classified as either pick and place, point to point, or continuous path.

Pick-and-place robots

The pick-and-place designation is normally reserved for the non-servo-type machine with fixed stops at the end of each axis. These machines normally have a limited capability. They are able to perform a limited sequence of events but at times accomplish these at very high speeds.

These simple pick-and-place machines can also operate at high accuracies. The pick-and-place machines are generally of the polar coordinate system, and most are small compared to the larger point-to-point and continuous-path machines. Many of these machines are air powered with very simple control systems.

The name "pick and place" probably comes from the fact that in general, the task this machine performs is that of moving to a position, grasping a part, removing it, moving to a second position and inserting the part.

Some of the more sophisticated pick-and-place machines have intermediate stops that can be cycled into and out of position during the program. In this way, each axis can be stopped at more than two positions. For example, by cycling stop number 1 into position and then operating the air cylinder or hydraulic cylinder driving the axis, the axis can be moved against stop 1, defining an end-point position. By then retracting the cylinder, moving stop 1 out of position, and moving stop 2 into a different position, cycling the same air or hydraulic cylinder will move axis 1 against stop 2, defining a second position. In this manner, fairly complex programs can be developed to pick a part from one position and place it in another.

The next two classifications, point to point and continuous path, are used to describe two different methods of operating a servo-controlled robot. These classifications refer to the method whereby programs are input, stored in the computer, and automatically played back.

Point-to-point robots

The point-to-point, servo-controlled robot is capable of moving to any point within its working envelope. Programming a point-to-point robot is accomplished with some type of teaching terminal, pendent, hand-held programmer or the like. Using this device, the robot is operated at slow speeds and is first moved to a point that is to become the first point in the program. When the point is achieved, an "enter" button records that point in the computer. Each of the axes are then operated again, using the teach pendent, until the second point in the program is reached. Again the "enter" button is pressed, recording the second point. It is important to note that the only information stored in the computer control system is the location of each axis of the robot when the "enter" button is pressed. The sequence by which the programmer is able to move the machine to the desired point is not retained in any way. A variety of programming aids are available, with each manufacturer claiming features that make its machine easy to program. These aids normally are designed to make the desired point easy to achieve using the hand-held programmer. Some of these aids are more useful than others; however, the basic concept of moving the machine to each of the desired points in sequence and entering each is the common programming method for point to point robots.

In executing the program, the robot will move to the first point in the program, then proceed in an approximate straight line to the next point, then to the next and so forth until it has executed the entire program. It is necessary to remember in programming point-to-point robots that the robot will move in a straight line betwen the points and not necessarily along the path that the arm was moved during programming. This fact can cause some difficulty when an inexperienced programmer is learning to program an industrial robot.

There is one disadvantage to this type of programming: The robot must be taken out of production and made available during programming. For this reason, the idea of remotely programming a point-to-point robot in the office, as is done with numerically controlled machine tools, seems to

Pick-and-place robots are usually limited to moving a part from one position to another position.

have some merit. Doing this, however, presents several major obstacles. The first is that generally, the programmer only knows the point at which the end of the arm or the end of the tool should be placed and does not necessarily know the position of each axis of the robot needed to reach that point. When the robot is moved so that the end point is in the proper position, it then simply reads the position of each of the axes to determine how they must be configured in order to achieve the final end point. When the end point is programmed in an office away from the robot, another method of determining the various joint and slide positions must be developed. One way of accomplishing this is to have the computer mathematically calculate the positions of each of the joints on the robot needed to achieve the desired end point. This sounds simple, but, in fact, is very complex. However, it has been accomplished today by at least one manufacturer and several universities and robotic research groups.

Another problem that complicates the first is that the joint sensors are not necessarily the same on identical robots. A robot joint provides the computer with a signal when it is in a certain position. That robot always will present the same signal when it is in that position. In this way, recording the signal stores the position, and driving the joint until that signal is achieved produces the necessary position. Another robot, however, of the same make and model, using exactly the same sensor, may present a slightly different signal when the joint is in that same position. Because of this problem, programs developed on one machine may not exactly duplicate on a second machine; therefore programs developed in the office will operate differently on different pieces of equipment.

To get around this problem, a correction table method has been developed that provides consistent positioning of robots, regardless of normal variations in the joint sensors. In this system, all mechanical positions that a joint can take are developed while the signals of the joint sensor are monitored. For each mechanical position of the joint, a signal from the sensor is read and compared to the standard signal desired from that mechanical point. If the sensor reading is different than the standard, a correction factor is stored in a special table so that the signal can be corrected each time it must be used. This correction table must be developed each time either the joint or the sensor is taken apart and will be different for each machine manufactured. This system does, however, allow a mechanical position of the robot to correspond to a precise and predictable sensor signal.

As these capabilities become practical and more common, the dreams of a completely automated factory driven by a CAD/CAM system seem more obtainable. A CAD/CAM system (computer aided design/computer aided manufacturing) is a system in which the product to be manufactured is designed with the help of a computer, which develops all of the necessary programs for the NC machine tools, manipulators and robots, and with the aid of computers, automatically manufactures the desired products. This type of system is the ultimate in automation, and while the first example of these may be seen in the next five to 10 years, widespread use is still in the future.

Another capability that has been given to servo-controlled, point-to-point robots is line tracking and position transformations. Line tracking means that a program developed on a stationary or stopped part can be executed later while the part is moving down a conveyor line. In fact, the speed of the line may vary, and the conveyor may stop and even reverse direction while the robot automatically compensates for the line movement.

Line tracking is accomplished in two ways. The first and simplest method is one in which the robot simply locks onto the line and moves physically with it while it performs its task. If the line speeds up, slows down or reverses direction, so does the entire robot. Although not as sophisticated as other methods, this system is simple, easy to understand and practical.

A second type of line tracking is accomplished with a method called "mathematical transformations."

In this system, the robot mathematically changes the program in space, "transforming" the program to allow for conveyor movement. In order to accomplish this, complex mathematical capabilities are necessary. This capability is available from at least two major manufacturers today and will likely become more common as time goes on.

Continuous-path robots

In certain applications, such as spray painting, industrial robots are called upon not only to move to distinct points in space, but to move along predetermined paths. In performing a spray painting operation, the robot must be able to duplicate accurately the curved, flowing motions of a person using a spray gun. Obviously, trying to accomplish this using a point-to-point robot would be difficult at best. In order to accomplish these kinds of tasks, a new type of robot has been developed. This robot is the continuous-path robot.

Continuous-path robots are designed so that their structure is somewhat lighter and less massive than that of the point-to-point robots. They are counterbalanced, using springs or other methods, and the drive systems may be disengaged, allowing a person to move the arm about physically. Programming a continuous-path robot generally requires an individual to grasp the end of the arm and move the arm carrying the tool, i.e., a spray gun, through the desired path.

The continuous-path robot operates internally very much like the point-to-point robot. Instead of relying on the operator to indicate the various points to which the robot is to travel, a continuous-path control system records the position of each axis many times per second, with each of those recordings being an individual point. In running the program, the points are played back at the same rate they were recorded, and the robot arm attempts to move to each of these points as they are played back. The resulting motion is a very close approximation of the original path which was entered.

Because the continuous-path robot records many, many more points than the point-to-point robot, the electronic memory required is considerably larger. For this reason, plus certain other characteristics of the continuous-path robot, it is generally more expensive than the corresponding point-to-point robot.

Continuous-path robots normally have less load-carrying capability than the larger servo-controlled, point-to-point robots. Since the arms and actuators have been designed to be as lightweight as possible for programming, their ability to carry heavy loads is somewhat diminished.

Continuous-path robots generally have the capability of moving at high speeds. This is necessary so that adjustments required to perform the programs can be accomplished. The smooth-flowing

In spraying, a robot must be able to duplicate the curved, flowing motions of a person using a spray gun.

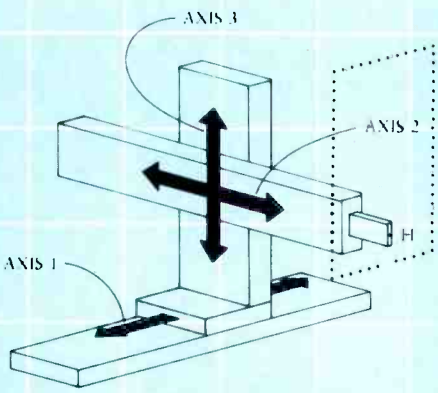


Figure 1. A rectangular-coordinate robot.

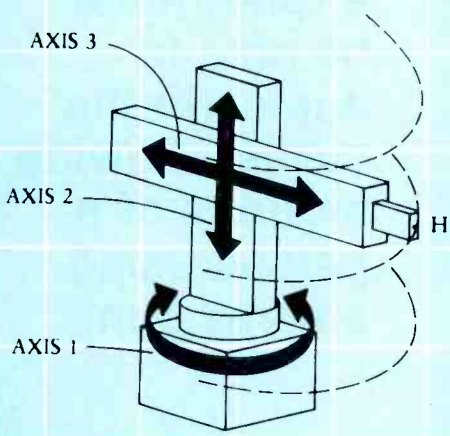


Figure 2. A cylindrical-coordinate robot.

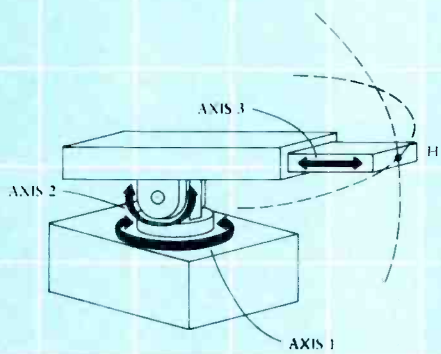


Figure 3. A spherical-coordinate robot.

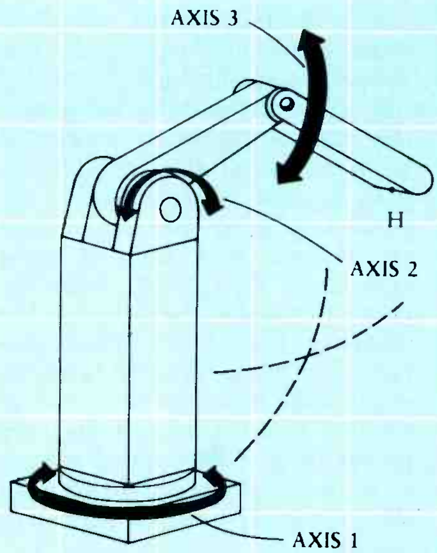


Figure 4. A jointed-arm robot.

motions of a continuous-path program make these machines look very humanlike in their actions and motions. This, of course, is because their motions are very humanlike; they are the motions input by the programmer.

Another classification system for industrial robots distinguishes the robot by the working envelope. A working envelope is simply the shape of the entire area that the end of the robot arm can reach. The shape of this area or working envelope is determined almost exclusively by the mechanical configuration of the robot.

There are four basic work envelope shapes. These four shapes are used by almost all of the robots produced today. The four shapes are rectangular, cylindrical, spherical and jointed arm. Diagrams of typical robots operating in each of these configurations are shown in Figures 1 through 4.

