Product Review:
Hitachi VC-6041 Storage Scope

Flash Sequencer
Multiple exposures

Supply Protector
Simple computer backup

Travelling Wave Tubes
Amplifying microwaves

Computer Review
Columbia 1600
February Specials
Others try to compete with the best — Exceltronix. But will they be here tomorrow? Celebrate out 5th year in business.

Monitors

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zenith ZVM-122 Amber</td>
<td>$195</td>
</tr>
<tr>
<td>Amdek Colour-1</td>
<td>$395</td>
</tr>
<tr>
<td>Amdek Amber - 300A</td>
<td>$259</td>
</tr>
<tr>
<td>Zenith ZVM-123 Green</td>
<td>$129</td>
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</tbody>
</table>

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Assembled and Tested

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
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</thead>
<tbody>
<tr>
<td>Z80 Card</td>
<td>$58.00</td>
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<tr>
<td>80 x 24</td>
<td>$84.00</td>
</tr>
<tr>
<td>16K RAM</td>
<td>$58.00</td>
</tr>
<tr>
<td>Prototyping Board</td>
<td>$14.50</td>
</tr>
<tr>
<td>Parallel Printer Card</td>
<td>$59.00</td>
</tr>
<tr>
<td>... with cable &amp; connector</td>
<td>$69.00</td>
</tr>
<tr>
<td>128K Board (No IC's)</td>
<td>$49.00</td>
</tr>
<tr>
<td>... with IC's &amp; 64K RAM</td>
<td>$129.00</td>
</tr>
<tr>
<td>... with IC's &amp; 128K RAM</td>
<td>$210.00</td>
</tr>
<tr>
<td>Crazy Card</td>
<td>$55.00</td>
</tr>
</tbody>
</table>

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We normally specify components using an international standard. Many readers will be unfamiliar with this but it’s simple, less likely to lead to error and will be widely used everywhere sooner or later. ETI has opted for sooner! Firstly decimal points are dropped and substituted with the multiplier: thus 4.7uF is written 4u7. Capacitors also use the multiplier nano (one thousandth of a microfarad) is 1000pF. Thus 0.1uF is 100nF, 4.7uF is 4.7nF. Other examples are 5.6pF = 5p6 and 0.5pF = 0.5p. Resistors are treated similarly: 1.8kohms is 1K8, 5kohms is the same, 4.7kohms is 4.7K, 100ohms is 100 and 5.0kohms is 5K.

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Aron Electronics Ltd., 409 Queen Street W., Toronto, Ont., M5V 2A5.

ETI—FEBRUARY—1984—5
Brother Update
No sooner did we complete our review of the Brother EP20 electronic typewriter (Dec. ETI) than they announced the new EP22. The EP22 has been expanded to include a 2K memory buffer and an RS232C interface which allows it to become a printer for your personal computer. It still retains the correction buffer and LCD readout that allows you to correct mistakes before they're typed. It works on flashlight batteries or an AC adapter, and seems to be one of the lowest-cost ways to get yourself a computer printer. Judging from the EP20, it should be a winner.

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Disk Drive: The PC301 comes with 2, 5½ packages. MS DOS 2.0 & 1.1 can run on COPAM PC 301.

Operating System: provides you with Microsoft MS DOS, allowing purchase of prewritten and designing of software packages. MS DOS 2.0 & 1.1 can run on COPAM PC 301.

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Fleming, first published a proposal to divide the earth into time zones. This was the first real attempt to bring some degree of order to what was then a chaotic situation. In 1884 the U.S. and Canada adopted the idea of standard time from which our present time zones (Atlantic, Eastern, Central, Mountain, and Pacific) are derived.

The more recent move by the British to tie their clocks into Western Europe shows how arbitrary "time" can be. They have long related local time to Greenwich, where zero meridian runs through that community near London, and to which all time is referenced. For the traveller, keeping time exerts itself in practical ways that most of us are aware of. Going east, you advance your watch an hour in crossing a time zone. Going west, you do just the opposite and "take off" time. If you go far enough west you cross the International Date Line — clear into the next day! This invisible "line", located at longitude 180 degrees, runs from the north to the south Pole, bisecting the Pacific Ocean. Going west, you skip a day; going East, you repeat a day. You don’t seem to get "psychologically untangled" until you return.

These time tricks are nothing compared to the earth’s rotation! The more recent move by the British to tie their clocks into Western Europe shows how arbitrary "time" can be. They have long related local time to Greenwich, where zero meridian runs through that community near London, and to which all time is referenced. For the traveller, keeping time exerts itself in practical ways that most of us are aware of. Going east, you advance your watch an hour in crossing a time zone. Going west, you do just the opposite and "take off" time. If you go far enough west you cross the International Date Line — clear into the next day! This invisible "line", located at longitude 180 degrees, runs from the north to the south Pole, bisecting the Pacific Ocean. Going west, you skip a day; going East, you repeat a day. You don’t seem to get "psychologically untangled" until you return.

These time tricks are nothing compared to the earth’s rotation!
Flying Clocks

to the difficulties placed on man when considering the smaller fraction of time — the second. To bring the interval of time between seconds to an accuracy approaching a billionth of a second or better, is work. But it pays dividends in useful applications! The early advocates of time standards likely never envisaged the wide use that the smallest increment of time, the second, would find.

Radio Time

It's not too long ago that the first accurate time signals were produced, with the generally wide acceptance of radio waves as carriers. It's been said the regular transmission of the time signal from the Eiffel Tower in France in the early part of this century was one of the wonders of the world!

To have time accurate to a fraction of a second wherever you are, you can do one of two things: be dependant on radio propagation of accurate time signals from stations such as WWV in the U.S. and CHU in Canada, or have at hand an independent "local standard" with an accuracy equal to or better than the radiated signals. Up until recently this was not easily done — even if cost wasn't involved — because science wasn't advanced enough to make it possible.

In the early use of radio time signals, a knowledge of the time delay inherent in radio waves between transmitter and receiver was an integral part of the system. The navigational aid Loran uses the delay factor of radio waves in a system whereby the difference in time from two known locations (usually fixed land stations a known distance apart) allows a ship at sea to determine its exact position merely by the delay interval between the two signals! This demonstrates an indisputable fact: that the time delay imposed by radio transmission puts limitations on its use for carrying accurate time signals.

Cesium Time

A newer and more accurate time source has now been introduced, which eliminates this problem because you carry your "time" with you. By making the standard light in weight and portable, it can be carried right to the location where time comparisons are to be made. Because they are relatively compact as well, they can be shipped via aircraft to any part of the world. These Cesium Beam Frequency Standards are referred to as "flying clocks" by Hewlett-Packard, the manufacturers.

"flying clocks" eliminate the problem of time delay in radio transmission, because you carry your time with you.

How do they work? First, something of the basic construction. As seen in Fig. 1, the primary source of the signal, whose accuracy is 1 part in 10¹⁰, is from a Cesium 133 atom. In the Cesium beam resonator a beam of cesium atoms is generated at A. Atoms at a particular energy state enter the cavity B. Here, they interact with a microwave field developed from a quartz crystal source C. The interaction of the two causes some atoms to "flip", or undergo transition to a different energy state. These are directed by the second set of magnets at E to the hot wire ionizer where they are given a positive charge. Passing through a mass spectrometer at D, they reach the electron multiplier which boosts the output to usable levels, which control the frequency control loop of a quartz oscillator.

Though a crystal is used as a frequency source, it is maintained accurately by the beam-tube resonant frequency. Because of this, the long-term stability of the standard is high. Final alignment can be done without reference to any other standard as the cesium-beam standard itself serves. It thus becomes a primary frequency standard with a high order of stability. Because it is relatively compact, the complete unit can be carried easily and airlines can transport the unit, all the while functioning, to almost any location on earth (as shown in our heading picture).

Some years ago a pair of these Cesium Beam Frequency Standards were used in a round-the-world experiment. With one clock going around the globe in a westerly direction and the other going east as far as Europe and return, they covered 25 time-keeping facilities including the Tokyo Observatory in Japan, the Royal Greenwich Observatory in England, the Swiss National Observatory, National Research Council in Ottawa, and the National Bureau of Standards in Boulder, Colorado. It is believed to be the first time a system of two mobile clocks maintained time in mutual agreement to within a microsecond in independant operation. They were checked when they crossed paths in Switzerland and again with the "house" standard at their home base in Palo Alto, California.

The experiment confirmed the accuracy of the official Swiss and U.S. time scales. Correlation between the two countries had previously been done using high frequency radio signals with a precision of only about 1 millisecond.

Worldwide Slowdown

With precision time come new aids to man. Among these, and perhaps the most exciting, is the locating of satellites in their proper orbit. The old standard second, based on the earth's rotation in a 24 hour period of 86,400 seconds, has actually been found wanting. More precise methods have shown that the earth is actually slowing down! Thus, the interval between successive seconds, however slight over several years, is nonetheless there. It is of little use as precision time when time intervals within one hundred billionths (one part in 10¹⁰) of a second are involved. Orbital placement of satellites is a time oriented procedure, and accurate time is of the essence!

It is interesting to note that permanently installed laboratory constructed "long-beam" cesium standards (of which the "flying clocks" are mini-versions) are located at various locations around the globe. They have been verified as primary frequency standards of extremely high accuracy. For example, the use of the portable Flying clock enabled a check to be made between the 4 meter cesium beam standard of the Swiss Horological Research Lab and the one at the National Bureau of Standards in the U.S. They were within 1 part in 10¹⁰ (or one hundred thousand million). Most of the world's frequency standards now use cesium-beam resonators as an absolute reference. Canada also has a "long-beam" resonator, at NRC Ottawa, and it similarly agreed with the travelling clocks.

Next time you hear the Dominion Observatory time signal at 1 p.m., you can rest assured that it is about as accurate as any time known — past or present! The CHU frequencies are synthesized from a rubidium frequency standard, in turn reference to the Canadian cesium standard daily. CHU may be received on 3.33 MHz, 7.335 MHz and 14.67 MHz.
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The TWT is not a new device. Its remarkable capabilities and some of its potential applications have been known for more than thirty years, ever since it was invented during the latter part of World War II by an Austrian refugee, Dr. Rudolf Komphner, while working on microwave tubes for the British Admiralty at the Clarendon Laboratory at Cambridge.

The TWT was not utilized during the war and remained an experimental laboratory device until the first practical tube was developed by J.R. Pierce (now Professor Emeritus of Electronics at Stanford) and L.M. Field at Bell Telephone Laboratories (BTL) in 1945, with first publication of the data in 1947.

From 1945 to 1950 most of the development work was done at BTL and Stanford University. The efforts were relatively low key. Meanwhile, the military services had other potential applications in mind — specifically radar and electronic countermeasures. The development of radars during World War II had been rapidly followed by the development of countermeasure techniques to deceive and jam them (see “History of Radar”, ETI, May 1983). The evolution of new radars in subsequent years has therefore been particularly predicated by continuous need to stay ahead of any new countermeasure tactics which might compromise the radar's effectiveness. The trend has been toward much higher powers and toward new techniques which would have the effect of increasing visibility even while being jammed. A good anti-jamming radar must be able to shift frequency over a wide bandwidth quickly to avoid dwelling on the jamming source frequency.

Similarly, the trend in countermeasures has been toward wide bandwidth system capabilities where the jammer amplifies wideband noise, or may deceptively retransmit the hostile radar pulse to offset the radar's ability to determine the target's position or track.

Since wide frequency bandwidths are essential to the employment of all these tactics, an amplifying device capable of broad operating ranges with sufficient gain, output power and efficiency is needed, and the TWT is ideally suited for the job.

Spin off developments from the military are in the area of space applications where TWTs and Travelling Wave Tube Amplifiers (TWTAs) have been used in scientific experiments, manned missions, and commercial communication applications including Syncom, the ATS series, Intelsat, Alouette, Hermes, Project Galileo, the Saturn mission, DSCS-III, the Space Shuttle, and TDRSS programs. Terrestrially, TWTAs are used in point-to-point microwave systems, so much so that one wag remarked that a microwave relay station is nothing more than a receiving antenna, a TWTA, a battery, and a broadcasting antenna.

**How to Make One**

One of the great beauties of the TWT is its simplicity. Essentially, a TWT is an RF amplifier which consists of an electron gun, a slow-wave structure, a collector, a beam focussing structure, a vacuum envelope, and a package or housing. It is customarily integrated with a power converter which accepts a single voltage from a power bus and generates the various voltages required. The combination of a TWT and its power converter is called a Travelling Wave Tube Amplifier or TWTA.

The first element is an electron gun. Its purpose is to generate an electron beam, and constitutes the basic mechanism of RF amplification in the TWT. It consists of five parts: a cathode, heater, focus electrode, and one or more anodes.

The emitting surface of the cathode is much greater than the required cross-sectional area of the electron beam entering the slow wave structure. This is called area compression and allows the electron beam to have the high current density which is necessary for efficient TWT operation while keeping the current density at the cathode emitting surface at the relatively low values
which are required for long-life cathodes. Typical values for the area compression ratios are from 15:1 to 50:1.

Customarily, two types of cathodes are used. The oxide cathode type operates at temperatures in the range of 650°C to 750°C and can provide emission current densities up to about 300 milliamperes per square centimeter. The impregnated or dispenser cathode operates at temperatures in the range of 750°C to 1200°C and can provide emission current densities up to about 6 amperes per square centimeter. The current densities are therefore directly related to the operational temperature, with the temperature being increased if the emission current density obtained from the cathode is to be increased. The life expectancy of the cathode is also temperature dependent, with evaporation of the active material from the cathode surface increasing as the operating temperature increases.

Wound in a bifilar manner, the heater brings the cathode up to operating temperature. It is wound in this fashion so that no appreciable amount of magnetic field will be introduced into the electron gun by the heater current. Any introduction of a magnetic field into the electron gun would result in difficulty in electron beam focussing, particularly in TWTs having large compression ratios which are particularly sensitive to magnetic perturbations.

Out of Focus

The focus electrode surrounds the cathode and controls the electrical field near its surface. The size and shape of this electrode is chosen to cause the electrons to leave the cathode on the proper trajectories and to converge into a well-defined electron beam as they pass through the anode. Usually, the focus electrode is electrically connected to the cathode within the electron gun, but in some cases the focus electrode connection is brought out so that a bias may be applied. This bias on the focus electrode can then be used to turn the electron beam off or to control the current in the electron beam. TWTs used in pulse applications, such as military radar systems, often have an additional element, called a grid, built into the electron gun. The grid permits the electron beam to be turned on and off with a smaller swing in the applied bias than is required with a plain focus electrode. The grid thus partially obscures the path of the electron beam, causing some perturbation to the electron beam. For this reason, high reliability devices usually use ungridded focus electrodes.

B-type impregnated or dispenser cathodes differ from oxide cathodes in that the B-type cathode exhibits what is pleasantly described as a "graceful degradation" of electron emission as a function of operational life. A TWT using a B-type dispenser cathode will suffer a gradual decline in gain and RF output unless the anode voltage is adjusted to maintain a constant cathode current. This can be accomplished by using a power converter and a servo-loop.

A Canadian-made travelling wave tube by Varian Associates. Photo by Ed Zapletal.

"TWTs have become the fundamental amplification process in most high power relay, satellite, and radar applications."

B-type impregnated or dispenser cathodes combine the high current density capability of a dispenser cathode with substantially less variation in electron emission over operational life.

In most applications, the design of the electron gun is chosen to permit the anode to operate at a positive voltage with respect to the body (ground) of the TWT. This positive voltage provides a barrier which repels positive ions inevitably generated within the electron beam. Without the positive anode, the positive ions would be attracted to the negative cathode and cause destructive etching of the cathode surface. In a few applications, the anode is at ground potential and no ion barrier is provided.

In some applications, there are two anodes. This is especially true for multi-mode TWTs where it is necessary to adjust the electron beam current over a wide range to permit the RF output power to be set at several levels. The first anode close to the cathode is used for beam current control. The second anode operates at a fixed positive voltage to provide the ion barrier.

Turtle Waves

After leaving the electron gun, the electron beam passes through the slow-wave structure. The purpose of the slow-wave structure is to reduce the velocity of the RF wave that propagates along the TWT so that the RF wave is travelling through the TWT at a velocity slightly slower than that of the electron beam. As the RF wave travels from the input end of the TWT toward the output end, it participates in a cumulative interaction with the electron beam. The RF ele-
tric fields on the slow-wave structure penetrate into the electron beam and cause some of the electrons to be accelerated and some of the electrons to be decelerated. As a result of this interaction, the electrons receive a periodic velocity modulation approximately in phase with the RF wave. As the beam travels along the length of the TWT this results in the electrons "bunching" into regions where the electron beam is more dense separated by regions where the electron beam is less dense.

As a result of the accelerating and decelerating fields, the electron bunches will tend to concentrate ahead of the accelerating fields and behind the decelerating fields. Since the average velocity of the electron beam is slightly greater than that of the RF wave, these bunches will tend to move "back" into regions where the RF fields will decelerate the electrons. Most of the electrons will therefore be decelerated. As the electrons lose velocity, they therefore lose kinetic energy, and this energy is transferred to the RF wave. This growing wave is characterized by a nearly constant gain per unit length under conditions of fixed beam current and beam velocity. In other words, the TWT gain is proportional to the length of the interaction region where the electron beam is coupled to the RF wave on the slow-wave structure.

The velocity of the electron beam is determined by the voltage difference between the cathode and the slow-wave structure. The slow-wave structure is nearly always operated at ground potential because the input and output RF ports, either coaxial or waveguide, will connect directly to the slow-wave structure. To provide the proper relative voltages, the cathode is operated at a negative potential so the electrons "see" an increase in voltage as they travel toward the grounded slow-wave structure.

The Law of Conservation of Energy determines how and where the RF energy comes from. The RF wave on the slow-wave structure grows at the expense of the kinetic energy of the electron beam. Since the electron beam loses kinetic energy as it interacts with the RF wave, the electron beam loses velocity as it progresses toward the output end of the TWT. This is part of the reason that the RF wave is caused to travel at a velocity somewhat slower than the electron beam. This arrangement causes the electrons to more or less "fall into synchronism" with the RF wave as the electron beam gives up energy to the RF wave. In all TWTs, it is possible to control the velocity of the electron beam as it enters the slow-wave structure by simply adjusting the cathode voltage. It is not possible to predict exactly what this velocity should be, so it is necessary to select the voltage to account for tolerances in the manufacture of individual slow-wave structures.

In addition, some high efficiency TWTs employ slow-wave structures in which the velocity of propagation is purposely changed along the length of the structure in order to maintain the desired synchronism as energy is extracted from the electron gun and its velocity is reduced.

The physical characteristics of the slow-wave structure can be of two types: helix structured or coupled-cavity structured.

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Helical Visions

In a helical slow-wave structure (the original design and still the most common), the helix itself is made of tungsten or molybdenum wire, supported by three or four ceramic rods which isolate the RF fields in or on the helix from the metallic wall of the surrounding vacuum envelope. Customarily, the support rods are made of aluminum oxide (Al₂O₃), beryllium oxide (BeO) or boron nitrate (BN). In some specialized applications, sapphire and diamond are used. The selection of materials has a major influence upon the power output capability and efficiency of a TWT.

The electron beam passes through the inside diameter of the helix, where the moderately high RF electric fields can interact effectively with the electrons in the beam. The dielectric in the helix support rods competes with the electron beam for the RF electric field, so it is desirable to select rods having the lowest possible dielectric constant (resulting in minimum competition for the RF fields). At the same time, these dielectric rods provide the only thermal path between the helix wire and the outside surfaces of the TWT vacuum envelope. The necessary compromises between these somewhat conflicting requirements place an upper limit on the capability of the helix structure to handle high power. This upper limit is different for each design since the frequency requirement dictates the size of the helix structure (as the design frequency is increased so the size of the structure is necessarily decreased).

Feedback

It is important to observe that a slow-wave structure will support RF energy travelling from output to input as well as from input to output. The wave travelling from input to output will experience gain, but the wave travelling from output to input will not experience gain. In the presence of the inevitable reflections at the output and input couplers, some of the RF energy could be reflected back toward the input along the helix and upon reflection from the input coupler, this signal would present RF feedback. All practical TWTs have sufficient gain that this feedback mechanism would result in self-oscillation. It is fairly simple to interrupt this feedback path by placing RF attenuation on one or more of the helix support rods. The attenuation is formed by placing a carefully controlled pattern of lossy material on the rods prior to their installation into the helix structure, pyrolytic graphite and titanium.
carbide being the most commonly used substances. The density of this attenuation pattern is selected to provide a very low reflection of RF energy so that any energy reflected from the output of the TWT is absorbed in the process. The region of the helix structure containing the attenuation is called a “sever” because the RF wave on the helix is terminated or “severed” at this point. Fortunately, the bunching of the electrons has been established by the time the beam reaches the sever. At the output end of the sever, the bunched electron beam re-establishes the RF wave on the helix and the interaction continues. This severing and relaunching process results in a reduction of RF gain by about 6 dB with only a small effect upon the efficiency of the TWT. This is considered to be a small price to pay for having a TWT which is unconditionally stable instead of having a TWT which would oscillate at the slightest provocation, such as turning it on. In very high gain TWTs, more than one sever may be used as a precaution to ensure that each section is stable. The usual practice in modern designs is to avoid having more than 35 decibels of gain in any one section of a TWT.

In a coupled-cavity structure, the cavity sections are usually made of copper brazed together to form a structure consisting of many cavities in cascade. There is a hole in the centre of the structure through which the electron beam passes. The ferrule surrounding the beam hole concentrates the RF electric field in the vicinity of the electron beam to enhance the interaction between the RF wave and the electron beam. The dimensions of the cavity determine the frequency of operation of the TWT. The coupling hole in the wall of each cavity serves to couple RF energy from one cavity to the next. Coupling holes are oriented on alternate sides of the beam hole so RF energy is directed through one cavity before being coupled to the adjacent cavity. The bandwidth of the TWT is determined by the size and shape of the coupling holes.

Since it is made of copper, which has high thermal conductance, the coupled-cavity structure is capable of handling much higher power levels than the helix structure, and is capable of operating over much narrower bandwidths than the non-resonant helix structure. The design of the coupled-cavities is tailored to the frequency and bandwidth for each application. When the application requires narrow bandwidths, the coupling hole is relatively small and the interaction impedance is high. This impedance determines the amount of interaction between the RF wave on the slow-wave structure and the electron beam. When greater bandwidths are required, the coupling hole is enlarged, the interaction impedance reduced, and the resulting TWT displays less gain per cavity and slightly reduced efficiency.

The only Canadian connection in TWT development and manufacture today is at Varian Canada, a branch plant of the international Varian Corporation but with world patent rights to manufacture items, including TWTs and klystrons, for the corporation as a whole. Some 70-80% of production at their Georgetown, Ontario, plant is earmarked for export.

The development and manufacture of TWTs in Canada was closely linked with US developments. There, the predominant interest was found in the Bell Telephone System, who for years did not follow up TWT developments very extensively due to their reliance on and satisfaction with ground lines; this despite the presence of Pierce on their research staff. These ground lines were predominantly dependent on equipment manufactured by Western Electric. By the time it became apparent that point-to-point microwave systems were the order of the day, in the early 60's, Europe and particularly Japan were far ahead in their development and implementation — Japan for example having a very extensive TWT dependent microwave system already in place using TWTs of proven design and reliability.

In Canada, there was some manufacturing by RCA (the M 600) which it sold to CNCP, and at Marconi in Montreal, using their parent company's English Electric design. The RCA TWT was used in the first Canadian transcontinental microwave system. The Marconi design, a PPM solenoid, was used in the ADCAM II military radio communication system along the Pine Tree Line between 1958 and 1962.

In 1964 Bell Northern Research commenced manufacturing the RA 1 used in radio. When Marconi, in 1962, decided to pull out of the TWT manufacturing market, some of the staff, in particular Connell Smith, now General Manager of Varian's Microwave Division, came to Varian and helped establish their TWT manufacturing division, Varian already being involved in klystrons. Since the Japanese, in particular Nippon Electric, were so far ahead in TWT design, and since, in Smith's words, "there was no need to re-invent the wheel," Varian entered into a cross-licencing arrangement with Nippon Electric, Varian getting NE's TWT designs and NE getting Varian's klystron designs. This cross-licencing arrangement has continued to the present day.

Some years later, when Western Electric decided to manufacture higher powered TWTs, it was decided to close down their Reading, Pennsylvania plant, selling the equipment to Varian: Varian taking over the manufacture of their designs, particularly the TH 1 tube. This tube only ceased production some two or three years ago, having been in continuous manufacture for some 20 years by either Western Electric or Varian, and as such represents one of the more successful designs in the recent history of electronics.

Varian's plant in Georgetown, now the only manufacturer of TWTs in Canada, is fully equipped, including its own glass blowing department, cleaning, and plating facilities, outgassing capability, and laser welding technology. As for the future of TWTs? According to Connell Smith, their "life expectancy is limited. They'll be used, I think, for another 10-20 years in some systems, but I think after another five years or so there won't be many new systems developed using TWT's", their place being taken by laser powered solid state devices.

But if you want to buy one, off the shelf, it will cost you some $2-4,000, unless you are into radar, in which case one will set you back, say, $30,000, without modifications.

"The only Canadian connection in TWT development and manufacture today is at Varian Canada. Some 70-80% of production at their Georgetown, Ontario, plant is earmarked for export. Varian has its own glass-blowing department, cleaning, and laser-welding technology."
be severed. In other cases, the attenuator is placed in a section of the waveguide which is coupled to the last cavity in the section to be severed. In either case, the loss of gain due to the presence of the sever is about 6 dB for each sever. As with the helix TWT, the gain in each section is usually limited to no more than 35 decibels.

Electron Disposal

Having generated an electron beam in the electron gun and having used some of the kinetic energy in that electron beam to amplify the RF signal, it is necessary to dispose of the electron beam. The collector does this job. In an elementary TWT, the collector would consist of a metallic surface upon which the electron beam impinges. This would be simple enough if the collector were to operate at ground potential, that is, the same potential as the slow wave structure. However, the collector cannot be operated at ground potential, known as “depressed collector” operation. Ideally, the negative potential on the collector would be chosen so that the electrons lose all of their remaining kinetic energy just as they reach the collector surface. However, the collector cannot be operated at this highly negative (depressed) voltage for three reasons. Firstly, the charge on the electrons already in the collector region creates electric fields which tend to repel electrons about to enter the collector. As the collector voltage is reduced toward the value at which electrons would strike the collector surface, the “space charge” within the collector and create an additional limit on the voltage at which electrons can be collected.

Thirdly, electrons do not all lose the same kinetic energy as they interact with the RF fields in the slow-wave structure. Some electrons lose far more kinetic energy than others. These electrons could not be collected at the same potential as electrons which did not lose so much of their kinetic energy. The voltage on the collector must be chosen so that all electrons are collected, otherwise some electrons would be reflected back toward the slow-wave structure and either collected at ground potential or “backstreamed” into the beam causing RF regeneration.

Because of these limitations, the collector voltage in a practical TWT cannot be “depressed” to the voltage at which little or no kinetic energy is dissipated in the collector. As such, practical TWTs usually operate with the collector voltage depressed.

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to a value which is 30 to 60 percent of the original accelerating voltage. This creates heat. Low and medium power TWTs dissipate this heat by thermal conduction into the TWT baseplate. At higher power levels it is often necessary to provide a heat exchange medium such as cooling fluid, water, or high velocity air flow. In rare cases, such as for high power spacecraft TWTs, the collector is cooled by radiation directly into space.

The amount of power dissipated in the collector can be reduced by making use of a collector which has multiple velocity sorting, or depressed stages. A collector of this design is commonly referred to as having two depressed stages. The voltage on the third stage is closer to the cathode voltage than would be possible in a single stage collector. This third stage, being the most depressed, collects those electrons which have the highest kinetic energy. The first stage collects those "rogue" electrons which have very low kinetic energy as they have interacted with the RF fields very little. The middle stage collects those electrons with medium kinetic energy.

**Magnetic Charm**

As for beam focussing, the electron beam must pass through a rather long slow-wave structure as it interacts with the RF fields. Upon leaving the cathode surface, the electron beam is formed into a stream of electrons in which the current density is fairly high. The electrons within this beam all possess negative charge and these negative charges cause the electrons to repel one another. This space charge effect, if left to its own devices, could cause the beam to expand in diameter and intercept the slow-wave structure. It is necessary, therefore, to provide a means of keeping the electron beam confined to a diameter which is smaller than the inside diameter of the slow-wave structure. This is usually accomplished by providing a magnetic field parallel to the direction of the flow. Electrons tending to stray away from the proper direction of flow will then cross lines of magnetic field and, in doing so, will experience a restoring force which tends to push them back to their original trajectory. Historically, this magnetic field was produced by surrounding the TWT with a large electromagnet (solenoid) or a large permanent magnet. Solenoid focussing is now used only on very high power TWTs where beams having very high current densities must be focussed. The solenoid is large and heavy, dissipates a large amount of power, and usually must be cooled by forced air or liquid. Permanent magnet focussing is seldom used, as the magnet is large and heavy and produces a large amount of stray magnetic field which might interfere with nearby equipment.

In an efficient scheme, the magnetic field is concentrated along the axis of the TWT by placing iron pole-pieces along the outside of the slow-wave structure and small cylindrical magnets between these pole pieces. These magnets are magnetized parallel to their axes, the polarity of adjacent magnets being reversed. This arrangement is called Periodic Permanent Magnet (PPM) focussing because of the periodic reversal of magnetic field operating direction. The PPM focussing system creates a series of convergent magnetic lenses. The ferrules on the iron pole pieces help to concentrate the magnetic field into the region occupied by the electron beam. The RMS value of the magnetic field produced in the electron beam is roughly equivalent to a continuous DC magnetic field of the same value, provided that the period of the magnetic field generated by the PPM focussing scheme is shorter than the plasma wavelength of the electron beam. The plasma wavelength of the electron beam is the natural period at which the electron beam would undulate if the beam were perturbed by an external influence (such as bunching produced by the amplification of an RF signal). The whole idea is for the magnetic field of the PPM focussing structure to redirect the electrons before they are permitted to stray too far away from their nominal trajectory. The PPM focussing scheme occupies much less space and weighs far less than an equivalent solenoid or permanent magnet focussing scheme. A further advantage is that the external stray magnetic field is very small for the PPM focussing scheme, especially if the PPM focussing "stack" has an even number of magnets.
Supply Protector

Does that flickering of the house lights all too often indicate that your ZX has just had its memory corrupted? Here's a very simple remedy, designed by Phil Walker.

DESIGNED PRIMARILY with the ZX81 home computer in mind but applicable to many others, this project aims to protect the program that you've just spent three hours correcting from short term power failure or accidental supply disconnection. The sort of thing we mean is the temporary (or worse) dimming of the lights caused by lightning strikes on the grid lines or load switching at a sub-station. These effects usually only last a few tenths of a second but can cause your computer to forget itself and delete your program — resulting in instant frustration!