Rectangular robots

Referring to Figure 1, you can see the general mechanics and work-envelope shape of a rectangular-coordinate robot. As you can see in this type of machine, all axes are linear or slide axes. Axis 1 is a slide left to right, axis 2 is shown as a slide in and out and axis 3 is a slide up and down. The shape of the work envelope as traced by end point H can be seen by the dotted line. While the use of rectangular coordinates for industrial robots has not been common in the United States, except for some arc-welding robots, there are several European assembly-type robots that use the rectangular-coordinate system. In assembly work, where precise points must be achieved and part assembly or inserting requires an up and down motion, these machines perform well.

Cylindrical robots

Referring to Figure 2, a general idea of the mechanics of a cylindrical-coordinate robot can be seen. Axis 1 at the base allows the robot arm to rotate. Axis 2 moves the horizontal arm up and down, while axis 3 moves it in and out. A maximum point that can be achieved by the end point H traces the shape of a cylinder as shown by the broken lines. Machines that operate in this manner are called cylindrical-coordinate machines. Many, if not most, of the non-servo point-to-point machines use the cylindrical-coordinate configuration. The long slides lend themselves well to the installation of physical stops or limit switches. There are, however, some sophisticated servo-controlled industrial robots that utilize the cylindrical-coordinate system.

Spherical robots

Figure 3 shows a typical spherical-coordinate robot. Axis 1 provides rotation on the base, while axis 2 allows the main body of the robot to rock point H up and down. Axis 3 allows the slide to move in and out. At its extremes, point H traces the shape of a sphere; hence the name "spherical coordinate system." The largest number of spherical coordinate machines are servo-controlled; however, there are some non-servo-controlled spherical-coordinate machines on the market.

The spherical-coordinate system was the one chosen by Unimate over twenty years ago for its line of industrial robots. This line of robots has been very successful; hence, a large number of spherical coordinate robots are in operation in industry today. The system has proven effective, and these robots are being utilized today to perform a wide variety of tasks.

You may have noticed by now that each of these designs, as shown, contains only three axes. Most industrial robots contain five or six independent axes, however, the two or three additional axes are normally utilized where we show point H. These axes operate a wrist that provides articulation to the end of arm tooling or "hand" of the robot.

Jointed-arm robots

The fourth and possibly most complex working envelope is the anthropomorphic or jointed arm. This design most closely resembles the workings of the human arm. It is made up of a base rotation axis 1, a shoulder rotation axis 2 and an elbow rotation axis 3. The operation of these axes to their extremes causes point H to trace out an envelope shape shown in Figure 4. The jointed arm design in general provides the largest working envelope per area of floor space of any of the robot designs. The anthropomorphic design, however, requires a coordinated movement of each of the rotary axes in order for point H to move in a straight line between one point and another. This required coordination can only be accomplished using a computer control system. Therefore, the jointed-arm or anthropomorphic design is used today only by servo-controlled-type robots. Even with the use of computer systems, providing an anthropomorphic type robot with the ability to develop a straight line between two points in space requires rather sophisticated control capabilities.

In trying to determine which of the robot configurations is best, it is necessary to determine the requirements of the particular application under consideration. Each of the working envelope shapes and mechanical configurations has its particular advantages and disadvantages. It is necessary, when attempting to place an industrial robot in a job, to select those machines whose advantages can be utilized and whose disadvantages can be minimized. Using a machine with the proper mechanical configuration and working envelope can go a long way toward simplifying any particular application.

The definitions and classifications given here are by necessity general, and it must be understood that many variations and permutations exist. Each robot manufacturer is forced to choose from the many options available in designing its product line. Once a general understanding of robotics design and operation has been developed, it will be necessary to compare available robots by looking for each individual manufacturer's product literature. By examining various trade journals and other publications, various robot-to-robot evaluations have been and will continue to be made as an aid to prospective robot users.

ES&T

Toward the automatic factory

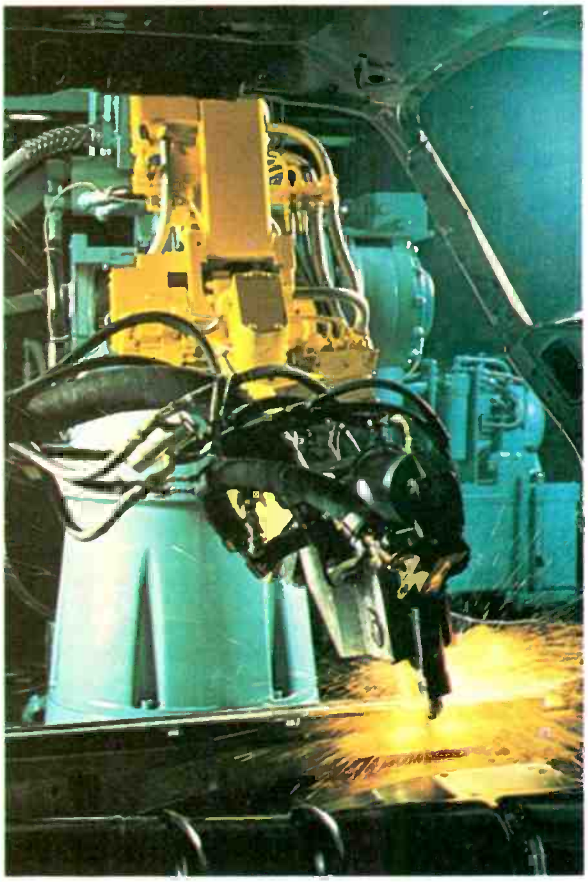
The articles about robots presented in this issue should make it amply clear that the state of the art in robots, at this time, is the industrial robot: a device that can be programmed and reprogrammed to perform any of a number of simple, repetitive tasks that require only the most rudimentary of decision-making ability and no sensory inputs.

This situation could change within the next decade or two, and anthropomorphic robots could be available in large numbers to relieve each of us of tasks like house and yard work.

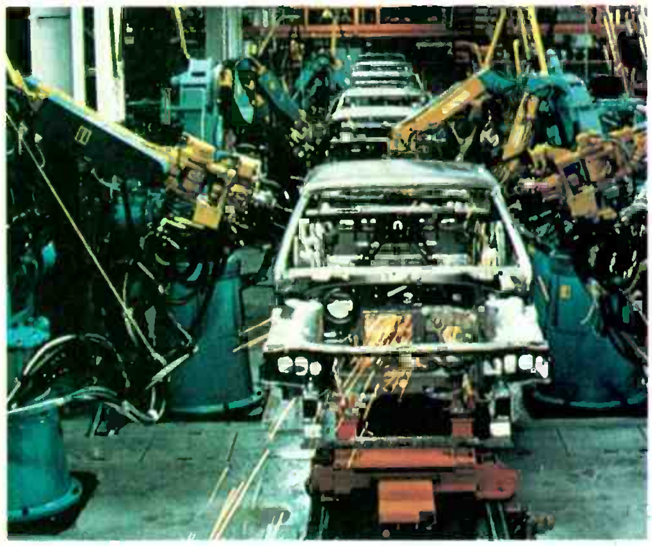
In fact, a recent article in the Wall Street Journal reported that last Christmas, Nieman-Marcus, the famous Dallas department store, had robots available for doing the housework. At $75,000 or so per copy, however, not one was sold. The same article further reported that Heath Company of Ann Arbor, MI, is working on a robot that is expected to be available in a year or so, in kit form.

But for today, the industrial robot is the name of the game, and the effects of their existence are expected to be far reaching. A combination of technologies available today could lead to what has been called the automatic factory: a place where raw materials enter and finished products leave with little or no human intervention. The technologies involved are such things as robotics, computer-aided design and manufacturing (CADAM), and electronic inspection techniques.

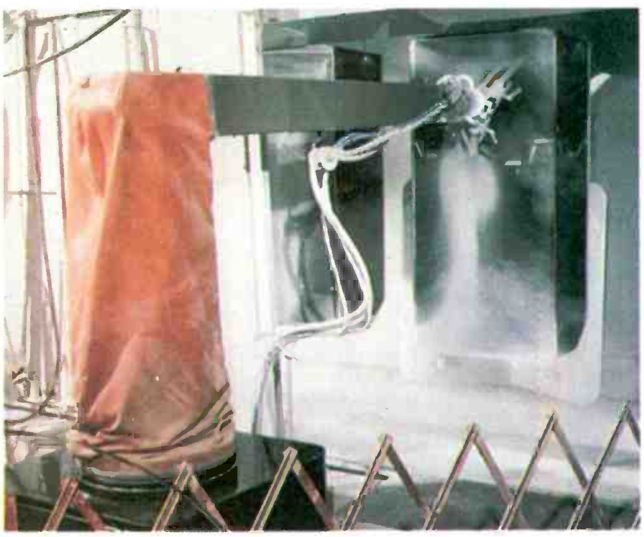
While industry exploits robots to the fullest extent possible, experimenters are also getting into the act. Several companies have begun offering low-cost robot arms that may be interfaced with personal computers and made to do rudimentary, repetitive tasks in the experimenter's home or lab.



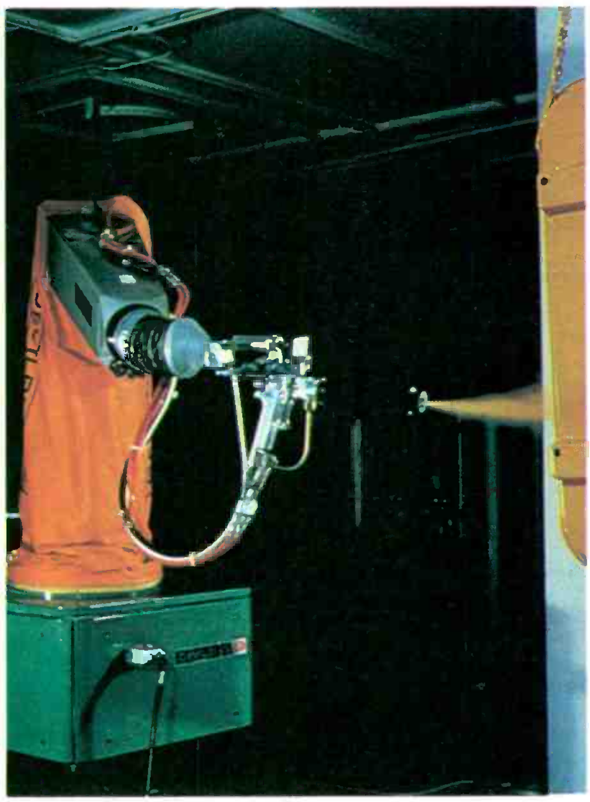
A computer-controlled robot, the T[3]-586 by Cincinnati Milacron, places spot welds on a car body as it moves past on a conveyor. The tracking capability enables the robot to spot welds without stopping the line.