The solution is embodied in this project. What is needed is that the computer should be rapidly switched over to a standby battery. This need only be able to supply the current drawn for a few minutes until the normal supply is restored. The ETI Zippy does this and also sounds an alarm to tell you that something is wrong.

The Circuit

The main part of the circuit consists of B1, D1 and IC1. B1 is a Nickel-Cadmium rechargeable battery with a capacity of 110 mAh at a voltage of around 8.4 volts. This means that when fully charged it should be able to supply a ZX81 for at least 6 minutes — longer if you do not have many extras plugged in. This will even give you time to save your program on tape (provided you have a battery powered tape recorder). D1 effects the switch-over from normal supply to Zippy's internal battery while ICI recharges the battery while power is available. The rest of the circuit provides the audible warning signal from the piezoelectric sounder when the normal supply voltage drops too low.

It is probably a good idea to charge the battery periodically so that you don't get caught out.

Construction

The project can be built into a small plastic box. It is a tight fit, so some care must be taken when siting the switch and input socket. The PCB is designed to fit along one side of the box with the battery along the other. Don't forget to cut the corners off the PCB where marked.

Assembly of the PCB is straightforward but care should be taken when fitting the diodes, transistor and ICs that they are the right way round. Connect all the lead-out wires except those to the sounder before assembling the complete unit.

In our unit, the sounder was glued to the outside of the case and the wires taken inside through a small hole. Holes should also be cut for the switch, input socket and output wire. Make sure everything will fit before deciding where these holes will be.

For a ZX81, the input connector is a 3.5mm jack socket and the output wire is terminated in a matching plug (after assembly), but for your system these can be as required. Beware... not all power supplies have the centre conductor positive, so check this before wiring up.

When everything is ready, put the PCB, switch and input socket in the case, thread the output lead out through the hole provided for it (you did cut one, didn't you?) fit a grommet if you want it to look nice, and wire up the sounder and other components as neatly as possible. Do not have the battery connected while you do this, as it has a very low impedance and can discharge with some violence. The PCB can be fastened in with a bit of sticky tape if you want but it cannot move about much in the limited space available.

PARTS LIST

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors (1/4 W 5% carbon film)</td>
<td>R1 68k, R2 10k, R3 100k, R4 10k, R5 1M</td>
</tr>
<tr>
<td>Capacitors (disc or plate ceramic etc.)</td>
<td>C1 47nF, C2 470pF</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>IC1 LM334Z, IC2 CD4093, D1 1N4001, IC2 CD4093, DI 1N41413, ZD1 BZY8BC15V, Q1 2N3904</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>X1 PB2720 piezo sounder, B1 8.4 V 110 mAh 9V size NiCd, SW1 min. on/off slide switch, Box to suit, 3.5 mm jack plug &amp; socket or as required, 9V battery connector, PCB, small grommet, wire, etc.</td>
</tr>
</tbody>
</table>

Fig. 1 Circuit diagram of Zippy

24—FEBRUARY—1984—ETI
B1 is the main energy store with a capacity of 110 mAh and a terminal voltage of 8.4 volts. IC1 is a constant current device whose operating current is set at about 0.6 mA by R1. This level of current can be sent through the battery constantly with little degradation of performance and will keep it ready for use.

D1 blocks current flow from the power pack to the battery but will allow current to flow from the battery to the supply lines if the power pack voltage drops below about 7.7 volts. This ensures that the supply lines never drop below this level. The internal regulator in a TX81 needs about 6.5 to 7 volts minimum at its input pin to keep it working correctly.

While the input voltage from the power pack is more than a volt or so greater than the battery voltage, Q1 will be turned on by current flowing through R3. This will keep C1 charged. This will cause the outputs of IC2a and IC2c to stay high and IC2b and IC2d to stay low.

If the input voltage falls below this level, Q1 will turn off and allow C1 to be charged via R4 until it reaches the switching threshold of IC2a. The output of IC2a will now go low and IC1 will be discharged via R4 until it reaches the lower switching threshold of IC2a whereupon IC2a output will go high again to repeat the cycle. While IC2a output is low the output of IC2b will be high. This enables a similar oscillator configured around IC2c. The frequency of IC2a oscillator is of the order of 2 Hz while that of IC2c is around 2 kHz; the resulting output from IC2c is bursts of 2 kHz which when applied to the piezo sounder make a slow beep-beep noise. IC2d is used to invert the output from IC2c and increase the signal voltage applied to the sounder.
Magnetic fields can be mind-bending when you try to understand what's going on. They can also bend the paths of poor little innocent electrons, too. John Dance shows us a practical import of this phenomenon.

DISCOVERED AS LONG ago as 28th October, 1879 by Edwin Hall of the John Hopkins University, Baltimore, the Hall effect found few applications until high-quality semiconductor materials became available since it is so small that it is difficult to detect in metals. Hall found that if a magnetic field is applied to a current carrying conductor at right angles to the direction of the current flow, a potential difference appears across the material in a direction which is at right angles to both the direction of the current flow and to that of the magnetic field.

In Fig. 1(a), the potential applied between the two electrodes causes an electric current to flow through the material. If this material is homogeneous and no magnetic field is present, the current flow through it is of uniform density. In the case of the P-type semiconductor material shown, current is effectively carried by the majority hole carriers which behave as positive charges, and these move in the same direction as the conventional current flow in the external wires.

If a magnetic field is now applied so that its direction is into the paper, Fleming's left-hand motor rule indicates that the moving holes will experience a force towards the left and will tend to curve in this direction, as shown in Fig. 1(b). As holes cannot flow out of the left-hand face of the block of P-type material, some positive charges will accumulate there. Similarly, negative charges will accumulate on the right-hand face of the block of material since no holes can flow into this face. The electric field created by these charges tends to repel the holes from the positively charged left-hand face towards the negatively charged right-hand face. The field increases until the positive charges are again moving uniformly across the block of semiconductor material as shown in Fig. 1(c). Any tendency on the part of the positive charges to move to the left will increase the electric field, causing the charges to move directly across the block of material so that the balance is accurately stored. A pair of Hall electrodes placed in the position shown in Fig. 1(c) can be used to detect the Hall voltage produced in this way.

In the case of N-type semiconductor materials in which the majority of carriers are electrons, the flow is in the opposite direction to that of the conventional current in the external wires. The left-hand rule again shows that the charge carrier movement is towards the left, but in this case, the negative charge carriers build up...
a negative charge on the left-hand side and a positive charge on the right-hand side. Thus, we can use the Hall effect to distinguish between $N$ and $P$-type materials by detecting the polarity of the Hall effect voltage produced.

In most metals one obtains a Hall effect voltage with the same polarity as in an $N$-type semiconductor material, since conduction is by means of electrons. However, the Hall voltage is much smaller than in semiconductor materials and a few metals, such as zinc, produce a Hall voltage of the opposite polarity; in such metals the interaction of the moving electrons with fixed positive ions results in the current being effectively carried by holes. Intrinsic (pure) semiconductor materials show a small Hall effect; although the numbers of electrons and holes per unit volume are approximately equal, the electrons are more mobile, and the overall behaviour is normally like that of an $N$-type material.

The Hall effect in semiconductor materials produces a much larger Hall voltage than in metals because the number of charge carriers per unit volume is far smaller. The Hall voltage, $V_H$, is given by the equation:

$$V_H = BI$$

where:
- $B$ is the magnetic flux density
- $I$ is the current flowing through the specimen
- $N$ is the number of charge carriers per unit volume
- $e$ is the charge of an electron ($1.6 	imes 10^{-19}$ coulombs)
- $t$ is the thickness of the specimen.

If one considers a piece of copper of thickness 1 mm carrying a current of 1 A in a magnetic field of 1 Tesla (10,000 Gauss), $V_H$ works out as a mere 62.5 nV, since $N$ is about $10^{28}$ electrons per m$^2$ for copper. It is extremely difficult to measure 60 nV in such a circuit. In silicon, however, $N$ may be 10,000 times smaller, so under the same conditions, one obtains a $V_H$ value of 625 uV which is a much more reasonable voltage for measurement.

First detected the effect using a thin gold foil.

Fig. 1. The Hall effect illustrated by hole flow.

Although most Hall effect devices are used in switching circuits, there are plenty of applications for linear Hall devices. The basic internal circuit of the Sprague UGN-3501M linear device is shown in Fig. 2; it can be seen that the small output from the Hall cell itself is amplified by an op-amp. Offset output nulling facilities are included in this eight-pin DIL device, but not in the UGN-3501T which has only 3 connections. The UGN-3501T operates from 8 to 12 V and the UGN-3501M from 8 to 16 V power supplies. The output voltage from a UGN-3501M device at various values of magnetic flux density with a 12 V supply, a 10 k load and two different values of resistor between pins 5 and 6 are shown in Fig. 3. The frequency response of these devices extends to about 25 kHz (-3dB). The sensitivity of the UGN-3501T is roughly twice that of the UGN-3501M.

Fig. 4(a) shows an application of the UGN-3501T as a ferrous metal detector. The pole of the magnet is fixed in contact with the Hall device and the output falls by 20 mV from 8 to 12 V and the UGN-3501M from 8 to 16 V power supplies. The output voltage from a UGN-3501M device at various values of magnetic flux density with a 12 V supply, a 10 k load and two different values of resistor between pins 5 and 6 are shown in Fig. 3. The frequency response of these devices extends to about 25 kHz (-3dB). The sensitivity of the UGN-3501T is roughly twice that of the UGN-3501M.

Fig. 4(b) is the circuit used. The pole of the magnet is in contact with the Hall device and the output falls by 20 mV.

Fig. 2. Block diagram of a monolithic linear Hall effect device.
By attaching the opposite pole of the magnet to the Hall device, it can be made to sense the absence of ferromagnetic material rather than its presence.

Fig. 5 shows the use of an LM324 operational amplifier to supply a voltage gain and to transform the differential output of a UGN-3501M into a single-ended output so that the circuit can drive a load which has one side grounded. The LM324 can be operated from a single power supply provided that the output does not swing below 0 V. The connections shown are suitable for the detection of the field from a south pole, but if that from a north pole is to be detected, pins 1 and 8 should be reversed.

Another application for linear devices is in fluxmeters, but calibration will be required. A typical UGN-3501M provides a differential output of about 1.4 mV in a 0.1 T field. The response is quite linear to 0.1 T, but the useful linear range can be extended to 0.3 T; if a resistor of about 47 R is placed between pins 5 and 6 (see Fig. 2).

Linear devices can also be employed in current measurement applications. The device may be placed in the gap of a toroid and the current passed through a coil on the toroid. This may be used for overload detection in electric motors, current limiting, etc.

Siemens have recently introduced a KSY10 linear Hall effect position sensor in which gallium arsenide (GaAs) substrate is employed. This device is unique in that it is manufactured by an ion implantation planar technique which produces a doped layer only 0.3 um in thickness; the use of this thin layer enables a sensitivity of 200 ± 30 V/AT to be obtained with a temperature coefficient of only about ± 5 x 10^-4 per degree K. For example, it will provide a Hall output of about 200 mV with a 5 mA control current in a field of flux density 0.2 T. The sensitivity can be selected in the range 30 to 300 V/AT by choosing the appropriate ion doping level during manufacture. The two Hall voltage output connections and the two control current connections are interchangeable, since the active sub-regions are symmetrical.

The output from the KSY10 device is proportional to the effective magnetic field and to the control current passing through the device. The sensor is only 1 mm deep, so it can easily be positioned in the magnet yoke of current converters for current measurements. The active area itself is a mere 0.2 mm by 0.2 mm and lies 0.35 mm behind the front of its mini-plastic case. The device is very suitable for determining the position or speed of toothed gears or of rack and pinion mechanisms. The wide band gap of the gallium arsenide material used, enables this device to be used at temperatures of up to 150°C, so applications in the engine compartment of motor vehicles are envisaged and it may also be used in brushless DC motors.

It is interesting to note that Yoshito Takehana's Group, of the Electronic Devices Development Division of the Sony Corporation of Tokyo, have developed a very sensitive silicon Hall effect sensor inside a special transistor. The output terminals of this magnetic sensor are in the reverse biased depletion layer; a magnetic field, perpendicular to the flow of the charge carriers between the base and collector terminals, will produce an output of about 85 V/cm at a flux density of 0.1 T. If such a linear device is successfully developed to the production stage, a much wider field of application may be opened to Hall effect sensor devices at some future date.

**Switching Devices**

Switching or digital Hall effect monolithic devices are especially easy to use and are finding many applications in keyboards, in vehicle circuits, in toys and in any applications where movement must be converted into an electrical digital type of signal.

The basic circuit of a typical Hall effect switching device is shown in Fig. 6. An on-chip regulator is usually incorporated in the device, since this is necessary to produce a constantly repeatable performance, especially in automobile applications where the supply voltage can vary over a wide range. The regulator supplies at constant current through the Hall cell (shown by an X in Fig. 6) and the two connections which supply the Hall output voltage, feed the inverting and non-inverting inputs of a comparator device, which in turn drives a Schmitt trigger circuit and an output stage.

When the magnetic flux density in the Hall cell changes, the Hall voltage from this cell will change so that the com-

![Fig. 3. Output voltage versus magnetic flux density for a UGN-3501M.](image)

![Fig. 4. A ferrous metal detector using the UGN-3501T.](image)
parator will switch the state of the Schmitt trigger circuit. A suitable amount of hysteresis is built into the circuit so that if a small increase in the magnetic flux density causes the output to switch into its other state, an appreciably larger decrease in the flux density will be required to cause the circuit to switch back to its former state. This prevents repeated rapid switching between the two states for very small changes in the flux density.

The Sprague UGN-3019T device (formerly coded ULN-3006T), is an economical product very suitable in most applications for the experimenter. This is an important use of Hall effect switching devices. The writer found that a UGN-3019T would switch to its low voltage output state when a small bar magnet was brought within about 3 mm of the centre of the body of the device. Owing to the built-in hysteresis in the internal circuit of the device, it did not revert back to the 'high' output state until the bar magnet was withdrawn to a distance of over 10 mm. The hysteresis characteristics of the ULN-3019T are shown in Fig. 9. A typical device switches to the 'low' output state at a field of 0.05 T and all devices are certain to switch at a field of 0.075 T at the centre of their face. A typical device reverts to the 'high' output at 0.0225 T and all devices at a value not less than 0.01 T. The device is unaffected by small stray magnetic fields from any transformers, relays, etc. which may be near to it.

UGN-3019T circuits are unaffected by the application of a field of the opposite polarity to that required to switch the output to the low voltage state. If the field is too weak to cause switching to the low output state, an improvement in the sensitivity can be obtained by placing a piece of iron or other ferromagnetic material on the far side of the device from the magnet as close to the device as possible. A greater increase in sensitivity can be obtained if the device is placed between two magnets with opposite poles on each side of the device. It is important that the magnet should be moved on a line directly towards the centre of the device, since a displacement of about 3 mm from the centre line can more than double the required flux density.

The UGN-3019T requires a supply current of about 7 mA (maximum 9 mA) with a 5 V supply and about 12 mA (maximum 16 mA) with a 12 V supply. A particular advantage of Hall effect switching devices over mechanical contact switching is their high speed of operation, the rise and fall times being measured in nanoseconds with operating speeds of up to about 100 kHz. The output pulses are 'clean' without the 'bouncing' which is characteristic of mechanical contacts. Monolithic Hall effect devices are comparable in price to reed switches.

Using Hall Switches

Fig. 5. A Hall effect switch using the UGN-3011M.

Fig. 6. Block diagram of a monolithic switching Hall effect device.

Fig. 7. The UGN-3019T — "T" type package.
IF YOU'RE like me, your first oscilloscope probably came from a surplus bin, probably took about 100 hours of repair time, and probably still sits on your testbench with its image rolling and swaying and occasionally capturing a signal. For this reason, I jumped at the chance to review the super-deluxe Hitachi VCi-6041 digital storage scope.

The price, as you might expect, is also super-deluxe, in the range of $8000 to $9000, so my surplus scope is going to have to make do for a while longer. The VC-6041 is obviously not aimed at the hobbyist market; you'll have to convince the boss that you just have to have one, for reasons of efficiency, of course. Or you can just drool...

The scope arrives wrapped in its own soft vinyl protective case; a pocket on the case holds the manual and test probes. Unsnap the flaps, and to the right of the CRT you'll see the same controls that appear on your typical scope. There the resemblance ends. Before we get to the good stuff, though, let's look at the features of the scope in its 'normal' mode.

The Good Stuff
The bandwidth is 40 MHz; the horizontal circuit is switchable from 0.2 seconds to 0.2 microseconds, and has a multiplier to increase things by a factor of 100. There are the expected controls for variable sweep, trace rotate, and position; over on the right we find the triggering control section. It looks rather standard: AC or DC, level, external input, and so on, but this is one of the sections where you begin to realize some of your investment. If you've used a sub-standard scope, or even a fairly good one, you've probably found out right away that a poor triggering amplifier can make the best of equipment rank with the worst. The VC-6041 shines
in the trigger department; the trace was always rock-solid, even with jittery or noisy signals.

Of course, you can fool the best of them; there's nothing like a TV video signal to muddle their little brains — they don't know whether to trigger on the sync pulse or the brightness levels. You can solidify the signal in general with fine adjustments, but you can't quite make it nice and clear. The Hitachi was certainly one of the easiest to use in this regard. The TV field position of the trigger mode switch actually cuts in a real sync separator; the trace just freezes. The higher-frequency components were a little wavy, but the storage mode can lock them right up — more on this later.

There are no surprises in the vertical amplifier. It has all the gubbins you'd want for your nine grand: 5 mV sensitivity, ALT and CHOP modes (which are crystal-clear), channels switchable to X and Y modes, and an AC-GND-DC switch. Well, there's one neat surprise. If you pull the position control out, it will now apply a DC voltage to the vertical for use in cancelling out any DC component in the signal. As you adjust it, this voltage appears for measurement on a front-panel output jack. Just the thing for troubleshooting if there's an evil DC there that shouldn't be. Click the control in again, and the trace returns to normal positioning.

There was a 0.5 V square wave at 1 KHz available from the front panel for self-calibration. It was a textbook squarewave.

And, of course, the included probes: they were compact, with a spring-loaded hook and a switch for X 1 and X 10.

The Really Good Stuff

Have you used an analog storage scope? You have? Then we shall all bow our heads and thank Whoever Runs Things for letting us in on digital storage functions.

The analog scope accomplishes its task by storing the passing trace in its phosphor; it's kept lit up by a bias voltage applied through an embedded mesh or an electron gun. It works well enough from DC to, say, 100 KHz, but if the writing speed increases past this, the stored line gets fainter and fainter. The only way to have a look at your signal is to let it build up via a mode usually called 'Integrate'.

To get rid of the stored trace and return to normal, a 'wash' of electrons is blitzed across the screen, clearing things up. It's called 'Erase' and looks like a small green flashbulb going off.

Digital, now, is the cat's pajamas for this sort of application. In the Hitachi, the screen is sampled at the rate of 40 MHz in the single channel mode. This means that you can snare a useable image with signal bandwidths up to 40 MHz! The sampled signal consists of 4000 horizontal and 2048 vertical points. They're packed off to the scope's memory circuit to await your pleasure.

Even More Storage

If you'd like to hang on to a particular display, the 'Hold' button will keep painting it on the screen forever, or until the hydro fails. If you should suddenly have a pressing need to look at some other source, but don't want to lose the original, you can send it off to one of two memories, from whence it can be recalled to either channel. This would be ideal if you're looking for weird glitches and things that go bump in the trace; you could recall several different versions of the signal and compare them. In fact, you could compare today's signal to last week's, assuming that the cleaners haven't pulled out the power cord.

Trying It Out

As I mentioned, video outputs tend to make scopes get dizzy, and even with the Hitachi's sync separator, there was a noticeable wander to the high-frequency components. The storage cures that. Just push the storage mode button and there you are: as steady as a pencil drawing, with the tiniest of traces clearly defined. This is largely due to the high bandwidth and fine resolution of the digital sampling circuit.

"The storage mode was as steady as a pencil drawing, with the tiniest of traces clearly defined. This is largely due to the high bandwidth and fine resolution of the sampling circuit."

The Storage Mode

Being impatient to see it work, the internal calibrator seemed a good a place as any to start. Press the storage mode, and there it was, preserved in blue and white, as pristine as the day it left the square-wave generator. Well, almost; a tiny bit of fuzz appeared on the horizontal part of the wave. The manual said it would low-frequency signals, though they didn't elaborate. Mind you, it was infinitely better than the blooms and fuzzies that appear on an analog storage scope.

Got a noisy, uncooperative signal? Press 'Number of Sweeps', and the LED readout comes to life. A lever makes it count up or down from 2 to 256, with the readout being the number of sweeps that are being averaged before display. It works beautifully to present you with a steady, cleaned-up signal.

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Astound your friends, freak out your budgie and blow your mind with the ETI Flash Sequencer.

Phil Walker

**Flash Sequencer**

**Fig. 1. Circuit diagram. The output connections (marked with an asterisk) depend on the opto device used — see text.**

This unit can be used with up to four separate flashguns connected directly to it and will enable you to get some very interesting action shots.

The delay between each flash can be set by means of the single control over a range of about 1 millisecond to 1 second. This should cover most needs of this sort of shot, but could be altered easily by changing component values.

**Use**

This is, of course, up to the individual user but with the basic unit described here it would probably be reasonable to set up camera and flash guns on tripods or similar firm supports. Then connect the trigger unit to the camera flash socket (use a suitable adaptor if necessary) and the flashguns to the unit. Set up the focus and aperture to suit the subject and flashguns used and set the shutter speed so that it is longer than the total delay on the unit. This usually means that you will have to work on a dark night or indoors if you use long delay times.

You will probably have to find the proper aperture setting by trial and error at first, but if you use a black or very dark background and your subject moves between flashes, the normal or slightly smaller aperture is a good starting point.

**The Circuit**

The main parts of the circuit are the input latch configured around IC1e and f, the se-
sequence generator consisting of IC2, IC1a, b, c and d, and the output pulse generators IC3, 4, 5, 6, 7 and Q2, 3, 4 and 5. The input latch can be reset to the READY condition by SW2 and will force the timing network to discharge all its capacitors by means of Q1 and D4 to 7. This state is indicated by the LED.

A negative-going pulse at the input or a press on SW1 will make the latch change state and allow the sequence to start. After the first delay period the LED in IC4 will be turned on for about 10 ms, causing its associated SCR (or triac) to turn on and trigger the flashgun to which it is connected. This action occurs when C3 has been charged by the current through RV1 and R6 to the upper threshold voltage of IC1b. The output from IC1b is coupled via a differentiating network (C7 and R8) to IC3c — also a Schmitt trigger. This negative-going pulse causes the output from IC3c to go high for about 10 ms, thus turning Q2 on and hence IC4.

IC1b having changed state, the current from RV1 is now diverted to C4 and will charge this up at the same rate until its voltage reaches the upper threshold of IC1d. A similar set of actions now occurs in IC3b and IC5, resulting in another flashgun being triggered and the timing current being diverted yet again to C5.

The sequence ends when C6 charges and the final flashgun triggers. The circuit is now ready to be reset for another operation.

By means of SW3, a negative pulse generated by C2 and R7 can be routed to the sections of IC3 such that one or all the outputs can be triggered with no delay. This could be used to advantage if the unit is triggered direct from a camera socket and no other lighting is used for special effects or just to get as much light as possible.

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ETI—FEBRUARY—1984—33
Flash Sequencer

**PARTS LIST**

<table>
<thead>
<tr>
<th>Resistor (all 1/4W, 5%)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>100R</td>
</tr>
<tr>
<td>R2</td>
<td>10k</td>
</tr>
<tr>
<td>R3,4,7-13</td>
<td>1M0</td>
</tr>
<tr>
<td>R5</td>
<td>10k</td>
</tr>
<tr>
<td>R6</td>
<td>1k</td>
</tr>
</tbody>
</table>

**Potentiometer**

RV1: 1M0 logarithmic

**Capacitors**

<table>
<thead>
<tr>
<th>Capacitor</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>10nF</td>
</tr>
<tr>
<td>C2</td>
<td>33nF</td>
</tr>
<tr>
<td>C3-6</td>
<td>1uF</td>
</tr>
<tr>
<td>C7-10</td>
<td>10nF</td>
</tr>
<tr>
<td>C11</td>
<td>470uF</td>
</tr>
<tr>
<td>C12</td>
<td>1000uF</td>
</tr>
</tbody>
</table>

**Semiconductors**

| IC1        | 40106B |
| IC2        | 4053B  |
| IC3        | 4093B  |
| IC4-7      | H11C4 (opto-SCR) or MOC3020 (opto-triac). See text. |
| Q1         | 2N3905 |
| Q2-5       | 2N3904 |
| D1-11      | 1N4148 |
| LED1       | Any red LED |

**Miscellaneous**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW1,2</td>
<td>Miniature push-to-make push-button switch</td>
</tr>
<tr>
<td>SW3</td>
<td>Three-way slide switch</td>
</tr>
<tr>
<td>SW4</td>
<td>Miniature on/off slide switch</td>
</tr>
<tr>
<td>PCB</td>
<td>Case to suit; 3.5 mm jack socket and plug; 9V battery and clip; four small grommets; four 1 metre flash extension cables; wire, cable ties etc.</td>
</tr>
</tbody>
</table>

**HOW IT WORKS**

IC1e and f are connected together to form a simple latch: R4 is included to avoid shorting the output of IC1e. When SW2 is pressed, the output from this latch is set high, this will cause C2 to discharge via R7 and turn Q1 on. Q1 will discharge C3, 4, 5, 6 via D4, 5, 6 and 7 while lighting LED1 via R6. At the same time IC2 will be disabled by the high level on pin 6 from the input latch. This prevents LED1 from being bypassed by the switches in IC2.

In this condition the outputs from IC1a, b, c and d will be high and C7, 8, 9 and 10 can discharge via their associated resistors. This will set the inputs to IC3a, b, c and d to high levels and thus the outputs to a low. Q2, 3, 4 and 5 will be off and the outputs of IC4, 5, 6 and 7 will not conduct.

Assume for the moment that SW3 is in the open position (delayed sequence). If SW1 is now closed or a negative-going pulse appears at the input, this will be passed on via C1 and D3 to the latch formed by IC1e and f causing its output to go low. Q1 will now turn off, extinguishing LED1 and releasing C3, 4, 5 and 6. IC2 will now be enabled and current can now flow in C3 via R6, RV1 and the three switch sections of IC2. This capacitor will charge up until its voltage reaches the upper threshold of IC1b (this is a Schmitt trigger device), whereupon IC1b output will go low. This causes the current to be diverted to C4, where a similar process occurs. At the same time the high-to-low transition is passed through C7 to IC3c whose output will go high from 10 ms or so. This will turn Q2 on and thus IC4 will turn on.

Some time later C4 will charge up to the Schmitt threshold and IC1d will go low, diverting the current into C5 while also causing IC5 to conduct. The cycle of events will continue with IC1c/IC6 and IC1a/IC7. The result of all this is that flashguns connected to the outputs of IC4, 5, 6 and 7 will be fired in sequence with a delay between each one determined by R6 and the setting of RV1 (and the residual resistance of IC2). IC2 is in fact a triple CMOS changeover switch with a typical on state resistance of 200 ohms. C7, 8, 9 and 10 have been included to ensure that the opto-coupler LED inputs are not driven continuously, as this would take a lot of current. These capacitors and R8, 9, 10 and 11 define the 'on' time to be about 10 ms. C12 will hold enough charge to provide this even from an aging battery. C11 and D11 isolate the rest of the circuitry from the LED drivers to maintain proper operation.

C2 and R7 (via SW3, D8, 9, 10) provide the alternative operating modes. The initial trigger pulse can be fed via these components to the sections of IC3 such that IC7 will turn on immediately or all the outputs will come on together. Care must be used here as the outputs may pulse again after the set delay time and thus trigger the flashgun(s) again if they recharge in time.

You may notice that the inputs to IC1a, b, c and d will only have their capacitors connected, and no DC path exists to bias them, once the switches have been operated. This will not cause any problems over the 5 seconds maximum of the timing period, as the leakage of the tantalum bead capacitors is quite low and they will have to discharge a long way before the Schmitt trigger gates change state.

---

**Fig. 2 Component overlay of the ETI Flash Sequencer**
when using this facility with long delay times set on RV1, as one or more flashguns may recharge and trigger again as the delay operates.

The circuit should not take more than about 10 mA when READY and much less than that when timed out.

The negative-going input pulse to trigger the unit can be derived from a switch or logic source.

**Construction**

Construction of this project should pose no great problems. Take care when positioning the front panel components that they do not foul the parts on the assembled PCB. Note that R1, D8, 9 and 10 are mounted on the panel. It is essential that all the diodes, ICs, and any other polarized components are mounted the correct way round.

We recommend that IC sockets are used for the CMOS devices and that care is taken to avoid static discharge damage to these devices.

**Output Connections**

There are two different connection points for the output from the opto-couplers. This is to accommodate either opto-SCR or opto-triac devices. If opto-SCR devices are used, the flashgun trigger leads must be connected across pins 4 and 5 with pin 4 negative and pin 5 positive. You will have to check the polarity of the connections to the base of the flashguns you use, and this will vary from make to make (ours had a positive inner). If you connect up for one particular make, the trigger unit may not work on another.

If you use opto-triacs, the flashgun trigger leads should be connected across pins 4 and 6; polarity is unimportant, which will save all the above messing about, so we recommend this option.

**Other Points**

As we found that sockets for flashgun connectors are unobtainable (unless already connected to something such as a camera) we bought four flash extension cables and cut the unwanted ends off. These were then taken into the box via small grommets and wired directly to the proper terminals. A small cable tie on each lead just inside the box served to take the strain off the connections. It may be a good idea to buy three one-metre extension cables and one much longer one, so that you can use the extra length from this for the camera-to-unit link (it will have the correct connector).

For greater protection the unit could be built inside a diecast box. This may also be necessary if static discharge causes premature triggering of a flashgun.

Calibration of the delay control would need special apparatus and would depend on the quality of RV1. But the type of device specified should give a reasonable subjective control over the required range.

---

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<thead>
<tr>
<th>Module</th>
<th>Description</th>
<th>Cost</th>
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<tbody>
<tr>
<td>SB2194: ENHANCING YOUR APPLE II — VOLUME 1</td>
<td>D. LANCASTER</td>
<td>$22.50</td>
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<tr>
<td></td>
<td>When the original Nature or Don Lancaster could not enhance an Apple II, you can, with help from Volume 1 in Dolphin 91. Know the rest of things, you'll learn (1) to miss text, L.O.S., and H.I.S. and draw together on the screen in any combination, (2) how to make a one wire model, and (3) how to make the 3D graphics and other special effects, plus (1) a fast and easy way to tear apart and understand something else's machine language program. Other good news!</td>
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<td></td>
</tr>
</tbody>
</table>

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PH249: THE BEGINNER'S HANDBOOK OF ELECTRONICS
D. HEISERMAN, PH251: BEGINNER'S HANDBOOK OF IC PROJECTS
This book contains over 100 projects (each including a schematic diagram, parts list, and descriptive notes). It is written especially for readers with no more than ordinary background in electrical theory without which there can be no comprehension of electronic circuitry and its main components. The text is divided into two sections, the former dealing with simple games and the latter dealing with integrated circuits. The text is divided into two sections, the former dealing with simple games and the latter dealing with integrated circuits. The text is divided into two sections, the former dealing with simple games and the latter dealing with integrated circuits. The text is divided into two sections, the former dealing with simple games and the latter dealing with integrated circuits.