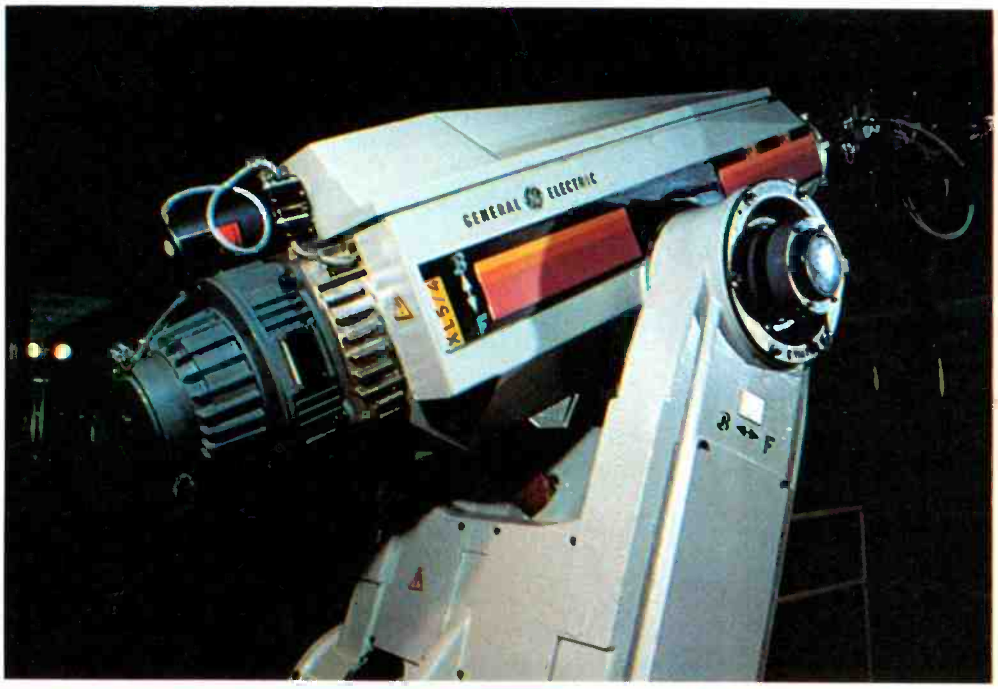
At General Motors Assembly Division plant in South Gate, CA, fourteen Cincinnati Milacron robots spot weld J-car bodies at a rate of 72 bodies per hour. Robots spot an average of 400 welds on each body.



Refrigerators are only one of hundreds of items being manufactured with the help of robots. This DeVilbiss TRL-3000 is spraying a refrigerator liner with powder coating.

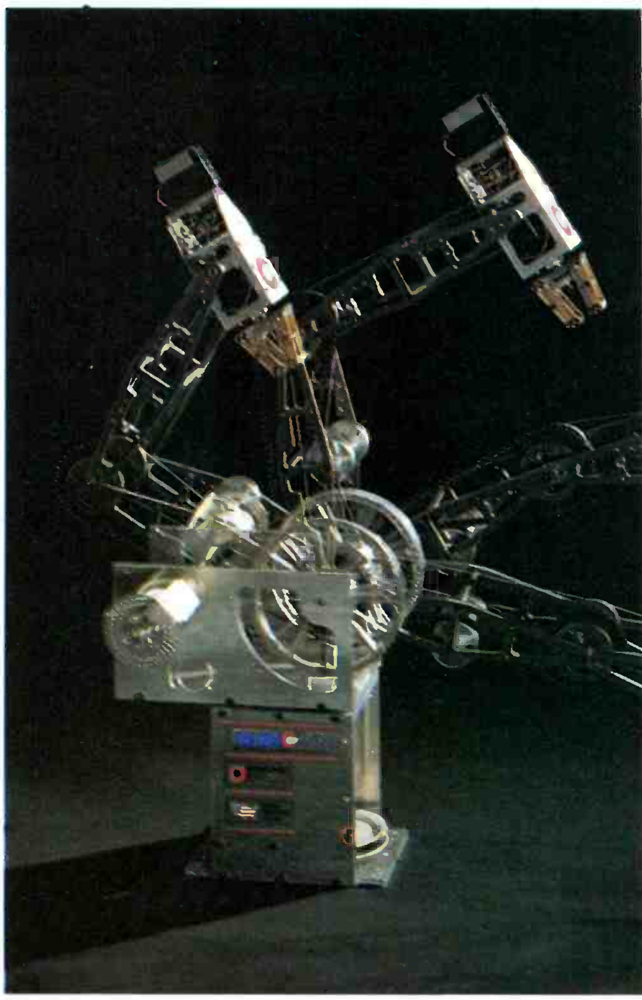


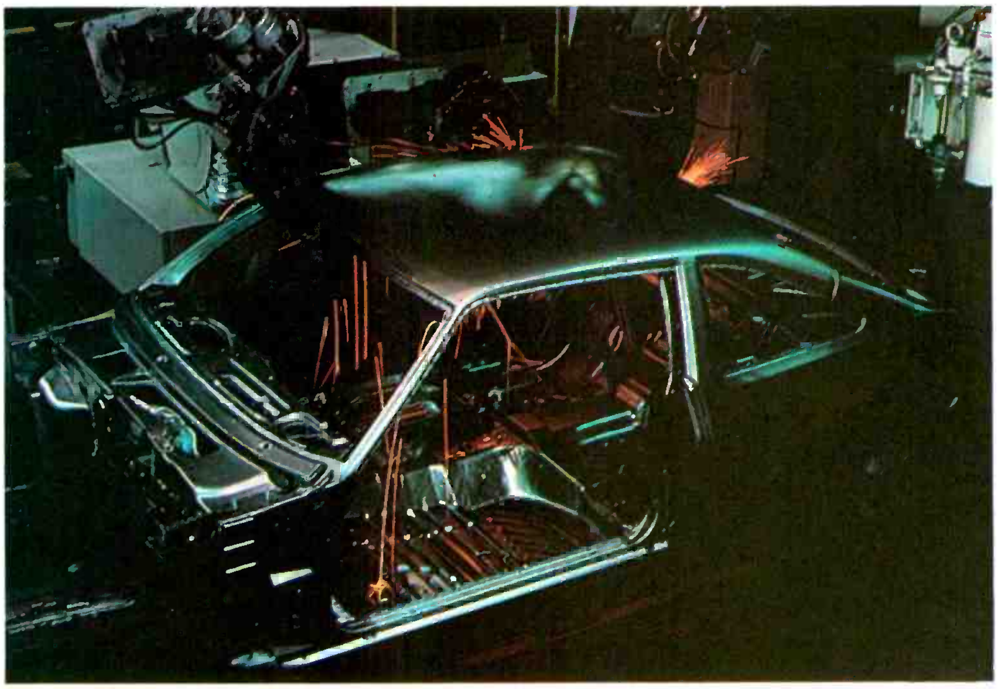
The DeVilbiss/Trallfa TR-3000 robot is often used for spraying paint and other elements involved in manufacturing. Here, the unit sprays a vehicle component with EH8 airless electrostatic.



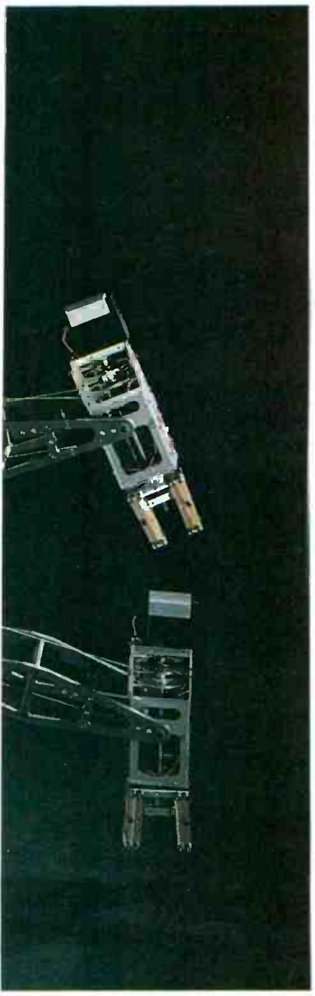
Driven by electric servo motors, the GE robot, GP 132, is a 7-axis, single-arm robot designed for general-purpose material handling.

With a payload capacity of 132 pounds, the GP 132, by GE, is suitable for loading and unloading large workpieces.

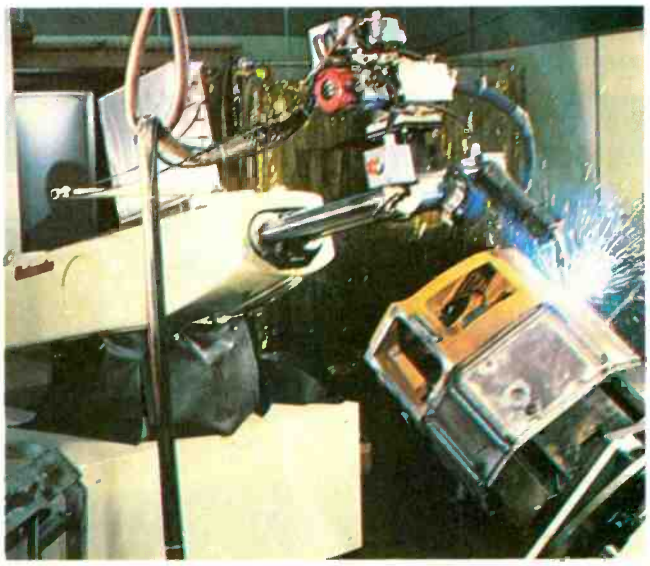




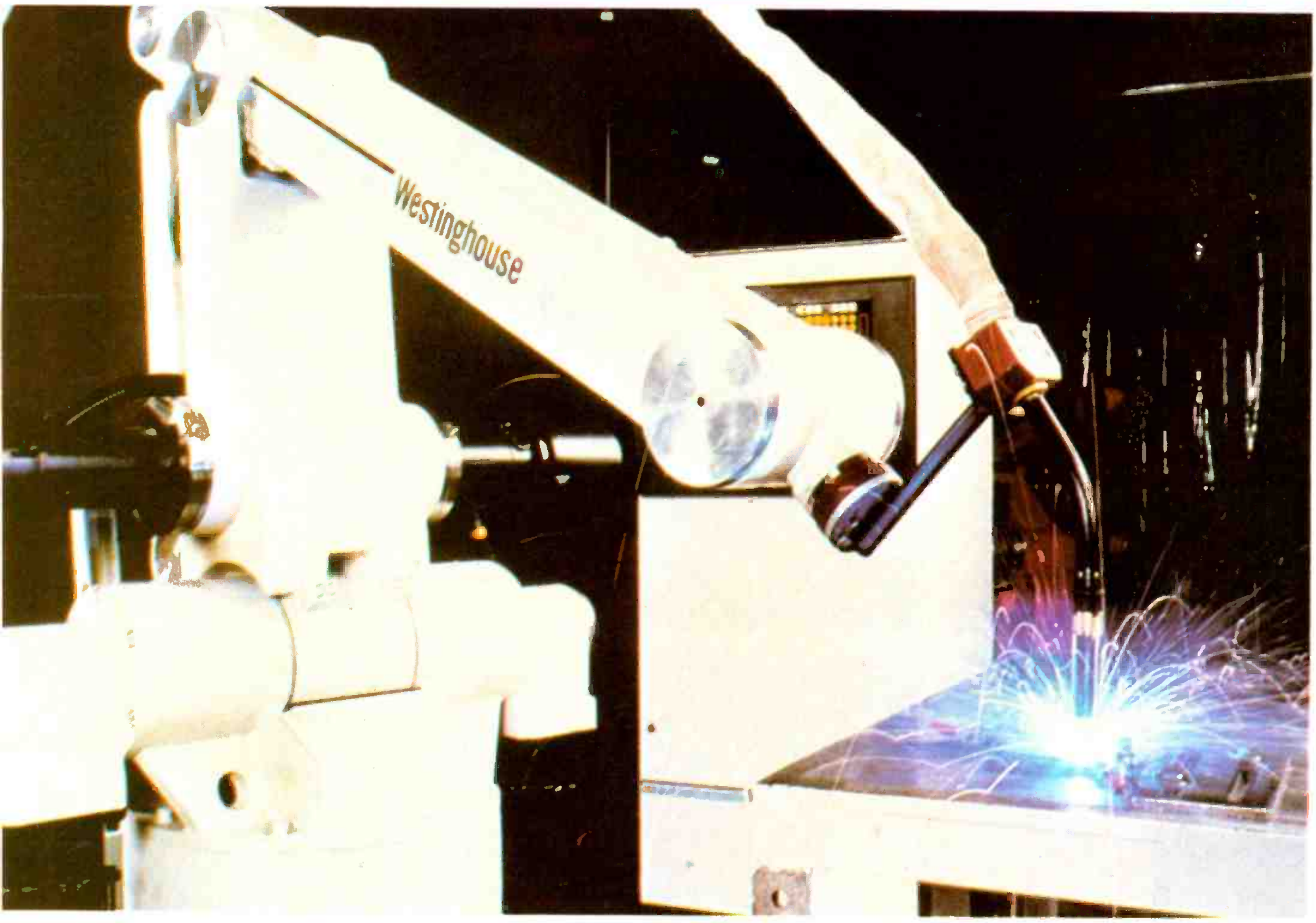
Unimate robots by Unimation perform spot welds on an auto body.