ELECTRONICS PROJECTS

TAB131: CONCEPTS OF DIGITAL ELECTRONICS
F.G. RAYNER, T.Eng(C.E.), Assoc. IERE
This book explains the mysterious modern digital electronics technology. Understand and use low-cost 7400 series IC's to produce working circuits including a power supply and a breadboard experimenter.

PB49: ELECTRONIC PROJECTS FOR BEGINNERS
F.G. RAYNER, T.Eng(C.E.), Assoc. IERE
Another book written by the very experienced author — Mr. F.G. RAYNER — and in it the newcomer to electronics, will find a wide range of easily made projects. There are a considerable number of clearly drawn simple projects showing how to use your own IC's and how to aid the beginner.

Furthermore, a number of projects have been arranged so that they can be constructed without any need for soldering and, thus, enable anyone to experiment with electronic circuitry without fear of damaging their equipment. Also, many of the later projects can be built along the lines as those in the "No Soldering" section so this may considerably increase the scope of projects which the newcomer can build and use.

PH101: HOW TO GET YOUR ELECTRONIC PROJECTS WORKING
R.A. PENFOLD
We have all built circuits from magazines and books only to find that they did not work correctly, or at all, when first switched on. The aim of this book is to help the reader overcome these problems by indicating how and where to start looking for many of the common faults that can occur when building up projects.

B P97: MINI-MATRIX BOARD PROJECTS
R.A. PENFOLD
Twenty useful projects which can all be built on a 24 x 10 hole matrix board with copper strips. Includes Dishaughter, Low-voltage Alarm, AM Radio, Signal Generator, Projector Timer, Guitar Headphone Amp, Transistor Checker and more.

BP103: MULTI-CIRCUIT BOARD PROJECTS
R.A. PENFOLD
This book allows the reader to build 21 fairly simple electronic projects, all of which may be constructed on the same printed circuit board. Sophisticated power supplies have been used in each design so that with a relatively small number of components and hence low cost, it is possible to build them for yourself or by reusing the components and PCB's all of the projects.

TAB131: DIGITAL ELECTRONIC PROJECTS
R.A. PENFOLD
A "Solderless Breadboard" is simply a special board on which printed circuit boards are complete with transistors, IC's, resistors, condensers and various other components. The components used are just plugged in and unplugged as desired. This book contains 110 projects of which 70 are new and 40 have been updated and improved. Included are 24 complete projects together with all the necessary theory and practical advice in order to build and test the many very useful and interesting circuits included in the book. The book is divided into two sections, the first dealing with simple games and the latter dealing with more complex circuits.

BP107: 30 SOLDERLESS BREADBOARD PROJECTS — BOOK 1
R.A. PENFOLD
A "Solderless Breadboard" is simply a special board on which printed circuit boards are complete with transistors, IC's, resistors, condensers and various other components. The components used are just plugged in and unplugged as desired. This book contains 110 projects of which 70 are new and 40 have been updated and improved. Included are 24 complete projects together with all the necessary theory and practical advice in order to build and test the many very useful and interesting circuits included in the book. The book is divided into two sections, the first dealing with simple games and the latter dealing with more complex circuits.

10 THYRISTOR PROJECTS USING SCRs AND TRIACS
R.A. PENFOLD
This book contains 110 projects which can be built along the lines as those in the "No Soldering" section so this may considerably increase the scope of projects which the newcomer can build and use.

BP107: DIGITAL ELECTRONIC PROJECTS
R.A. PENFOLD
A "Solderless Breadboard" is simply a special board on which printed circuit boards are complete with transistors, IC's, resistors, condensers and various other components. The components used are just plugged in and unplugged as desired. This book contains 110 projects of which 70 are new and 40 have been updated and improved. Included are 24 complete projects together with all the necessary theory and practical advice in order to build and test the many very useful and interesting circuits included in the book. The book is divided into two sections, the first dealing with simple games and the latter dealing with more complex circuits.

BP107: DIGITAL ELECTRONIC PROJECTS
R.A. PENFOLD
A "Solderless Breadboard" is simply a special board on which printed circuit boards are complete with transistors, IC's, resistors, condensers and various other components. The components used are just plugged in and unplugged as desired. This book contains 110 projects of which 70 are new and 40 have been updated and improved. Included are 24 complete projects together with all the necessary theory and practical advice in order to build and test the many very useful and interesting circuits included in the book. The book is divided into two sections, the first dealing with simple games and the latter dealing with more complex circuits.
Electronics

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C. RAYSON

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R.A. PENFOLD

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BP84: RADIO CIRCUITS USING IC's $5.40
I.R. DAVIS

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This book will help the reader to find possible substitutes for a particular component. Examples are included. Also shown are the material type, polarity, manufacturer and use of the Equivalents. The Equivalents are sub-divided among manufacturers. This book has been used to good advantage when working with digital circuits.

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FOR THE PAST FEW months, ETI has been reviewing a series of fairly low-priced computers. Last month, it was the Atari, the month before it was the Sord, and so on. We've seen how a manufacturer can remove the nonessentials and the high-priced features and try to give you reasonable computing power at a price you can afford. Well, this month we're looking at a no-holds-barred, let's-mortgage-the-dog-and-buy-one, full-featured, IBM-compatible, 16-bit machine. It's called the Columbia MPC 1600. MPC, by the way, stands for Multi-Personal Computer. More specifically, we're reviewing the model with the 5-megabyte hard disk drive.

Before looking at the Columbia, we should first look at the background facts. Specifically, at the IBM PC, a computer that bears a striking resemblance to the Columbia. So striking, in fact, that a lot of IBM executives would probably very much like to strike the designers of the Columbia with a blunt instrument. To be perfectly honest, what we have here bears a striking resemblance to a certain situation involving Apple and a number of makers of a certain form of mechanical fruit. Well, they do say that imitation is the sincerest form of flattery.

It should probably be mentioned here that it is considered impolite to even mention the word clone in the vicinity of those who make and sell what are properly called 'IBM-compatible' systems.

Mechanicals
For a ten or eleven thousand or so dollar computer (most of this price tag being attached to the hard disk drive), even for one that looks like nothing so much as an oversized bar of soap with a disk drive on the front, some of the features are rather poorly thought out. For that much money, one would feel entitled to expect perfection, or something indistinguishable therefrom. Well, one must admit that it costs a lot of money to build a computer with all these features, and it would pro-
bably cost a lot more if everything had to be utterly perfect.

Take the keyboard, for example. Please, take the keyboard! Why is it that just because IBM puts a really silly keyboard on their PC, everybody who imitates it does the same? The Apple cloners added shift lock and lower case to Apple's original keyboard, so why couldn't the makers of PC 'compatibles' take a clue from them?

IBM probably put the bubblegum keyboard on the PC out of sheer blind arrogance. They probably figured the world didn't deserve better. When you own half of western society, you can afford to do things like that. They put decent keypads on their typewriters, so you can't say they don't know any better. Some people accuse Prime Minister Trudeau of being arrogant. Well, wait till they take a serious look at IBM. Am I sounding too much like Mary Gross? Or maybe IBM just wanted to see how many clone companies they could sucker into building exact replicas of the bubblegum keyboard (or maybe how many people they could sucker into buying the thing). What bugs me is that they're probably right now sitting around in the boardroom of their world corporate headquarters laughing themselves silly at the phenomenal success of their PC and at the number of companies blindly building carbon copies of it and its keyboard.

It should, of course, be added in the Columbia's defence that keypads are a matter of personal preference among computer users, and that there may be some who will love the Columbia's. The same could apply to IBM itself. My advice: never buy a computer, or anything else that has a keyboard on it, without first at least typing in your name to see if you like the feel of the thing.

Getting back to the Columbia, let's look at the screen. Well, that's probably what you'll spend the most time looking at if you buy one, unless you're a hunt-and-peck typist, or unless you're going to have to spend more time worrying about how you're going to pay for it. The character set is really overdone, all of the characters having serifs. Those are those little doohickies on the tips of the various characters. The uppercase Y, for example, looks like a miniature wineglass. They look really classy, but for the long run, a sanserif character set, like the Apple's, is easier on the eyes.

Also, the screen flashes as it scrolls. Even the Apple clone I'm writing this review on doesn't do that. It's really distracting, and unworthy of an upper-financial-strata machine like the Columbia.

The machine does do high-res and colour graphics. The high-res is quite acceptably high — 640 by 200 pixels in black-and-white, and 320 by 200 in four colours. The manual refers to an 'old' colour board and a 'new' one, and the review system seems to have the 'old' one. There are a total of eight colours — black, white, the three primaries red, blue, and green, and the three secondaries yellow, cyan, and magenta — and you can select between two sets of three for your foreground colours and use any of the eight as your background colour. Text mode allows you to have all eight on the screen at once. The 'new' board is claimed to give more flexibility, in choosing any of sixteen colours as the four that you can use at any one time in graphics mode.

The Hard Facts

Being nice to the machine for just a moment, it does have a five-megabyte hard disk in it. There's room enough to burn in five megabytes. Right now, there are no less than sixty files on that disk, some of them quite good-sized, and yet less than one fifth of the available space is in use. Also, disk access is wonderfully fast. It isn't perfectly instantaneous, but it beats floppyss. I must admit, however, that after having used floppyss for so long, I don't really notice the disk access delays as much anymore, and so the improvement is not all that earth-shaking for me.

Somebody once did a study of computer delays, and came up with the idea that there are three classes thereof. The first is the type of delay that's so fast as to not be noticeable. The delay between striking a key and seeing it on the screen is an example of this. The second is the delay of up to a few seconds, enough to catch your breath, and is typical of disk accesses. The third is the long delay, as for a printout, or for saving a program on cassette tape (people still do that, believe it or not, archaic as it may seem), which gives you time to get up for a fresh cup of coffee. They found that the actual length of the delay mattered less than the class of delay. If you have to stop typing and wait for the computer, it doesn't matter if it's for half a second or for five. Thus, the speed difference between a floppy and a hard disk, while noticeable, is not going to be earth-shattering. It's the storage capacity that makes the hard disks worthwhile, although it must be admitted that the speed could make the difference between a reasonable wait and a drastically longer wait when you're working with large files or spreadsheets.

One thing that is worthwhile is having huge amounts of RAM (random access memory, or core to an old-timer) in the computer. This one has 128k of memory inside, more than enough to run Space Invaders in, although if that isn't enough, you can add memory up to a limit of one full megabyte. BASICA (the machine's fancy version of BASIC — more on this later), for example, when you get it going, says it has 57418 bytes free. No, that's not a typo, that's fifty seven thousand and change. Most microcomputers don't have that much total memory. It's enough to make the owner of your typical garden-variety micro turn green with envy.

Every byte of this 128k of RAM has a parity bit on it that lets the machine verify
that no memory glitches are occurring. This can’t tell you which bit went wrong, or correct things itself — and might even miss a multi-bit error — but at least should give you a feeling of security. As I discovered while editing this review on a lesser micro, memory glitches can be both elusive and maddening if you can’t pin them down. When you start up the Columbia, by the way, it can verify its memory for you, if you wish.

The system comes with the expected Centronics-type parallel printer interface, and has not one but two serial ports, one each in the RS-232 standard’s DTE and DCE configurations. You can add all manner of peripheral cards. The machine is hardware compatible with the IBM, so cards designed for the IBM should work in the Columbia. Typical peripherals include a Z-80 card (this is beginning to sound like an Apple clone, isn’t it?) that lets you run good old CP/M, or an 8087 arithmetic chip in case you’re into numerical analysis and you want tens of thousands of eighteen-digit computations done ten minutes ago.

One neat feature is the time/date facility. Every time you turn the computer on, or hit reset, it wants to know what the date and time are. It then keeps time until you turn it back off. This means that programs can, for example, say ‘Good morning, sir’, ‘Good afternoon, sir’, or whatever, when they are run. What’s more useful is that every file is marked with the time and date it was last modified. This is nice, because then you can tell exactly what you’ve modified recently. The only problem is that it’s much too tempting to just hit the return key twice when you power the machine up. The machine will then assume zero o’clock on Tuesday, January first, 1980.

Software
The machine runs MS-DOS, the 16-bit DO’S from Microsoft. It’s a lot like good old CP/M, but with various nice features, improvements, extras, luxuries, and so on. There’s some heavy command line editing, for example. The command prompt becomes A: instead of A>, but otherwise almost anything that went in CP/M goes in MS-DOS. The machine will boot off the hard disk, if it’s happy with the thing. This could mean the death of floppies, but don’t hold your breath.

The utility set changes slightly. An internal command, COPY, replaces PIP, and STAT, at least as far as checking for free space goes, is replaced by CHKDSK, which also checks the validity of the disk directory. DIR gives the sizes of the individual files.

The computer comes with a complete set of Perfect software. At least that’s what the manufacturer has the temerity to call it. It’s good software, but a basic programming principle states that no such thing as perfect software exists. The set of Perfect software that comes with the computer (note the difference between the uppercase and the lowercase ‘p’) includes Perfect Writer, Perfect Speller, Perfect Calc, and Perfect Filer. These programs are integrated, so the same basic set of command keys should do the same basic things in all four programs. Also, the calc program, for example, is set up so that you can transfer spreadsheets or portions thereof to the word processor for inclusion in a document.

If you’re more into programming things yourself, you’ll want to look at the languages. Microsoft includes an assembler, called Macro-86, with the operating system, in case anyone is into hacking and wants to program the system directly. Normal human beings will likely, however, be more interested in the two BASICS.

GW-BASIC — at least that’s what the manual called it, although it was BASICA on the disk, and was similar to what most people know better as MBASIC — ran beautifully. It is essentially upwards compatible from Microsoft’s CP/M MBASIC, meaning that if you know MBASIC, you can be programming in GW-BASIC almost right away. This version adds statements to handle the hardware features of the PC, including graphics, sound, and the function keys. You can program the ten function keys with messages of up to fifteen characters each, including return keys. This means that, for example, you can set it up so that all you have to do is hit the F1 key to get ‘LIST (return)’. Another key can RUN, and so on. Also, this BASIC gives you interrupts — you can tell BASIC to call a subroutine whenever one of the function keys is hit, whenever something is ready at the communications port, or whenever the optional light pen or joysticks do their thing. Your program can go on its merry way until this happens, and then zap — you’re in the subroutine.

The other BASIC, called just plain BASIC, trades off the fancy frills that BASICA gives you for compactness and operating speed.

Conclusions
There are those who will insist that they buy a computer that has a genuine IBM nameplate on the front, and then there are those who resent IBM’s dominance of western culture and will insist on buying a rebel machine. The IBM reputation works both ways. A more practical consideration is that of availability. If your IBM dealer proposes putting your name on a three-month waiting list and back-ordering a PC for you, while your Columbia dealer is willing to load one into the back of your car, you might want to go for the one that you can be computing on this evening.

All I can say is, if you’re planning on buying a big computer like this, know what you’re doing.
Build your own resistance, capacitance, or inductance substitution box, using D.E. Patrick’s economical design.

BUILD THE junk box 1, 2, 3, 3 resistance subber in Fig. 1, and you can select any resistance from 1 ohm to 9,999,999 ohms in one-ohm steps, which will save 35 resistors over lab type decade units doing the same thing. Instead of nine resistors per decade, only four are required. Thus, instead of expensive 10-position switches, you can use cheap junk box and surplus slide or toggle switches along with critical resistors for lab grade quality at a fraction of the cost.

For example, in the first decade, any value from 0 through 9 ohms can be selected by switching in needed values, while the others are bypassed. The other decades operate in the same way, and since decades one through seven are in series, any value from zero to 9,999,999 ohms can be selected.

Another alternative is to use a 1, 2, 3, 5 resistance sequence, giving 11 ohms possible for the first four switches and a total possible resistance of 12,222,221 ohms for the same number of switches and resistors. Thus, any resistance from zero to 12,221,221 ohms can be selected in one-ohm steps. Also, switching in additive parallel capacitance using slide or toggle switches eliminates the need for fancy hard-to-find rotary switches. We can see this in the 1, 2, 3, 3 and 1, 2, 3, 5 capacitance subbers in Fig. 2.

In Fig. 2, instead of placing resistors in series or bypassing them as in Fig. 1, capacitors are placed in parallel. Further, using the same configuration as in Fig. 1, an inductor 1, 2, 3, 3 or 1, 2, 3, 5 subber can be built. Here inductors would be added in series or bypassed as described earlier.

**Construction Hints**

There’s obviously nothing critical about construction. Use #14 to #12 solid copper wire to prevent copper losses and decent switches to prevent contact resistance losses. The resistors, capacitors, or inductors used should at least have a 5% tolerance; however, 1%, .01%, and .0025% values can also be used, especially since only 28 are required.

The same pattern for the resistance subber is used for the inductance subber.

Figure 1. The resistance subber box. The values shown are in ohms for a 1, 2, 3, 3 sequence. For a 1, 2, 3, 5 sequence, substitute the values shown in brackets.
However, you are limited at the low end using very small inductors, generally under 50 uH or so without tuning coils because of wiring inductance and at the high end you've got to add iron or ferrite. But, if you've got access to an RCL bridge you can measure the inductance from the input terminal and tweak the coils to the desired inductance. Another problem in an inductance sub box is caused by mutual inductance from one coil to another. But this can be overcome by using shielded coils or adding shielding between sections.

In a capacitance subber, you are again limited at top and bottom ends as described in the inductance sub box configuration. You can use caps below 50 pF, but because of interwire capacitance it is hard to really get any accuracy without using a cap tester or impedance bridge to measure capacitance from the input terminals. Also, for capacitors in excess of 1 uf, it's usually necessary to use polarized tantalums, electrolytics, etc., which limits accuracy and can increase physical size.

Some Final Notes

The heart of any truly accurate subber is the tolerance of the components used more than the design. The 1, 2, 3, 3 and 1, 2, 3, 5 subbers described here are cost effective because of the fewer critical components required. However, buying new critical components should be avoided if possible to keep costs down. For example, high quality resistors with tolerances from .01% to .0025% can most easily be found in the surplus and scrap markets. Old surplus five and six digit nixie tube DVMs, differential voltmeters, damaged bridges, et al can usually be picked up at scrap prices, stripped out, and used. And where most scrap dealers are after aluminum and precious metals, it's relatively easy to buy critical components at scrap prices by the proud.

For capacitance 1, 2, 3, 3 subber: 10p, 20p, 30p, 30p, 100p, 200p, 300p, 300p, 1n, 2n, 3n, 10n, 20n, 30n, 30n, 100n, 200n, 300n, 300n, 1u, 2u, 3u, 3u, 10u, 20u, 30u, and 30u capacitors.

For capacitance 1, 2, 3, 5 subber: 10p, 20p, 30p, 50p, 100p, 200p, 300p, 500p, 1n, 2n, 3n, 5n, 10n, 20n, 30n, 50n, 100n, 200n, 300n, 500n, 1u, 2u, 3u, 5u, 10u, 20u, 30u, and 50u capacitors.


For inductance subbers: use values to suit in 1, 2, 3, 3 or 1, 2, 3, 5 ratios.

For all subbers: 28 SPDT slide or toggle switches
Case; hardware; #14 to #12 solid hookup wire; banana jacks; etc.
**Product Review**

continued from page 31

**Applications**

According to Hitachi, the VC-6041 is ideally suited for analysis of video and computer circuits; the averaging function is particularly good for noise analysis. The very high bandwidth of the storage function is superb for looking at any high-frequency source, such as ultrasonic equipment, and the single-sweep capability is suited to examining one-time phenomena such as impact testing. Medical technicians can make use of the plotter output for recording physiological data.

In fact, it would be probably impossible to find an application where this scope didn’t make your life easier.

**And Lastly...**

The price tag, while reasonable for equipment of this quality and flexibility, means that you aren’t likely to get one for your birthday. On the other hand, reading about it will aid your fantasizing when it comes time to replace that war-surplus Dumont.

If the digital storage appeals to you, but you don’t need all the bells and whistles, there’s also a scaled-down version, the VC-6015. It has 100 KHz bandwidth, but no cursor or averaging. Further information on the scopes can be obtained from Hitachi Denshi Ltd., 65 Melford Drive, Scarborough, Ontario, M1B 2G6.

Now if you can just convince the boss that the lab equipment should be upgraded...

by Bill Markwick
Thirty years after the fact, the British reveal to the world that it was they, and not the Americans, who invented the first practical electronic computer. Roger Allan lets us in on the secret.
THE LIFTING of the British Official Secrets Act after it had run its customary thirty years has resulted in an absolute mother lode of detail and information concerning the wartime allies’ *modus operandi*. So great is the volume of data now available, that virtually all general histories of the Second World War published before 1975 have been rendered redundant. Historians, utilizing their customary care, are slowly sifting through the mountain of information available, and while their work is far from complete (in fact, most of the documents haven’t even been read yet), a number of interesting elements have come to light that touch on some rather peculiar subjects, including, odd as it may seem, computers — or more specifically, the very first computer, moreover, one which not only preceded ENIAC (customarily considered in all the textbooks as being the first) by several years, but one which had a computational ability not matched by mainframes for over a decade, capable as it was of working at some 25,000 logic decisions a second.

The history of the German Enigma machine and how it produced a seemingly unbreakable code is fairly well known — including how the Canadian, William Stephenson, and his colleagues at Bletchley Park, north of London, broke it (see Stephenson, ETI, Sept. 1982). Their methods of decipherment were slow even when the code was broken, and as the codes (dependent on the positions of a number of rotors internal to the transmitting machine) were changed regularly, sometimes as often as once a day, the decipherment of the new code produced by the machine produced great gaps in the available intelligence derived from this source.

Further, the Germans had a second machine known as the Geheimschreiber or ‘secret writing machine’. Unlike Enigma, which was used by front line commanders as well as for communications to and from headquarters, the *Fish*, as it was known to the British, was only used by the upper echelons of the German High Command. Hitler using it for overall strategic directives, the Ministry of Foreign Affairs for communicating with neutral embassies, and so on.

When the British broke the Geheimschreiber code has not yet been determined (it is still buried in the pile of currently unread data at the Public Record Office, Britain’s national archives, in London), but most probably it was late in 1941. Decipherment was slow and by hand, and as the code was changed on a daily basis, most often the decipherment, when it was completed (which was rare), was completed weeks or even months after it was sent. The machine, more complicated than the Enigma, worked on ten rotors, each one of which could be set differently. This produced a code of several billion possibilities, rather a long job to sort out by hand, even when utilizing Boolean algebra. It had the great advantage in that it automatically enciphered a signal typed on it in clear and sent it to the telegraph or radio station at the rate of sixty-two words a minute, without the need for a cipher clerk (which was one of Enigma’s great weaknesses). In order to receive the message a similar machine was needed, which automatically typed out the text. It was in essence a teleprinter, based on the telegraph code of Baudot and Murray. This code contained thirty-two separate elements embracing twenty-six letters, ten numbers, punctuation, teleprinter functions, line feed, carriage return, letter spacing and letter and number shift. In order to fit all this into thirty-two elements, the code had to be used twice over; in a lower case for letters and in an upper case for numbers and punctuation.

In early 1942, Bletchley Park was a hodgepodge of interesting characters — mathematicians rubbing shoulders with archeologists, front line battle weary officers chatting with physicists, and so on. It was from this compendium of diverse sorts, producing a marvelous cross-fertilization of ideas, that the major British intelligence operations were determined and built, where the Enigma codes were cracked, for instance.

**Not a ZX-81 Yet ...**

In early 1942 a Cambridge mathematician, M.H.A. Newman, joined the staff, and it occurred to him that perhaps it would be possible to build a machine that would automatically and very quickly do the sorting and comparison work currently done by hand, but would do it much more quickly. He persuaded the Powers That Be to act on his idea, and a section was set up under his direction, known as the ‘Newmanny’, in Hut F at Bletchley Park. Under his direction, a team of mathematicians, with the assistance of several engineers from the British Post Office Research Station at Dollis Hill, built a machine. It used 80 valves, and stood in two general-issue Post Office equipment racks about 8 feet high. It utilized a photo-electric reader and could scan 2000 telegraph characters a second.

Its operation was quite straightforward. Five unit Murray Code elements were punched onto a paper tape, containing the German cipher, which was fed into one of the two readers. The tape was joined to form a large loop which ran continuously over a system of pulleys past photoelectric cells. A key tape, smaller in length than the first tape and containing the deciphering telegraph units, was fed into the second reader. Telegraph tape, like old style computer tape, had sprocket holes in it. As the sprockets rotated, they drove the two tapes. As one tape, the key tape, was shorter than the first tape by one character, every revolution of the tape produced a different key unit passing through the reader against the message units. Named the “Heath Robinson” after the constructor of crazy machines, it essentially depended on a statistical system of breaking codes. It could operate at two thousand characters a second — that is, when it worked, which it frequently didn’t, as the tapes kept breaking.

As Odette Wylie, a WRNS who worked on the machine, has been quoted as recalling, “It was a long time before we found some sufficiently gluey material that would stand up under the strain of going round and round at a high speed. The fact that we had to get the two tapes to run exactly synchronized was also a very difficult operation. When they did break, it was not just a question of breaking and lying on the floor, they flew into the air and got entangled in the machine, in little corners, very difficult to get out again.”

Further, the binary system counting procedure was inaccurate, due to the unreliable relays, and the single loop of tape which provided the key was inadequate.

**Invention**

It was about this time, January 1943, that two Post Office engineers, T.H. Flowers and S.W. Broadhurst, specialists in high-speed switching, joined Bletchley Park. Familiar with Alan Turing’s 1936 paper on the creation of an artificial brain, and realizing that vacuum tubes had a very high degree of reliability if kept in constant operation (rather than being switched on and off), they suggested the building of a “Super Heath Robinson.” After some opposition, the Powers That Be gave the go-ahead, and the first computer, the Colossus Mk I, was built. Design commenced in February 1943, and it was delivered at working order in December of the same year.

Based on some 1500 valves, the ma-
The ten Geheimschreiber rotors were simulated by ten rings of thyatron triode valves, which, containing argon gas, acted as very high speed switches and were capable of passing high current. One valve in a particular ring was conducting at any given moment, when its neighbour would take over, thus simulating the passage of the loop continuously through the photo-electric readers.

The interface between the machine and the operating cryptoanalyst was via a bank of switches, whereby the cryptoanalyst would ask the machine to make certain adjustments to the cipher keys. She would be sitting in front of an electric typewriter looking for the tell-tale letter recurrence which would indicate a gradual solving of the cipher text. Once the code was broken, it could reproduce the results ad infinitum for all further traffic using that code — to the extent of $10^{11}$ consecutive elementary Boolean (and/or) equations without error.

It was therefore the first electric computer, and the first statistical brain containing a memory which did not make mistakes.

Similar to the Enigma machine, the Geheimschreiber was constantly being improved, and during the war there appeared five versions (models 52AB, 52C and others). One of the modifications consisted of some of the rotors rotating irregularly, being driven by prawns, retaining an eccentricity. The Colossus Mk I was unable to handle this eccentricity. As such, an improved version, the Colossus Mk II, was designed to deal with this modification to the German Fish.

**IF Unbroken THEN Keep Trying**

The function built into Colossus Mk II to solve the eccentric rotors was Conditional (branching) IF logic — it could make decisions. While this is fundamental to modern computers, this machine was the first to use it. It utilized 2500 valves, and its reader could scan 5000 characters a second. Five such readers could be placed in parallel, giving it an overall operating speed of 25,000 characters a second — a speed not duplicated by other computers for over a decade. Output was fifteen characters a second on an electric line printer.

The speed at which this machine was designed and built is quite extraordinary. The go-ahead was given in March of 1944, with a delivery date by D-Day, June 6. The first of ten Colossus Mk IIIs was delivered on June 1.

As to what the twenty cryptoanalysts, twenty engineers and 250 WRNS operators at Bletchley Park attached to the “Newmamry” deciphered on the Colossus has as yet not been determined, other than that it was used for the Ultra intelligence, never on Enigma messages.

The story of what happened to them after the war is simply told. They were dismantled, and sold in unidentified lots to the surplus stores, along with the other electronic bits and pieces from Bletchley Park.

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**Affordable Precision**

Arkon is now handling the Hitachi line of high-performance digital multimeters. These precision instruments are able to meet the most stringent requirements of both engineer and hobbyist, yet fit comfortably in the palm of the hand and are easily transported.

In addition to these meters, Arkon also carries the complete line of Hitachi scopes and other test equipment by such manufacturers as Hioki, and Lutron. In stock as well is a good selection of components including semiconductors and ICs, kits, tools, and manuals. Everything that's needed to get the job done.

If you're tired of having to go from store to store to get the items you need, you'll appreciate the selection at Arkon. Make it a point to drop by soon, or circle no. 5 on the reader service card.
Designing Microsystems Part 6

So far we’ve covered the brains of a computer, but it’s still deaf and dumb, electronically. This month Owen Bishop takes on the role of ear, nose and throat specialist.

THE CPU, its ROM and its RAM, the subjects of previous parts of this series, are a tightly-knit section of all computer systems. In most micros, they are mounted together on a single computer board. This month, we are concerned with the way in which this section of the computer circuit communicates with the rest of the circuit and with devices outside the computer proper. This aspect of computer design is known as Input/Output, or I/O for short.

In The Right Key

Leaving aside special purpose computers such as those used in control applications, the most important source of input to the computer is its keyboard. This is where our finger-tips send information (instructions on what to do, and data to do it with) to the computer. As I write this sentence, my fingers are pressing keys on a computer keyboard. Each key is marked with a letter of the alphabet, a numeral or other symbol. There is also a space bar and two shift keys. How does the computer know which keys I have pressed? If I press the fifth key from the left of the second row down, I want it to put ‘r’ on the screen. If I also press a shift key, I want ‘R’. How does it know which key means which letter?

If a keyboard is to provide input to the CPU, it must somehow place information on the data bus. The keyboard of the computer which I use for word-processing does this in a simple way. The method is one which is commonly used in micros at the lower end of the price range. Figure 1 shows the main features of the circuit. The first point to note is that there is a bank of eight buffers between the keyboard circuit and the data bus. It would be no good if data were put directly on to the bus every time I happened to touch a key. That might be just the moment when the MPU is reading from RAM. My pressing key ‘r’ just then could have disastrous results! It is essential that there is something between the keyboard and the data bus. This is the function of the buffers.

Addressing The Problem

Enabling is under the control of a logical circuit, an address decoder. In Part 3 we described how an address is decoded in order that a particular memory cell in ROM or RAM can be read from or written to. The same technique is used here. Although the keyboard is not memory in the sense that it stores information, it is addressed in the same way as memory. Most addresses are allocated to RAM or ROM, but a few are allocated to the keyboard.