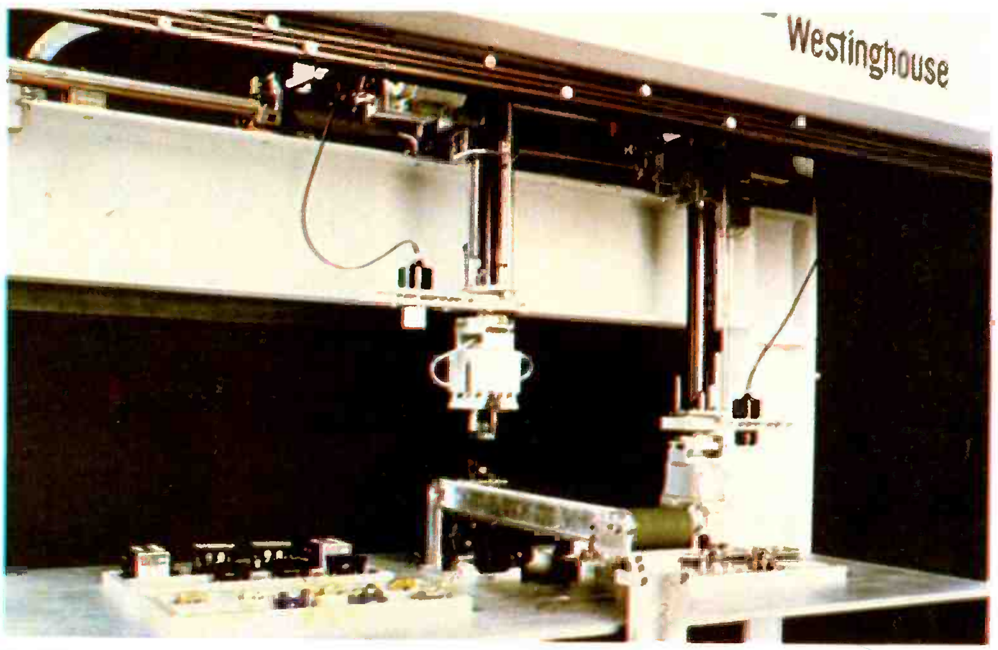
The Rhino XR-1, from Sandhu Machine Design of Champaign, IL, is a low-cost robot designed for education, research and industry. It stands 32 inches high and contains six motors, one for each axis point in the arm-like mechanism. The unit must be linked to a computer to be operated.



An example of continuous-path welding by a Unimate robot at Air Research.



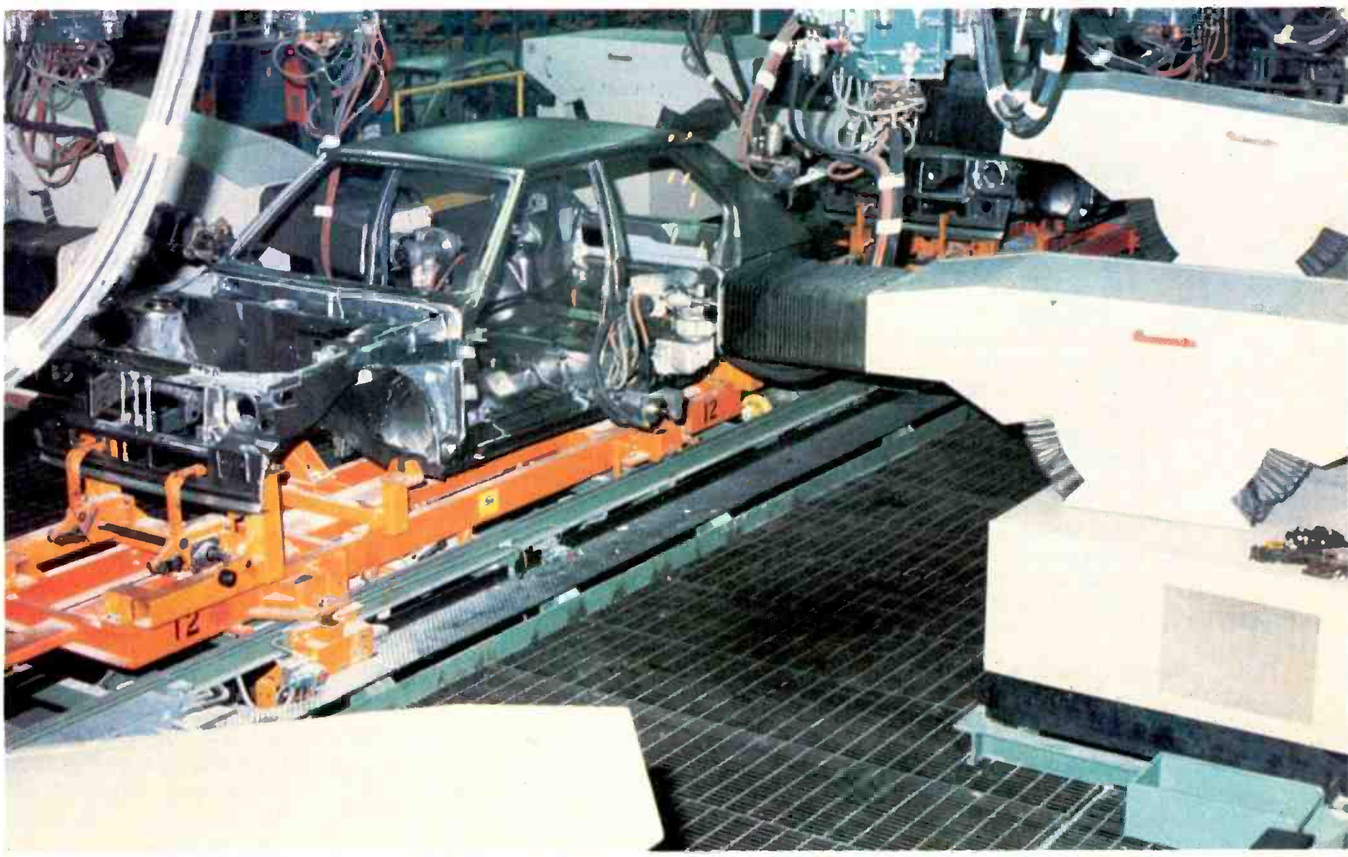
The Series 4000 by Westinghouse is a low-cost, precision, robotic welding system that uses a pulsed gas-metal-arc welding power source. The four major parts of the system are an electric, servo-controlled, arc-welding robot; a computerized robot control; a pulsed-current welding power source; and a wire feeder.



The Series 5000 robot system by Westinghouse is available with one, two or three arms, and can be used to assemble electrical relays and breakers, complex integrated circuit boards, automotive components and complex office machines.

Robotics in practice: Future capabilities

By Joseph F. Engelberger, Unimation



Auto spot welding by a Unimate robot. *(Photo courtesy of Unimation.)*

Whatever the intentions of their creators, robots are always going to be compared with men in terms of their attributes and general behavior. Although they might be fine for doing repetitive, dirty, boring, dangerous jobs in factories, and even though they can often do such jobs with positive economic advantages, robots remain stupid, insensitive and limited devices when they are compared with human beings.

No robot can hope to match man with his acute senses, ability for free thought and judgment, artistic appreciation, capability for self reproduction, efficient conversion of food into energy and body cells, and properties of recovery from many illnesses and injuries. The gulf between man and robot will always remain, but, although it cannot be closed, this gap is going to be reduced as technology advances.

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Future attributes

Figure 1 is a recapitulation of the principal attributes to be found among the range of successful robots in manufacturers' current catalogs. The last item listed is by no means the least important. Any manager who has a possible robot application is obviously going to satisfy himself not only that the potential robot recruit to his workforce is capable of doing the job, but also that it can be bought or hired for a price that stands up to scrutiny by at least one of the recognized techniques of economic evaluation.

Features that are considered to be desirable goals for future robots are listed in Figure 2. State-of-the-art technology already places several of these characteristics within the grasp of the robot designers, and some are to be seen on experimental robots operating in laboratories. The more sophisticated these devices become, the more they will obviously cost. But, trends toward continuing or even increasing labor cost inflation favor such developments, so it is

1. Work space command with six infinitely controllable articulations between the robot base and its hand extremity
2. Teach and playback facilities—realizing fast, instinctive programming
3. Local and library memories of any practical size desired
4. Random program selection possible by external stimuli
5. Positioning accuracy repeatable to within 0.3mm
6. Weight handling capability up to 150kg
7. Point-to-point control and continuous-path control, possibly intermixed in one robot
8. Synchronization with moving workpieces
9. Interface allowing compatibility with a computer
10. Palletizing and depalletizing capability
11. High reliability—with not less than 400 hours MTBF
12. All the capabilities available for a price that allows purchase and operation within the traditionally accepted rules for economic justification of any new equipment

Figure 1. Robot qualities already commercially available.

1. Rudimentary sense of vision to provide
   a) recognition data
   b) orientation data
2. Tactile sensing giving
   a) recognition data
   b) orientation data
   c) physical interaction data
3. Computer interpretation of the visual and tactile data
4. Multiple appendage hand-to-hand coordination
5. Computer directed appendage trajectories
6. Mobility
7. Minimized spatial instrusion
8. Energy-conserving musculature
9. General-purpose hands
10. Man-robot voice communication
11. Total self-diagnostic fault tracing
12. Inherent safety (Asimov's Laws of Robotics)
13. All the capabilities above available for a price that allows purchase and operation within the traditionally accepted rules for economic justification of any new equipment

Figure 2. Robot qualities sought for the future.

Kinematics	Automation technology	Character recognition
Dynamics	Numerical control	Industrial engineering
Servo design	System engineering	Manufacturing engineering
Fluid power	Rotating machinery	Physiology
Digital electronics	Gear design	Bionics
Analog electronics	Structural engineering	Psychology
Computer structure	Tribology	Sociology
Integrated circuit design	Metallurgy	Economics
	Metrology	Futuristics
Computer software	Sensory instrumentation	Oceanography
Cybernetics		

Figure 3. Disciplines useful to the robotics game.

likely that such advances will become economically viable sooner rather than later.

If the features listed in Figure 2 are difficult to achieve, some of them become even more elusive when attempts are made to combine them with other features of the same robot. For example, it is possible to mount a small video camera at the end of a robot arm to provide some sort of visual signals, but this would work against item 7 on the list, minimized spatial intrusion. Another important factor in any new development is the effect on robot reliability. Unless special care is taken in the design and selection of components, and in the quality of construction, added complexity will downgrade the statistical probability of failure from the 400 hours MTBF already achieved.

The problems notwithstanding, it is reasonable to expect that the attributes of Figure 2 will be attained because the technological demands are not outrageous and the merit of the need is clear. One can evaluate prospects for success from the viewpoint taken by the U.S. Department of Defense in a 1967 program titled "Project Hindsight." The conclusion was that innovations happen when there is a juxtaposition of:

1. A recognized need
2. Competent people with relevant technology
3. Financial support.

Given all the attributes that robots already offer and the bank of experience that existing robots have accumulated, there is a mounting pressure for additional capability. This is what the Air Force study called "a recognized need." Worldwide, competent people are joining the fray. Robotics is a great fun game and there is immense opportunity for satisfaction in making a contribution. The people who elect to become roboticists bring with them a relevant technology.

The relevant technology is broad indeed. Figure 3 catalogs some of the relevant disciplines. The more successful roboticists may very well be technological generalists. The industrial world has the competent people with the relevant technology; the need is recognized; and the third ingredient, financial support, is coming from a myriad of sources. First of all, there are the robot manufacturers who devote a percentage of their revenues to advanced research and development. These pioneers have been joined by government organizations who sponsor research and development in the public interest. Gains in productivity and the release of man from onerous tasks are considered to be in the public interest. Grants go to universities, non-profit research laboratories and even to industrial concerns. The Comecon countries likewise divert a portion of their wherewithal to robotics research and development. The amount of activity generates increasing pressure and the attributes listed in Figure 2 become urgent needs for those with finance, and attainable needs for those with the technical expertise. Most, if not all, of these attributes will be on hand before the end of the decade.

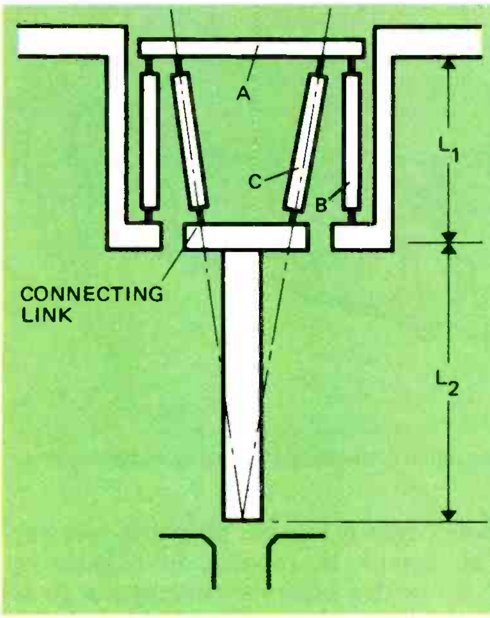


Figure 4. The vertical links (B) give a compliance center effectively at infinity, so lateral forces produce only lateral motion. The other links (C) give a compliance center at the end of the peg that allows only angular rotation in response to a moment applied at the tip.

the application potential will burgeon. This eyesight evolution will move ever faster during the decade of the 1980s and every triumph will be accompanied by a geometric progression in robot utility.

The second most important frontier is tactile sensing and here invention has already occurred. Draper Labs, in its efforts to computer control the interaction between parts that must be mated, came upon a serendipitous conclusion that such parts-mating can be eased by a completely mechanical passive accommodation. The device known as the Remote Center Compliance (RCC), is shown schematically in Figure 4. It is already being used experimentally by researchers attacking the problem of programmable assembly.

Priorities in development

It is important to emphasize that of the missing robotic attributes, the two crucial ones are vision and tactile sensing.

We all know that human vision serves its possessors in a spectrum that ranges from the near-blind to 20/20 vision. A combination of 20/20 vision and 20/20 ability to analyze scenes is not in the cards for robots in this century, if ever. But each advance that permits a robot to peel away a cloudy curtain and thereby understand its surrounding environment will enhance the robot's utility.

It is a simple vision system indeed that tells a robot whether or not an opaque item is present or absent. Photocell devices to accomplish this binary task have been available for decades. A more advanced vision system can detect not only presence or absence, it can also identify an object that is present. The next step is to not only identify, but to determine the position and orientation of an isolated part, perhaps a black part on a white background. Then, the robot's eye, by increasing discrimination, can detect a part that is one level of gray against the background of another level of gray. Finally, the robot may be given the ability to discriminate among a number of gray parts that are in juxtaposition and perhaps even obscuring one another. At each stage of sophistication, new opportunities will arise for robots in the factory.

The importance of being able to see, to interpret what is seen and to react intelligently to what is seen cannot be overemphasized. The workplace is being rationalized. More and more often, factories will take pains to preserve orientation, but when the robot can cope with disorientation, then

Sensory perception is getting full measure of attention by industrialists and academics. Consider the typical laboratory facility depicted diagrammatically in Figure 5. This is the facility being used by SRI International in its exploration. The system has the hierarchy of computer capability,

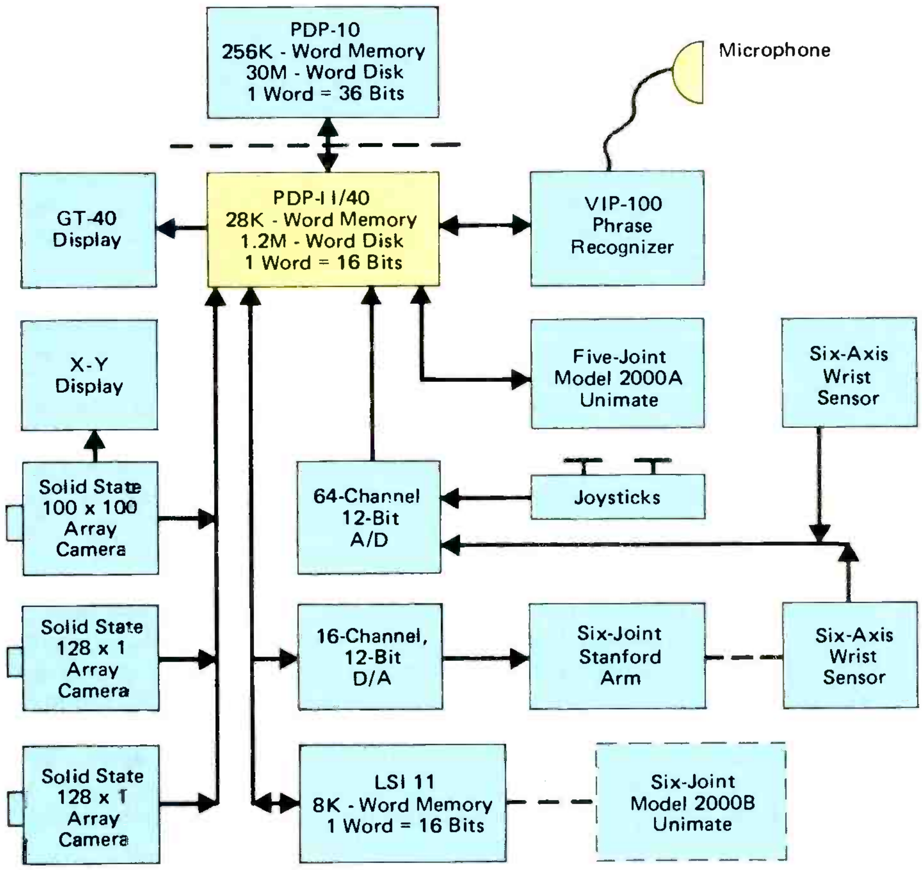


Figure 5. A diagram of a laboratory setup for evaluating robot sensory perception and manipulator dynamics.

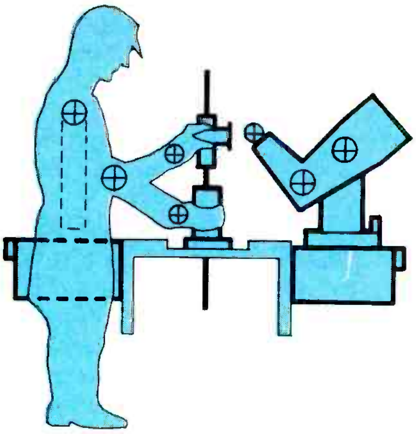


Figure 6. A human-size robot.

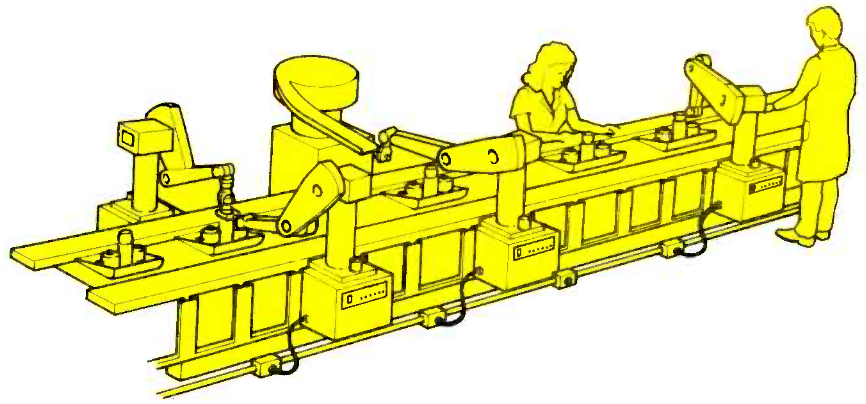


Figure 7. The introduction of robot arms into a conventional indexing assembly line.

it uses vision input and wrist force sensor input and voice input. Throughout the industrial world, similar facilities under the command of bright technicians are being used to create the missing algorithms of sensory perception.

Future applications

Each addition of attributes, or enhancement of attributes, will open up new application opportunities. It is safe to conjecture regarding some of these that are on the threshold of being realized. However, it may be that the existence of an advanced robot with enhanced attributes will occasion new applications that as yet have not aroused the speculation of roboticists. There is historical precedence because many current applications were hardly in mind during the robot development phase. One thinks, for example, of investment casting, which has become an application exceptionally suited to robots with currently available attributes.

One field that is sure to be carved out by robotics is assembly. This is the one future application that will be considered in detail because it is imminent and because it enjoys such intensive development effort today. Before discussing assembly, however, it might be well to describe briefly some prospective applications that have been suggested and for which there is more than a glimmer of hope for success.

1. *Cleaning parts.* The requirement is to remove randomly located flash from plastic parts as well as metal parts. The inelegant solution of cleaning an entire surface, whether it needs it or not, is too time-consuming, but the robot with sensory perception would be able to pick out the areas in need of attention.