In my computer, the keyboard is addressed at 3800 to 38FF, though only a few of these addresses are actually used. The address-decoding logic gives a low output (to enable the buffers) whenever ‘0101 1000’ appears on the upper eight address lines (A15 to A8). The lower eight address lines (A7 to A0) go to the keyboard matrix. As it enters the matrix, each line goes to a buffer. These are inverting buffers with open-collector outputs.

Fig. 1. A typical keyboard circuit. To simplify this, only one row of keys has been drawn.

The buffers are under the control of the MPU. Each buffer has a data input, a data output and an enable input. The keyboard uses eight such buffers and they are all enabled together. When the enable input is held high (+5 V) the buffers are in the high-impedance state: in effect, the outputs are disconnected from the data bus. The buffers are held in this state when the MPU is busy reading RAM, or, for any other reason, does not want to know what is happening at the keyboard. When the enable input is made low (0 V) the outputs of the buffers take the states opposite to their data inputs (they are inverting buffers). The data present at the inputs appears inverted on the data bus lines.
resistors connecting them to the +5 V supply line. When a key is pressed, an address buffer output becomes connected to a data buffer input. The fact that the address buffers have open-collector outputs means that if a buffer has a low output, it pulls the level down to 0 V. Otherwise the level remains at +5 V.

The Soft Solution

The rest of the input procedure depends on software: the monitor program in ROM contains a routine for reading the keyboard. The MPU addresses the keyboard by putting '0011 1000' (= 38 in hex) on the high address lines (A15 to A8) and putting '1' on only one of the remaining address lines. For example, to address the first row of keys, the full address is '0011 1000 0000 0001' (= 3801). For the next row we have '0011 1000 0000 0010' (= 3802), then '0011 1000 0000 0100' (= 3804) and so on through 3808, 3810, 3820 and 3840 to 3880 (all hex numbers, remember). The MPU puts these eight addresses in rotation on the address bus. When any one of these addresses is on the bus, the address decoder circuit enables all the data buffers. If no key is being pressed at that moment, all data outputs are low. But if one of the keys is being pressed at the same time as its address buffer output is low, a 'high' appears on one of the data lines. Thus if I press key 'r' when the MPU is addressing 3802, line A2 is high, so its buffer output is low. Since key 'r' connects this output to the buffer for data line D2, '0000 0010' (=02 in hex) appears on the data bus. The MPU now has to go to a monitor routine to interpret this data. Using this routine, it finds out that if the data is '02' when the address is 3802, then key 'r' has been pressed. An instant later, it will be addressing 3880 and, if the data becomes '0000 0001' (=01), it can then tell that the shift key also has been pressed, and that the upper-case 'R' is intended.

The MPU continually scans the keyboard in this way when waiting for input, decoding the data according to which address is in force at that instant. This approach to input relies heavily on software, and it takes several operations to detect and decode each keystroke. Response is relatively slow. The routine required is further complicated by the need to deal with two keys being pressed simultaneously or in very rapid succession. It is necessary to check that a pressed key has been released before attempting to decode the next key that is pressed. This feature is known as two-key rollover. Fortunately, microprocessors work so quickly that even an experienced touch-typist is not able to outpace the keyboard decoding routines.\large

Encoding Made Easy

Although the circuit described above is simple and cheap to build, the MPU is required to do a lot of work. If this work could be done elsewhere, it would leave the MPU with more time to spend on other and perhaps less routine jobs. The alternative approach to keyboard decoding is to employ a special decoder IC (Fig. 2). Again, the keys are connected at the intersections of a matrix, but now both sets of lines come from the encoder IC. The IC has its own clock circuit and scans the matrix rapidly to find which X line and which Y line have been connected by a pressed key. Having detected a key-press, the output latches of the IC are set to produce a seven-bit code corresponding to the pressed key, taking into account whether or not the shift key or possibly the 'control' key has been pressed at the same time.

You can think of the keyboard encoder as having some of the features of a ROM. When a set of eight memory cells in ROM is addressed for reading by the MPU, its output latches deliver to the data bus the byte stored in that cell. Similarly, the memory cells of the keyboard encoder each contain one code byte. The X and Y lines from the keyboard correspond to address lines. When a particular address is set up by pressing a particular key or combination of keys, the corresponding memory cells place their stored byte in the output registers of the IC. The data stored in the registers remains there until the MPU addresses the encoder. Then its register puts the stored code on the data bus and the MPU reads the code. Note that the MPU only has to perform one addressing operation: the keyboard address in the Apple II for example, is C000. This operation is much quicker than the laborious scanning operation described earlier. The only other thing the MPU has to do is to address the encoder reset (address C001) to reset the latches, ready for them to be set by the next key-press. Note that the encoder holds the code until the MPU requests it. In the previously described system, if the MPU is expecting input from the keyboard, it must continue to scan the keyboard in case it should miss a key-press.

Ask Me In ASCII

Whereas the code generated by the circuit of Fig. 1 depends on how the circuit is wired, the code generated in Fig. 2 depends on the codes programmed into the memory of the IC during manufacture. In order to promote good communication between keyboards, MPUs and other I/O devices, a standard code has been drawn up for use in computer systems. This is the American Standard Code for Information Interchange, known as the ASCII code (Table I). Most keyboard encoders produce ASCII code and most computers understand it!

A quick glance at Table I reveals that the seven-bit codes cover more than the printable alphabetical and numerical...
characters and symbols. The first two columns contain what are usually termed control codes. These are instructions for the control of peripheral devices, especially printers. They are generated when the CONTROL key is pressed at the same time as one of the alphabetical keys. The code BS, for example, is generated by pressing CONTROL and H, and means 'backspace'. Since this is a frequently used command, many keyboards have a special 'backspace' key () which generates this command with a single keystroke.

CR means 'carriage return'. When you press the RETURN (or ENTER) key, the keyboard sends a CR code (000 1101) to the computer. This can be used, for example, to tell the computer that the program line which has just been typed in, is complete and ready to be stored in program RAM. If the MPU sends such a signal to the printer, it instructs the print-head to return to the left-hand edge of the page. The DC1 to DC4 codes are Device Control codes, available for miscellaneous functions differing from one machine to another.

A further refinement found on some

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The code is obtained by combining the high nibble (top margin) with the low nibble (left margin) to make a byte. For example the code for upper case W is '57'. The code '20' represents a space.
systems is a FIFO or first-in-first-out device. It is wired between the encoder IC and the data line buffers. As each key is pressed, the encoder sends the corresponding ASCII code to the FIFO, which stores it. Typically, it can store up to 16 ASCII codes. The codes are sent out to the buffers in the same order as they are fed in. When the MPU is ready to read a code, a strobe signal to the FIFO results in the next available code being sent to the buffers. In this way, we have asynchronous transfer of data between keyboard and CPU. ‘Asynchronous’ means that the MPU and keyboard do not have to keep in step. If the MPU is temporarily busy and not able to accept input from the keyboard, the data queues up in the FIFO until the MPU is ready to accept it.

Plugging In Peripherals

Now that micros are becoming more commonplace, people are beginning to recognize that they are capable of far more than just playing arcade games or taking charge of the bookkeeping. There is an increasing interest in being able to connect external devices to the micro — anything from a simple game control to a robot arm. The more recently made micros, even those in the lower price range, now incorporate ICs which allow a variety of peripherals to be attached. These I/O channels are often referred to as 'ports'.

There are two main types of port IC. The parallel I/O device (or PIO) allows data to be transferred between the computer and the peripheral several bits at a time. Commonly there are eight lines, allowing transfer of one byte at a time. The serial I/O device (SIO) transfers data a bit at a time, but groups bits into eights (usually) so that a byte is transmitted as a series of eight bits. We will deal with SIOs in a later issue.

Parallel Lines

Although it is only recently that PIOs have become standard on many low-cost micros, they have always been an almost essential feature of the simple computers intended principally for control applications. A well-known example of a PIO is the INS8154 (Fig. 3). Our old favourite, the Sinclair MK-14, had a socket to take an 8154, though the MPU used in this system (the 8060 or SC/MP) has a few direct I/O terminals of its own. Its three 'flag' outputs can be programmed to have high or low outputs, giving a three-bit data output. The MPU also has two 'serial' inputs which allow two sets of input data to be fed directly to the MPU. This feature of built-in I/O is quite enough for simple control applications and may dispense with the need for a separate I/O IC.

The Acorn System 1 is a well-established control computer. It has sockets for two 8154s, the second of which is used for I/O between the CPU and the cassette recorder. As with the keyboard, an I/O device has to be 'located' in a certain part of memory: we say that it is 'memory-mapped'. When addressing the 8154, the top eight address bits (A15 to A8) are used for establishing the base address of the IC in the way we have already described. The IC has two chip-select inputs, one of which (CS1) is active-high, and the other (CS0) is active-low. Either or both inputs can be used to enable the chip, making it easier to work out an economical address-decoding circuit.

The M/I O input is unusual, for as well as being an I/O device, the 8154 carries 128 bytes of RAM. This memory/I0 combination is handy for control systems, for which 128 bytes may be all the RAM that is needed. The M/I O input is usually controlled by line A7. The remaining lines (A6 to A0) are decoded inside the 8154. To operate the 8154 as RAM, the M/I O input is made high. If the base address is A000 (as in the Acorn System 1), RAM extends from A080 to A0FF (bit A7 always high for memory operations).

To use the IC for I/O, the M/I O input is made low (bit 7 always low for I/O). This section of the IC thus comes in the range A000 to A0FF. Actually, only a few of these addresses are used. Some of the addresses are used to initiate certain modes of operation; others are used when sending or receiving data. The method of programming the IC is too complex to go into here, but we can outline what it is possible to do.

Data is passed between the CPU and the IC by way of the eight-bit data bus. Data is passed between the IC and the outside world (TTL levels only) by the 16 I/O lines. These are organized as two eight-bit ports, A and B. Each port can be controlled and addressed separately. Reading and writing to the device is totally under the control of the MPU. The registers in each port can be instructed by the MPU to act as outputs, or as inputs. It is also possible to control each line of a port individually, so that some of them are inputs and others are outputs.

When data is being output, it is transferred to the IC and appears on those lines which have been selected as outputs. The data stays there, even though the original signals may have been removed.
from the data bus and the MPU is busy doing something else. The data can remain until the external device is ready for it, allowing an asynchronous transfer of data, as mentioned earlier. When the CPU reads from input lines, the data it receives is that which is being transmitted from the peripheral at that instant.

The Hardware Handshake

Obviously there can be problems in transmitting data through an I/O. How does the MPU know that the peripheral has received the data which has been sent to it? It is no use for the MPU to send a new set of data until it is sure that the peripheral has actually received the previous set. Conversely, how does the MPU know that there is a set of data waiting at the input port? How does the peripheral know when this data has been read by the MPU? Again, it is no good for the peripheral to be inputting data to a port if the CPU has switched that port to the output function.

In some systems, the sequence of operations and their timing may be such that complete transfer of data is assured. In other systems, it is necessary to provide for signals to be sent between the MPU and a peripheral to control the flow of data. This is known as 'handshaking'.

The Z80 PIO (Fig. 4) has special control inputs and outputs and the necessary logic circuits to provide for handshaking. Like the 8154, it has two eight-bit ports, each of which can be individually programmed to act as an input port or an output port. Port A can also be programmed as a bidirectional port, allowing direct communication between the peripheral and the data bus. Alternatively, the individual lines of the port can be set for input or output, as described for the 8154.

Figure 5a shows how data is sent from the MPU to a peripheral. As soon as data has been written to the IC and has appeared at an output port, the READY output goes high; this is a signal to the peripheral. When the peripheral receives this signal it knows that it must read the data. As soon as it has read the data, the peripheral puts a low pulse on the STROBE line. This causes the IC to generate a low pulse on the INT line. This goes to the MPU, telling it that the data has been read. The MPU may now send a further byte of data to the peripheral.

When inputting data (Fig. 5b), the peripheral begins by making STROBE low. The INT pulse generated by the I/O device interrupts the MPU to tell it that there is data to be read. At the same time, the READY output goes low, indicating to the peripheral that the data is being held, waiting for the MPU to read it, and that no more data should be sent in the meantime. As soon as the computer has read the data, the end of the B pulse resets READY, so that the peripheral knows that reading is complete and more data can be sent. Thus the sender and receiver each know which state the other has reached. Data is transferred between them in either direction without loss.

The 8154 has a similar handshaking procedure, but this is limited to port A. The INT line has the same function as the INT line, but Fig. 3 shows that there are no special control lines to correspond with READY and STROBE. Instead, two of the lines of port B are taken over for this purpose when port A is used in the handshake mode. The remaining six lines of port B can be used independently, in the usual way.

Dealing With Interruptions

We have seen how the interrupt is an essential part of handshaking by PIO devices. The interrupt may also be used when other peripherals want to communicate with the MPU, either through an I/O device or directly to the data bus. Often, there are several peripherals connected to a system, yet all give the same interrupt signal. How is the MPU to know which one of these peripherals it is dealing with?

One method is 'device polling'. Each device has a latch circuit which gives a high output when the device is trying to input data to the MPU. The latches are enabled by an address decoder, and each is separately addressed. When interrupted, the MPU goes to its interrupt routine program, disabling the interrupt function for the time being; this prevents it from being interrupted again while it is attending to the current interrupt. The interrupt routine instructs it to read each register in turn to find out which device is interrupting and to jump to a particular subroutine according to which device has interrupted. Note that this program polls...
the devices one at a time in a predetermined order. We can program the MPU to test first the registers of devices which cannot wait long to be serviced, leaving other less urgent devices until later. In this way, the software establishes a system of priorities.

The Z80 has a vectored interrupt mode which simplifies the process of finding out which device is interrupting; at the same time as the device interrupts, it puts certain data on the bus. This data is read by the MPU and combined with other data already in memory to form the address where the appropriate interrupt routine begins. Each peripheral identifies itself by putting this particular set of data on the bus, causing the MPU to jump to the corresponding servicing subroutine.

**Who’s Shouting The Loudest?**

Most I/O devices have two ports, some have three, and many computers have more than one I/O device. If the MPU has two or more peripherals and all are trying to communicate with it at the same time, the situation is like a political meeting with everyone trying to shout at once! There must be a system of priorities so that, when one of the more important peripherals is communicating, the less important ones are ignored. We have seen that software provides priority, but only after the interrupt has occurred. Hardware priority ensures that a high-priority peripheral will always get preference whenever it interrupts. The most commonly used method is known as daisy-chaining.

Daisy-chaining works like this. All the PIOs or other peripherals are connected to the INT line by open-collector outputs. The line is normally held high by a pull-up resistor connected to +5 V, but when any one or more interrupt outputs goes low, the voltage on the line is pulled down and the MPU goes into its interrupt routine. In order to be able to generate an interrupt output, a peripheral must be receiving a high voltage level at its interrupt enable input (IEI). Normally, the interrupt enable output (IEO) of the peripheral has the same level as its interrupt input. The IEI on a peripheral receives its input from the IEO of the peripheral with the next higher priority. In Fig. 6, if none of the PIOs are interrupting, every one of them is receiving a high level at its IEI from the PIO next above it in the chain. Every one of them is able to initiate an interrupt when it wants to do so. When a peripheral is interrupting or is

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**Fig. 6. Daisy-chain priority control: all PIOs are connected to the INT line. PIP no. 3 is interrupting and passing a low signal to nos. 2 and 1 to prevent them interrupting.**

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waiting for the MPU to respond to its interrupt request, its IEO becomes low. All peripherals below it (with lower priority) then have the low level fed down to them, and are then unable to generate interrupts.