2. *Automotive paint spraying with absolutely no human presence.* If every human being is eliminated from the automotive paint spray booth, then conditions for spraying paint can be optimized and the problems of health hazard and environmental protection can be eliminated. This application is being vigorously attacked by a General Motors team of engineers who have developed an extremely sophisticated paint spraying system that involves robot arms. One could conclude that GM is leaning to the distributive vs. the stand-alone robot.

3. *All kinds of packaging and, specifically, packaging that requires vision.* An example under current study is the packaging of chocolate candies that arrive at a packaging station in disoriented fashion and which must be found, oriented and nested in candy boxes at a high rate of speed.

4. *Electrical harness manufacture.* Traditionally, electrical harnesses are made on a "harness board" and human operators lead wires around pins to specified destinations, after which these wires are bundled to complete the harness. Every harness has its own board and this may involve vast amounts of tooling storage. Work is under way to automate this process with a robot arm to lead and bundle the wires. Programmable automation will be used to create a universal harness board.

5. *Package distribution.* Loading of trucks to distribute packages is a harsh task that may succumb to robotics in conjunction with a supervisory computer to explain to the robot how the packages should best be loaded to achieve a high packing density.

6. *Handling soft goods.* The robot with both visual and tactile sensing and perhaps a universal gripper may be able to help the hard-pressed garment and shoe industries, which are very labor-intensive and whose work load is slowly being relegated to the Third World.

7. *Sheep shearing.* Sheep shearing is seriously being considered for robotics by an Australian concern that has devised means for immobilizing sheep during the shearing process. The sheep-shearing robot must have contour following capability and it must have force-sensing capability. As the investigators say, if this application were successful, robots would have finally entered a "primary industry."

8. *Prosthesis.* Work has been done to build extra-skeletal structures around humans who have lost control of their limbs. This has not been very successful to date and, at best, it is a travesty of human dignity. Another solution is to put a robot under voice command of the paraplegic, thereby giving the paraplegic the full-time benefit of an automation servant. This "Man Friday" concept would provide a physical extension of the unfortunate handicapped person without the need for the one-on-one emotional strain of a physically complete human continually serving the handicapped individual. It is possible, it is worthy and it just might obtain sufficient

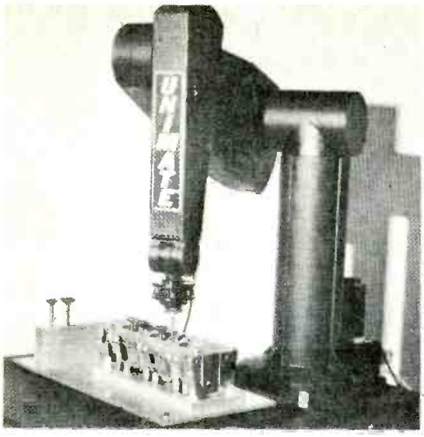


Figure 8. A human size robot—the Unimate 500.

1. Operates in real time
2. Programmed in joint, world or tool coordinates
3. Contains editing to add, delete or replace
4. Built-in diagnostics
5. Speed scaling
6. Programming interaction while operating
7. Instructions for looping, branching, position indexing
8. Interfacing outputs and inputs
9. Automatic approach and departure
10. Program compensation for workplace orientation
11. Off-line floppy disc program storage
12. Continuous-path operation at constant tool speed
13. Line-tracking capability
14. Sensory perception interface-closed loop and interactive override
15. RS232C computer interface

Figure 9. Attributes of a VAL computer language for addressing a PUMA robot.

financial support to become a reality.

9. Service industries. An officer of McDonald's restaurant once asked Unimation if a robot could produce the hamburgers, the fries and the Egg McMuffins. Unimation engineers demurred, but with a bit more rationalization in the fast-food business, it might be possible to put sensate robots to work and then hire the youngsters just to entertain the clientele.

Another service application might be the collection of garbage. With garbage picked up curbside in standardized containers, a garbage truck could roll along the street under human command while a robot at the tailgate would pick up, empty and return garbage containers to the curbside.

10. Household robot. Even a household robot may be practicable before the end of the 1980s decade. Given the advanced attributes and a house that is designed to match the needs of both robot and human inhabitants, we might bring the servant class back into being.

Application in assembly work

Closer to reality than all the foregoing, however, is the use of robots in assembly. In the discussion of robotics vs. hard automation, it has been noted that a great deal of assembly is already done with special-purpose automation. On the other hand, there is a vast amount of assembly work that does not lend itself to special-purpose automation. The bulk of assembly is still done by people and some 40% of the so-called blue-collar workforce is engaged in assembly.

Professor Boothroyd of the University of Massachusetts asks why assembly work still requires human attention. He concludes that the bulk of batch production assembly operations will not enjoy conventional automation for a variety of reasons. He points out that conventional automation generally involves a special-purpose one-off machine and therefore cannot be considered for assembly of products other than those satisfying all of the following requirements.

- A volume of at least one million per year.
- A steady volume of production.
- A market life of at least three years.
- A size of the order of between 0.5 and 20 inches with individual parts to be automatically assembled generally between 0.05 and 5 inches in their maximum dimensions.
- Consisting of parts that do not deform significantly under their own weight or will not break when dropped from a height of about 3 inches onto a hard surface.
- Parts quality must not require human operator adaptability.
- Part-on-part, "pancake" assembly must be possible.

These are clearly serious constraints and because we do get all of our various assemblies together, it must be concluded that humans are not so constrained. The hope now is that robots with their new attributes will also not be constrained and therefore able to take over batch production assembly operations.

A program of more than routine dedication is the General Motors program that carries the acronym PUMA, Programmable Universal Machine for Assembly. In this effort, Unimation is a GM subcontractor. GM specified a robot with space intrusion comparable to that of the human being and with a weight-handling capacity of 5 pounds. Surprisingly, the GM analysis indicated that 90% of the parts used in an automobile weigh less than 5 pounds. Figure 6 is the GM spec drawing for a robot designed to human size. Figure 7 is another GM sketch indicating how these robot arms might be introduced into an otherwise conventional indexing assembly line.

Figure 8 is a portrait of the Unimate 500 robot, which has been designed to meet the requirements of the GM PUMA system. It is expected that PUMA systems will be able to do automotive subassemblies such as dashboard, taillights, window cranks, transmissions, speedometers, carburetors, alternators, etc.

Of importance to the ultimate success of this venture will be the VAL language, which is embedded in the Unimate 500 robot's computer control. The functional attributes of this very powerful language are listed in Figure 9. It should be noted that this language equips the robot to accept and act upon sensory perception signals, be they visual or tactile. Originally, the GM program expects to use robots without sensory perception, but as this equipment becomes available, the PUMA system should be able to cope with ever-more sophisticated tasks.

ES&T

PHOTOFACTS

These Photofacts for TV receivers have been released by Howard W. Sams & Company since the last report in ES&T.

GENERAL ELECTRIC

Chassis PC-A	2095-1

PHILCO

B385PWA	2089-1
Chassis E32-24/25	2090-1
Chassis E31-1/4	2094-1

SANYO

Chassis A2P-84000/86000	2092-1

SONY

TV-125	2090-2

SYLVANIA

Chassis E51-11/13/15/17	2084-1
MWA156W	2092-2
Chassis E51-23/24/25/26/27/28/34	2094-2

TMK

790C	2078-3
7052	2082-2
725	2087-2
700	2088-3
705	2089-2

TOSHIBA

Chassis TAC110/111/112/160/161/162	2090-3
Chassis TAC101/150	2091-1

WARDS

GGV17301A/7611B/7781A	2077-2
GGV16300A,C/6310A,C/6611A, GGV17480A/7611A/7700A,C/ 7710A,C/7720A/7730A/7750A	2079-2
GEN-11780A	2081-3
GEN-12100A	2082-3
GEN-12100B	2084-2
GGV-17650A,B/660A,B/670A,B/680A,B	2093-1
GEN-11180A,B	2095-2

ZENITH

SN2535AR/589AR/593P,SV4531E	2089-3
SS1925W6	2091-2
Chassis 5NB1X/4X	2092-3
N1310A4, PT4/382W4, N1720W4,V3310C4	2093-2

CALENDAR OF EVENTS

September

14-16
Wescon '82, Anaheim Convention Center, Anaheim, CA. For more information, call 1-800-421-6816.

14-16
Mini/Micro Computer Conference and Exhibition, Disneyland Hotel, Anaheim, CA. Contact Electronic Conventions, 999 N. Sepulveda Blvd., El Segundo, CA 90245, 1-800-421-6816 (in California, 1-213-772-2965).

29-Oct. 1
Communications Technology Management's third annual telecommunications conference, "The Information Services Industry: Blueprint for Corporate Success," Washington, DC. Contact Regina Schewe, 1-703-734-2724.

October

11-13
EIA Fall Conference, Century Plaza Hotel, Los Angeles, CA. For more information, contact the Electronic Industries Association, 2001 Eye Street N.E., Washington, D.C. 20006.

November

1-2
15th Annual Connector Symposium, sponsored by the Electronic Connector Study Group with cooperation of more than 50 connector manufacturers, Franklin Plaza Hotel, Philadelphia, PA. Contact Electronic Connector Study Group, P.O. Box No. 167, Fort Washington, PA 19034.

30-Dec. 2
Midcon/82 High-Technology Electronics Exhibition and Convention, Dallas Convention Center. Contact Electronic Conventions, 999 N. Sepulveda Blvd., El Segundo, CA 90245, 1-800-421-6816 (in California, 1-213-772-2965).

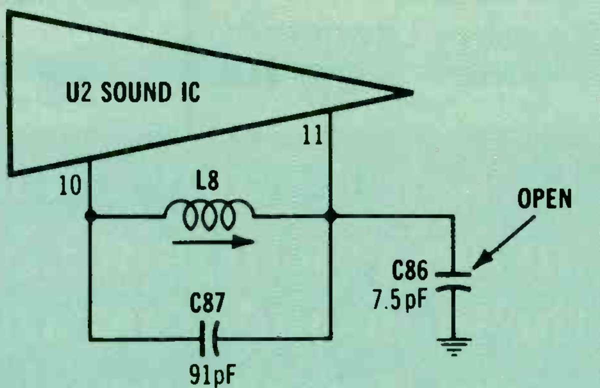
January

18-20
Southcon/83 High-Technology Electronics Exhibition and Convention, Georgia World Congress Center, Atlanta. Contact Electronic Conventions, 999 N. Sepulveda Blvd., El Segundo, CA 90245, 1-800-421-6186 (in California, 1-213-772-2965).

SYMCURE

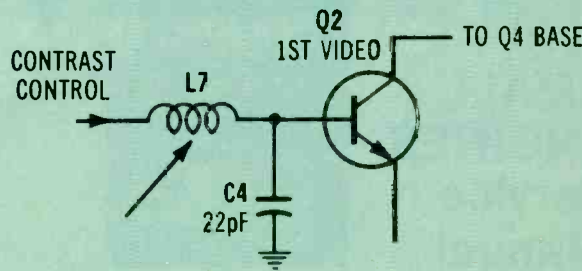
Symptoms and cures compiled from field reports of recurring troubles

Chassis – RCA CTC97 1
PHOTOFACT – 1862-1



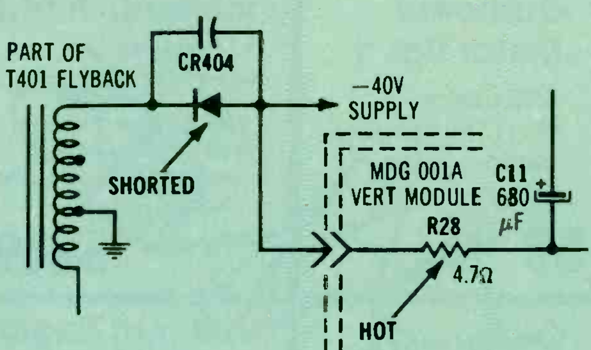
Symptom – Distortion and low sound volume on channel; normal noise off channel
Cure – Check quad coil capacitor C86 and replace if open

Chassis – RCA CTC97 2
PHOTOFACT – 1862-1



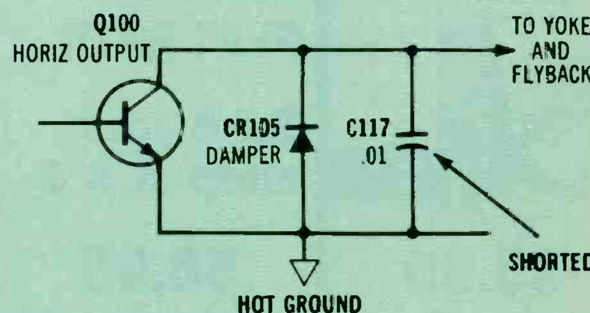
Symptom – Loss of luminance, but color is normal
Cure – Check peaking coil L7 and replace if open

Chassis – RCA CTC86 3
PHOTOFACT – 1807-2



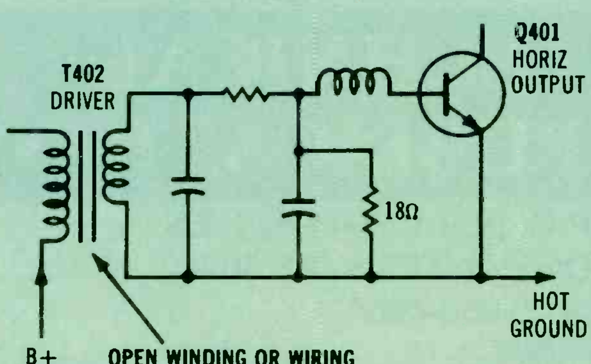
Symptom – No height; new MDG001A vertical module does not help, and resistor R28 on module is too hot
Cure – Check diode CR404 and replace with fast-recovery type if shorted

Chassis – RCA CTC101 4
PHOTOFACT – 1896-2



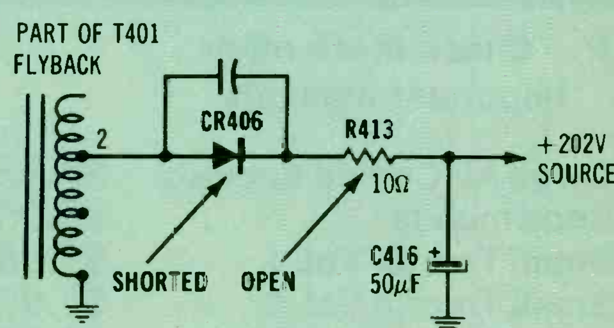
Symptom – Line fuse blows; Q100 output appears to be shorted
Cure – Check retrace-tuning capacitor C117 and replace with original type if shorted

Chassis – RCA CTC92 5
PHOTOFACT – 1883-3 (1788-2)



Symptom – No sound or picture; tic-tic sound from regulator
Cure – Check wiring and windings of driver T402 for opens. Repair wiring or replace T402 as required

Chassis – RCA CTC92 6
PHOTOFACT – 1883-3 (1788-2)



Symptom – Excessive brightness with retrace lines; may shutdown after several seconds
Cure – Check for shorted CR406 and open R413. Replace as needed

(continued from page 8)

four outputs.) I do not see how this could ever work properly. Also, what about the cost of these replacement parts? I feel that it would be unethical to charge the customer for these parts. The profit margin is cut again.

Next is the case of the improperly wired power transformer. I must admit Babcoke was thorough. I might have missed this, but I do not think it would have done any damage. The filter capacitors would have formed in at the higher voltage, and if the bias was adjusted correctly, the outputs would not draw excessive current. Still he was correct in rewiring the transformer, but how long did it take to draw the schematic? Did he charge the customer for this time? I do not believe it is profitable to attempt repairs to any unit without the factory schematic. A phone call or letter to customer service would probably have gotten him a transformer wiring diagram. Also, the owner's manual usually contains a diagram for multivoltage units. Did he ask the customer?

Another point to touch on is the final check-out of the unit. Babcoke states that he operated the radio at moderate volume for several hours. What about distortion checks, power-output checks, stereo-separation checks, and phono pre-amp checks? All of this should be a part of professional audio repair. As stated previously, I doubt that the distortion check would be within limits with replacement transistors.

Finally, I reiterate my point about servicing unfamiliar products. Had Babcoke been an authorized Marantz servicer, he would have known that they issued Service Bulletin number M-2325-2 on October 29, 1975 advising of a problem with the same intermittent diodes that he found after many hours of work. This is certainly a disservice to the customer, as the original problem could have been repaired in a very short time. Also, what about the other channel? I bet he will see this unit again soon.

In conclusion, let me say that I know there is a great temptation to take in anything that comes in the door. I have fallen to this temptation on occasion, and usually find that it costs me time and money. I guarantee you will gain the respect of any potential customer by explaining that you do not have the factory schematic and parts to repair his unit, and advise him of where to take his unit or who to contact about it. You do lose a potential profit by doing this, but I find the customers come back with other products or tell their friends of your honesty. Keep in mind that the profit you lose is only a potential profit. If it turns out not to be an "easy fix" you will probably spend too much time on the repair and lose money.

I invite you to publish my comments in your magazine. They may help someone else avoid a potential disaster.

J. Robert Leonard
Audio Systems Specialists
Metairie, LA

ES&T

NEW PRODUCTS

Test lead set

Etronix has introduced a new universal test lead set. This set comes with interchangeable accessories, which include test probes, tip plugs, alligator clips, spade lugs and banana plugs.

Circle (51) on Reply Card

Ratchet screwdriver

A new tool combining the speed of a motor and the strength and touch of a human hand is available from *Jergens*. The Jergens/Hios DoLucky screwdriver is run by a

motor for 99% of the work and uses a manual twist only for the final securing touch.

Designed as a light tool for maintenance and servicemen in every industry, the tool gives speed, reliability and versatility. The light motor, powered by a low-voltage rechargeable battery, can run a screw more quickly than a manual driver. A built-in rachet allows the operator to apply final torque.

Circle (49) on Reply Card

VOM

Simpson Electric Company has introduced the compact Handi-VOM. This new instrument, model

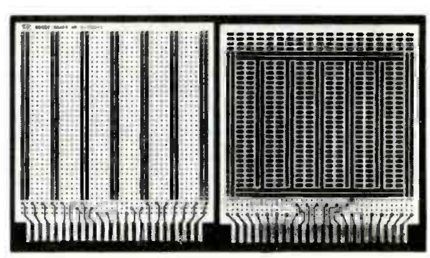
165, is pocket-sized, yet has full-size VOM ranges and functions.

The unit features a 3¼in meter with 2-color scale plus a knife-edge pointer, and 22 ranges achieve full measurement capability for ac/dc voltage, dc current, resistance and dB (four ranges). A single switch selects all functions and ranges, except the 1000Vac and dc ranges, which are on separate input jacks. Full-scale accuracy is ± 3% dc and ± 4% ac.

Circle (78) on Reply Card

Universal PC board

Model H-PCB-1 is the first in a new series of PC boards from *OK Machine and Tool* for the serious amateur. The 4" x 4.5" x 1/16" board is made of glass-coated epoxy laminate and features solder-coated 1oz copper pads. Also, the board has a 22/22 2-sided edge connector, with contacts on



standard 0.156 spacing. Edge contacts are non-dedicated for maximum flexibility.

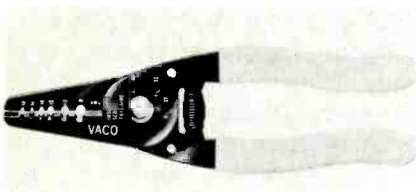
The board contains a matrix of 0.040in-diameter holes on 0.100in centers. The component side contains 76 2-hole pads that can accommodate any dip size from 6 to

40 pins, as well as discrete components.

Circle (75) on Reply Card

Wire strippers

The 70372 multipurpose wire stripper from *Vaco Products Company* meets a multitude of electrical wiring needs. It strips solid or stranded, copper or aluminum wire from 18 to 8 gauge. It also



cuts wires, cuts three popular bolt sizes, features a serrated plier nose for pulling wire and has holes for looping and bending wire.

The 70373 precision wire stripper also accommodates a number of wiring functions. It strips solid or stranded, copper or aluminum wire from 26 to 14 gauge and 0.1 to 2.1 metric wire. It also performs wire cutting, pulling, looping and bending functions.

Circle (76) on Reply Card

Preamp kit

Winegard Company has announced the introduction of a new preamplifier kit, model GA-870K, which converts a consumer's TV system to low-loss cable, while providing amplification of signals received by the antenna.

The kit includes the GA-8700

high-input Gold Star preamplifier, 50ft of coaxial cable with connectors, and 6ft of coaxial cable with VHF/UHF band separator. The preamplifier, which mounts to any new or existing antenna, will strengthen weak, distant TV stations and amplify distant FM stations.

Circle (77) on Reply Card

Wireless surveillance camera

The *Aleph* model CP-35 wireless remote surveillance camera creates a photographic record of protected areas when triggered by a hard-wired or wireless detection device or when triggered by the hand-held wireless remote control unit. The unit allows up to 36 sequential photographs to be made without reloading and permits manual or automatic interval timing between exposures.

The wide-angle camera and receiver unit is mounted using two screws. An LED readout displays

the number of exposures remaining on the film and a warning melody sounds for two minutes when six exposures remain and when the film supply is exhausted.

Circle (79) on Reply Card

Fiber-optic instrument

A new fiber-optic test instrument is now available from *Fotec* that measures in units of watts or decibels simultaneously. This dual output simplifies measurement of fiber attenuation or connector loss in decibels as well as allowing measurement of other parameters in absolute power. Similar to other Fotec fiber-optic converters, the

new Fotec C200 uses an external voltmeter to display the results of the measurement.

Circle (82) on Reply Card

Power consoles

PMC Industries has introduced a new line of rack-mounted power consoles with built-in ac line transient surge suppression. They are for use in research, production, and OEM applications where valuable equipment, computers and microprocessor-based instruments are to be protected from line surges and spikes caused by lightning, and internal and external building equipment.

Both models include a main On-Off switch, indicator light and resettable 15A circuit breaker. One unit with seven outlets turns all power on and off by one switch only. The other unit has each of its 10 outlets individually switched with lighted rocker switches.

Circle (80) on Reply Card

Anti-static dip removers

Three sizes of anti-static dip removers have been introduced by *ITT Pomona Electronics.*

Molded with anti-static glass-filled nylon, models 5016, 5024 and 5040 are designed to pull stubborn component leads from printed circuit boards and other electrical connections. The removers help prevent electro-static buildup and

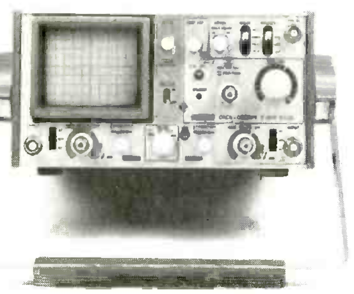
a resistivity of $10^3\Omega$ per square controls surface charges and protects sensitive electronic circuits.

Circle (83) on Reply Card

Oscilloscope

With the introduction of the V-209 20MHz, dual-trace oscilloscope, *Hitachi Denshi America* continues the expansion of its new field-service scope line.

The 10-pound mini-portable V-209 offers a 3½in rectangular CRT, a standard internal rechargeable battery and high sensitivity (1mV/div. at 10MHz). Other features include a built-in TV sync separator circuit, auto-



focus and human-engineered front panel layout that groups controls into functionally related clusters.

Circle (86) on Reply Card

Power head and holder

The *Edsyn* DS317 low static potential silverstatt Auto-vac power head and holder is a pin-

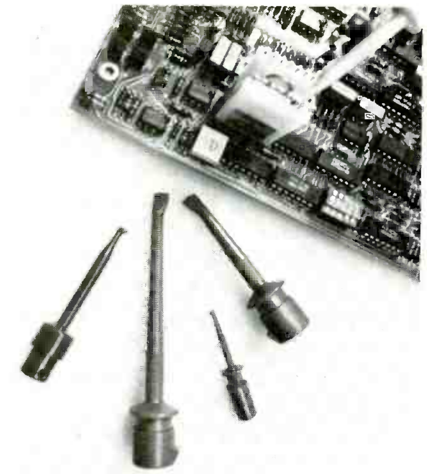
point vacuum cleaner for hard-to-reach places. The power desoldering system requires only an automatic vacuum-controlled source to become operational. It is designed for use with all electronic circuit components, but specifically MOS-LSI semiconductor devices sensitive to static electricity. The DS317 features fully automatic operation and comes with a combination tip cleaner and tool holder.

Circle (84) on Reply Card

Testing device

A P Products has introduced Probe-It plunger-actuated clips for testing electronic connections.

The Probe-It cap is pressed to extend the hook contact placed on the lead or wire under test. Releasing the cap provides hands-free trouble-shooting and circuit testing. The hook contact retracts



into the plastic tip when removed from the lead, minimizing the possibility of shorting components.

Circle (85) on Reply Card

Solder system

A modular, temperature-controlled soldering system has been added to the soldering system 9000 series by the *Ungar Division of Eldon Industries.*

The System 9200 is intended for use where variable soldering temperature is not desired.

Operating temperature of 600°F, 700°F or 800°F is determined by the selection of a modular heater, which can be quickly changed. The new system utilizes Ungar's recently developed Thermo-Duric heater, which combines a heater/temperature sensor.

Circle (87) on Reply Card

ES&T

NEW LITERATURE

A new catalog of hard-to-find tools for electronic assembly and precision mechanics is free from **Jensen Tools.** The catalog features test equipment and introduces six new kits to the Jensen product line.

The contents include more than 1000 tools of interest to field engineers, technicians, telecommunications technicians, instrument mechanics, locksmiths and electronic hobbyists.

Major categories covered are tool kits and tool cases, test equipment, tweezers, screwdrivers, cutters, drafting supplies and power tools.

Circle (100) on Reply Card

MCM Electronics has announced the publication of its new 96-page, electronic-parts catalog, featuring more than 3000 items. A few of the items in their expanded line include Atari home computer equipment, Hunter tools, AC energy centers, video belts, Audio Technica headphones and microphones, telephone accessories and car stereos.

Circle (101) on Reply Card

The 1982 edition of the Consumer Electronics Annual Review, now in its 15th year, is a definitive guide to production and sales statistics for the major consumer electronics products during the last decade.

"It also provides," according to Jack Wayman, senior vice president, **Electronic Industries Association (EIA) Consumer Electronics Group,** "important information on recent marketing developments and product trends."

Two pages in the publication provide a catalog of pamphlets, books and films provided for the consumer and the trade by the EIA Consumer Electronics Group. The origin and history of consumer electronics plus a chronology of industry highlights appear in the back of the booklet, which also has a history of the industry's allied trade associations.

Circle (103) on Reply Card

A new 16-page catalog has been published by **BP Electronics** that describes and illustrates almost 200 video products.

Included are converters, switchers, control centers, a variety of switches, amplifiers, strippers, tools, quick connects, wall plates, cables, clamps, connectors, adaptors, plugs, splitters, directional taps, separators, couplers, mixers, matching transformers and antennas.

Circle (104) on Reply Card

A new 216-page catalog published by **Tucker Electronics Company** lists approximately 3800 different pieces of reconditioned electronic test equipment and microwave components. Instrument categories include amplifier, analyzers, bridges, frequency measuring equipment, signal generators, lab standards, meters, scopes, power supplies, recorders, RFI/EMI equipment and more. Each unit is described and priced. All instruments are available for either sale or short-term rental and all units are reconditioned and calibrated to manufacturer's specifications.

Circle (105) on Reply Card

The Eraser Company has put together a new brochure with photos and descriptions of their hand tools that are specifically useful in the manufacture of electronic equipment.

Pictured are tools ranging from the $3.45 industrial fyberglass brush for cleaning printed circuits, up to the $199 Multi-Former, which cuts and forms both axial and radial leads on electronic components.

Circle (106) on Reply Card

ES&T

THE MARKETPLACE

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For Sale

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AUTOMOBILE RADIO AND TAPE REPLACEMENT PARTS: Delco, Chrysler, Philco-Ford, Motorola, Panasonic and many others. Large inventory. **Laran Electronics Inc.**, 3768 Boxton Road, Bronx, NY 10469 (212) 681-9600 out of New York state (800) 223-8314. 5-82-tf

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REPLACEMENT COLOR YOKES—DEALERS ONLY. Zenith 95-2501-2532-2887 etc. $22.95. Magnavox 36180-1 etc. $24.95. Sylvania $24.95. American-made fuses in bulk. Request circular on your letterhead. David Sims Enterprises, Inc., 665 East Jericho Tpke., Huntington Sta., NY 11746. 800-645-5030, NY State (516) 549-3925-1592. 5-82-tfn

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MOST POPULAR CRITICAL SAFETY COMPONENTS: Magnavox 250663-11 and 250663-17; G.E. EP25x60 and EP25x75, $3.49 each, 10 for $32.00. 430Mfd @ 200 WV (Mallory) axial electrolytics $2.45 each, 10 for $22.00. **NORFOLK ELECTRONICS,** P.O. Box 91, 55 Railroad Avenue, Garnersville, N.Y. 10923. 7-82-6t

TV TROUBLE ANALYSIS TIPS. Over 300 symptoms/remedies by circuit area; tough ones over the years. Save time and money. Send $12.50 to CHAN TV, 8151 Grandview Rd., Chanhassen, Mn. 55317. 5-82-tfn

FOR SALE: B&K 820 Digital Capacitor Meter, Excellent condition with Nicads, Charger, and case. $125.00—Heathkit oscilloscope IO-4205 Dual Trace, Excellent condition—Built by FCC 1st class. $315.00. Call 412-694-8822. Sam Jacobs, Derry Electronics, 511 W. 4th Ave., Derry PA 15627 8-82-1t

FOR SALE: Heath kit IB-1103 180MHz frequency counter $200.00, Heahtkit IM-2202 3½ digit DVM $150.00, Lear Lite Model A-120 communications receiver $15.00. Write Ralph Deterling III, 62 Conant Road, Lincoln, MA 01773 8-82-1t

SPECIALS, RG-59/V COAX CABLE. 100% shielded—$49/M: F-59 connectors with separate ring $11.95/100. 75-300 OHM Matching transformers $39/100. CZ Labs, 55 Railroad Ave., Gavnerville, NY 10923 (914) 947-1554, 8-82-tfn

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RETIREMENT PENDING— 1. B&K 466 CRT tester and rejevenator; 2. B&K 606 tube tester; 3. Sencore 156 align-o-pak; 4. Sencore FC 245 Freq Counter with PR47 Prescaler to 600 Mz, with external antenna and cables; 5. B&K 283 digital multimeter with isolation and demodulation probes; 6. B&K 280 digital voltmeter with stand; 7. B&K 510 transistor checker; 8. B&K 820 capacitor checker; 9. Zenith modules, caddies and tubes, call after 5 pm central time and we'll deal. Davis 317-463-5273. 8-82-1t

NEW SONY VARACTOR TUNER ASSEMBLIES. Includes BT-852 U-V tuner, control panel, printed boards and cables, $29.95 postpaid, HTS ELECTRONICS, 4400 S. Wayside, Houston, TX 77087. 8-82-1t

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Wanted

WANTED FOR CASH: 53, 7F7, 7N7, 6AF6, 6HU8, 304TL, 4CX1000A, 4-1000A, all transmitting, special purpose tubes of Eimac/Varian. DCO, Inc., 10 Schuyler Avenue, North Arlington, New Jersey 07032, Toll Free (800) 526-1270. 5-82-tfn

NEEDED: SENCOR VA48 good condition, Francisco Aznar, Box 207, Paterson, NJ 07503 201-523-4302 after 6 pm. 8-82-1t

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MECHANICALLY INCLINED INDIVIDUALS: Assemble electronic devices in your home. Knowledge or experience not necessary. Get started in spare time. Turn your spare or full time into cash. NO investment. Write for free details. **ELECTRONICS DEVELOPMENT LAB**, Box 1560ES, Pinellas Park, FL 33565. 5-82-tfn

LEARN TO REPAIR ATARI'S: Did you know that more than 2 million Atari Home Video games have been sold and that most of them are now out of warranty? Why not learn how to repair these games and expand your shop's earning potential. At Electronic Institute of Brooklyn we have put together a Video Taped course for the T.V. technician which will take the mystery out of repairing Atari games. These repairs can be done using equipment you probably already own. Included in the course are the video tape, schematics for the two different boards, technical literature for the IC's, and a list of sources for replacement parts. We have condensed months of research into a neat package that will enable you to start repairing Atari's right now! Our course is available on VHS or Beta system tapes. For more information or to order CALL TOLL FREE 1-800-221-0834 or (212) 377-0369. Electronic Institute of Brooklyn, 4823 Ave. N, Brooklyn, N.Y. 11234. 7-82-4t

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212-110	800-791
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212-129	800-791
212-130	800-791
212-131	800-791
212-132	800-791
212-133	800-791
212-134	800-791
212-135	800-791
212-136	800-791
212-137	800-791
212-138	800-791
212-140	800-791
212-140-01	800-791
212-141	977-36
212-141	977-36
212-141-01	977-36
212-141-01	977-35
212-141-01	977-36
212-141-01	977-36
212-141-02	977-36
212-141-02	977-36
212-141-03	977-37
212-142	977-46
212-142	977-38
212-142-02	977-46
212-143	977-40
212-145	977-41
212-145-01	977-41
212-145-01	977-42
212-146	977-41
212-146-01	977-41
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