Another method involves the use of a special priority encoder IC such as the CD4532. It is the hardware equivalent of the device-polling software mentioned above. It has eight inputs, each of which is connected to a peripheral. When any peripheral is causing an interrupt, it also puts a high level on its own encoder input. The encoder also has four outputs which can be connected to the data bus through buffers which are enabled whenever the MPU wants to read the encoder. Their outputs indicate in binary code which peripheral is interrupting. For example, if peripheral no. 6 (connected to input 6) is interrupting, the outputs put binary code 6 (0100) on the data bus. By reading the bus, the MPU can find out which device is interrupting. If more than one peripheral is interrupting at the same time, the binary code for that with the higher priority (highest number) appears at the output.

Sending A Cable
We have been so preoccupied with logic that we have largely ignored one of the main problems of the input and output of data — the wiring between the computer and the peripheral. If this is to be long, special line-driving buffers must be employed, though if the computer and equipment are in the same room, this is rarely necessary. Computers work so fast that electrical signals can travel only a few metres during one cycle of operation. If wires are long, it may be impossible for the computer and its peripherals to remain perfectly in step with one another. This is one of the reasons for employing I/O ports with asynchronous interchange of data, as described above.

A more practical problem is the sheer number of conductors required. An eight-bit connection (the minimum commonly used) requires eight lines, plus a ground line and probably several control lines as well. There is a wide variety of multi-way connectors available for joining cables to computers and peripherals. Most are designed for use with ribbon cable.

Electromagnetic interference between adjacent conductors is a serious problem, especially with long runs of cable, and can lead to errors in the data being transferred. The data signals themselves are not so likely to interfere with each other, since they are all put on to the lines at the same instant, and there is a short period before they are read (again, all at the same time) during which switch-on and switch-off disturbances can settle. However, if the cable carries control signals, which are generally not turned on and off at the same time as data signals, these may interfere with the data carried in adjacent conductors. One solution is to ground alternate conductors, and use only those between them. A better solution is to use twisted pairs; one wire of a pair is used for the signal and the other wire is grounded. Special ribbon cable is made with twisted pairs with untwisted regions spaced along it, where it may be cut and linked to connectors using insulation-displacement.
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This small **Trigger Oscilloscope** with 6x7 cm screen has been specifically designed for field service personnel and advanced amateurs. The vertical input sensitivity can be increased to 2mV/cm at full bandwidth using the variable control. Even a very small signal — beginning at 3mm display height — triggers the sweep generator easily up to at least 30MHz. A TV low-pass filter facilitates the display of video signals at frame frequency. For the purpose of checking semiconductors and other components, even in circuit, a **Component Tester** is incorporated. Pressing a single button is sufficient to switch from oscilloscope to test operation and v.v.

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HAVE YOU ever wanted to make back all the money you spent on your computer? This new book, which reads like an Amway distributor's manual, describes a number of legitimate ways of doing so.

The author, a 17-year-old entrepreneur, tells how he started out by writing reviews for computer magazines at $50 or so a shot. He gives advice for those thinking of doing the same, telling how to write good reviews (for example, never open a review with a question, like this one does), how to get products to review, which magazines are good to write for, and how to get them to print your end product.

He goes on to describe more lucrative fields of endeavor, like writing articles about computers, writing software (especially video games) and getting it published, writing books, opening one's own computer store, becoming a consultant or a computer tutor, marketing various computer-related products, and so on. He even includes a chapter on investing one's profits and managing them so as to pay the minimum amount of taxes possible to Uncle Sam (although similar tactics might be applicable with respect to the Great Canadian Beaver, or whatever our national mascot is).

The book itself runs to only 72 pages, and, by the author's own admission, took no more than twenty hours of solid work to write. What he is telling is essentially his own success story, which the reader is expected to emulate if he/she also wants to be successful. This does mean that the section on writing software reviews, for example, which is something that the author has done, receives better coverage than the section on opening your own store, which is something that he has apparently not done yet, and which he therefore can but theorize and offer helpful hints on.

Knight opens the book with the proposition that 'It is better to be rich and happy than poor and miserable'. He does not claim that making money with computers is for everyone, but does say that, if you really enjoy computers, seeking fame and fortune with them is a valid proposition. He says that it is important that you enjoy whatever line of work you are in, and adds that if you are willing to work diligently, you will be sure to make a profit. What we have here is a fine example of an American capitalist.

The front cover, incidentally, features an illustration of a computer printing up a series of American dollar bills. Now, in the U.S., there is, or at least was, a law prohibiting the depiction of money in print (on the front covers of books, for example). One wonders if the Feds are hot on Mr. Knight's tail yet. Besides, computers don't print things, printers do.

In conclusion, the book is of limited interest, being primarily for those who worship the dollar and want to make it big with computers, or for those who are interested in whiz kid success stories.

Anthony DeBoer
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magnets are mounted on a spinning disc and these magnets pass close to the face of the Hall effect IC. Each time a magnet passes the device, the circuit switches first to its low output voltage state, and then back to the high output voltage state as the magnet moves away from the device.

An alternative system is the 'vane switch' technique, in which soft iron vanes attached to the rotating metal disc pass between the magnet and the Hall device. Each time a vane passes through this gap, the magnetic flux no longer reaches the Hall device owing to the shielding effect of the iron in the vane, and the Hall circuit switches back to its high output voltage state.

Fig. 10(a) shows a system for detecting rotation which uses a radially-magnetized ring magnet. Suitable inexpensive ring magnets for use with either type of system are readily available. Up to eight pulses per revolution per 10 mm diameter of the magnet disc are possible, so 80 pulses per revolution can be obtained from a 100 mm diameter disc. These two arrangements have been designed for the UGN-3030T device; this is similar to the other devices discussed, except that switching to the low voltage state occurs at a typical flux density of 0.016 T (maximum 0.025 T) and returns to the high voltage state at 0.011 T (minimum -0.025 T). The power supply current required is only about half that needed for the UGN-3019T. It should be noted that to ensure switching of the UGN-3030T back to the high voltage state, a field of the opposite polarity is required of flux density -0.025 T; this is provided by the use of alternate polarity magnetic poles in the ring magnets of Figs. 10(a) and 10(b).

Fig. 10. Ring magnet revolution indicators.

continued on page 67
More on Assembler

by John Rudzinski

BASIC PROGRAMMERS, in all their splendour, tend to be a tad hesitant to learn assembly language. This is usually a condition brought on by the mistaken idea that one must first purchase the thickest book available on the subject, and then spend a lifetime and a half trying to decipher the pretty charts and anagrams. Programmers following that route usually end up mailing copies of the book to sworn enemies.

A simpler way of going about learning the language is to compare it to what you've already learned. If you've been programming BASIC on an Apple or a Commodore machine, you've been writing code that eventually trickles down to your computer's 6502 processor after going through an interpreter. By ensuring that the 6502 gets your instructions faster, you can expect a more rapid execution of your program.

### Machine Code

<table>
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<tr>
<td>1000:45 54 49 20 4D</td>
<td>LDX #$FF</td>
<td>LET X = 255</td>
</tr>
<tr>
<td>41 47 41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1008:5A 49 4E 45</td>
<td>INX</td>
<td>X = X + 1</td>
</tr>
<tr>
<td>30C:AF FF</td>
<td>CPX #$5C</td>
<td>IF X = 12</td>
</tr>
<tr>
<td>100E:88</td>
<td></td>
<td>THEN...</td>
</tr>
<tr>
<td>100F:E0 0C</td>
<td>JSR $FDFO</td>
<td>...GOTO $101C</td>
</tr>
<tr>
<td>1011:FO 09</td>
<td>STA $1000</td>
<td>A = PEEK</td>
</tr>
<tr>
<td>1013:BD 00 10</td>
<td></td>
<td>($1000 + X)</td>
</tr>
<tr>
<td>1016:FE 1E</td>
<td>BEQ $101C</td>
<td></td>
</tr>
<tr>
<td>1019:4C 0E 10</td>
<td>LDA $1000,X</td>
<td></td>
</tr>
<tr>
<td>101C:00</td>
<td>STA $1EE1,X</td>
<td>POKE 9605 + X,A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>END</td>
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In this admittedly redundant example, a seven is POKEd into 2053, which equates to $0805 in hexadecimal, and the PRINTed. No large deal, this ... the middle two instructions are unnecessary in both the BASIC and assembly versions, and are there to illustrate that conversion between the two languages is possible.

Incidentally, the address of $FDFO is the printing routine in the Apple ... change it to $FFD2 for the Commodore machines.

### Cut! Print!

And now, for something completely diffident, printing on the screen. There are two ways of going about this: you can either direct each byte to be printed through the ROM's print routine, as above, or selectively introduce the bytes into screen RAM.

The first method is ponderous, and only worth the effort if you plan to print reams of ASCII on your screen. What you'd gain in speed would be greatly offset by the amount of work you'd have to put into something that could preferably be accomplished by simple PRINT statements in BASIC.

Screen RAM's an amusing thing ... it's one reason why the Commodore 64 ends up as a 37 after you take it out of the box and apply some voltage. The act of sorting character values directly into screen RAM locations of your choice saves scads of time, as you needn't bother channeling each byte to be output to the print subroutine.

The following program is a simple 'print-to-screen' listing for the VIC-20. VIC users aren't blessed with the integrated M/L monitor that comes with the Apple and PET computers, and must seek outside help. Jim Butterfield's public domain Super VICMON program makes for an excellent acquisition, and is available from the Toronto Pet Users Group. Others, though perhaps a little more costly, are available as well.

### Little Black Book

Screen addresses vary between machines, of course. The VIC's screen RAM begins at $1E00, the 64's addressing starts at $0400, as does the Apple's. While the Commodore 64's screen addresses are consecutive, however, the Apple's screen takes a little getting used to, as each numerically consecutive row has seven rows between them.

If you plan to utilize your screen through either assembly or machine language, it might be wise to have a screen map drawn out for reference.

To that end, then, below are listings of the same program for the Commodore 64 and the Apple II.

---

62—FEBRUARY—1984—ETI
Commodore 64

Machine Code  
 Opcode
0800:45 54 49 4E 45 41 47 41
0808:5A 49 4E 45
080C:A2 FF
080E:E8
0811:F0 09
0813:BD 00 08
0816:9D C7 05
0819:4C OE 08
0819:BD 00 08
081F:E0 OC
081E:E8
080C:A2 FF
0808:DA C9 CE C5
0800:C5 D4 C9 AO CD CI

Machine Code  
 Opcode
0819:BD 00 08
0813:9D C7 05
0811:F0 09
080F:E0 OC
080E:E8
080C:A2 FF
0808:DA C9 CE C5
0800:C5 D4 C9 AO CD CI

In this example, there are three major things happening. The X register is incremented at a dizzying rate. When X = 255, the Y register is incremented by one. When Y = 255, the Accumulator is incremented. When the Accumulator hits the magic number 0C (12 decimal) the program breathes its last.

VIC owners should change the addresses in the left column to suit their memory configurations.

Now, a four second delay may not be optimum. Perhaps three seconds would make or break your program. If this is the case, change the number that the Accumulator is compared to, presently resting at address $0819. A lower number will shorten the delay, and a larger one will increase the amount of time that nothing appears to happen before you regain control of your computer.

If you'd rather use this as a subroutine rather than a stand alone program, change the byte currently at $081C from #$00 to #$60, the RTS opcode.

And Now, The Punchline

Immediately following you will happen upon a short list of 6502 assembly/BASIC equates. They’re not exact, and should be no means be taken literally, but they'll give you an idea of what all those cryptic opcodes mean.

It will take more than one article or one book for you to gain a working understanding of assembly language, and there are many good books presently available. A programmer's reference guide for your computer is a must, as it will introduce you to ROM subroutines that will make programming a much easier task. You’ll have to learn hexadecimal notation, the art of knowing that 10 is also #$60. Too, you'll have to learn by doing, as reading about bricklaying will not get any houses built without your direct involvement.

Try. Make mistakes. They're inevitable, just as they were when you learned BASIC ... but somehow, though, you made fewer as you progressed in your programming.

Commodore 64

Machine Code  
 Opcode
0800:45 54 49 4E 45 41 47 41
0808:5A 49 4E 45
080C:A2 FF
080E:E8
0811:F0 09
0813:BD 00 08
0816:9D C7 05
0819:4C OE 08
0819:BD 00 08
081F:E0 OC
081E:E8
080C:A2 FF
0808:DA C9 CE C5
0800:C5 D4 C9 AO CD CI
More Pop Amps

Simple measuring circuits based on operational amplifiers

Owen Bishop

No. 4: Very high impedance voltmeter

ONE PROPERTY of operational amplifiers that is of special importance, in this application, is that their input terminals have very high impedance; for example, the input impedance of the 741 is 2MΩ. But the CA3140 op-amp chosen for this circuit is a CMOS IC with the almost infinitely high impedance of 1 teraohm (10¹² ohms). The effect of this is that if one input is connected to a point in a circuit which has potential, say, of 5V, the amplifier behaves as a 1Ω resistor between that point and ground. The current flowing away from that point is only 0.000000000005A (or 5 picoamps), which is good since, when measuring voltages, our aim is to draw as little current as possible from the circuit; a cheap testmeter with a 2kΩ/V coil, working on the 10V range, would draw 250uA under the same circumstances.

If this was a circuit with high resistances and small currents, taking as much as 250uA from it might cause much disturbance. The potential at that point would fall and the voltmeter reading would be seriously in error — perhaps showing only half of the correct value. In addition, the operation of the circuit might be totally upset, and the reading could be completely meaningless. Even a more expensive meter with a 20kΩ/V coil would draw 25uA. This is still relatively large and the readings would still be in error. The high-impedance input of the operational amplifier, therefore, is a great asset in voltage measurement, especially in circuits in which impedances are high and currents are small.

Feedback

The circuit diagram shows that the output of the op-amp is connected directly to the inverting input. If the non-inverting input (the input to the circuit as a whole) is at zero volts, and if the output is at zero volts, the inverting input is also at zero volts. There is no difference between the inputs, so output stays at zero volts. Then if, for example, the input to the circuit is raised to +2V, the non-inverting input is temporarily higher than the inverting input so the amplifier output swings positive until it reaches +2V. This output voltage is fed back to the inverting input so we now find that both inputs are at 2V, and no further swing occurs.

The effect of feedback is to force the voltage at the inverting input to follow the voltage at the non-inverting input exactly. Since the voltage at input and output are equal, we call this circuit a “unity-gain voltage follower”. The crucial point is that...
the input terminal has high impedance; it can be connected to an external circuit without unduly upsetting the voltage levels of that circuit. On the other hand, the output of the op-amp has low impedance (about 100R) so it can sink or source a relatively large current without its output voltage level being affected. When connected to a cheap testmeter, it provides all the current required to drive the meter coil. A really reliable voltage reading is obtained in this way.

Using The Circuit

Switch on the power, then select the voltage range required. Join the input terminals together; both inputs of the IC are now at zero volts and RV1 should be adjusted to bring the output to zero. Now the circuit can be used just as you would use a multimeter. Although voltages down to a few millivolts may be measured, remember that, with a ±9V supply, voltages greater than about ±8V saturate the circuit, so that the maximum voltage that can be measured is about ±8V. If you want to measure higher voltages, increase the power supply to ±18V, and input voltages up to ±13V may be measured. This circuit can also be built around the 741 op-amp with a 10k preset for RV1. The input impedance of the 741 is much lower (about 2MΩ) though still considerably better than that of a low-cost meter used alone.

No. 5: Peak Voltage Detector

Sometimes we want to be able to measure a voltage that is rapidly changing, but it may be changing so fast that we cannot take the reading quickly enough, or the needle may not follow the changes. Again, a brief surge of voltage may be over before the needle has had time to respond! The Follow-and-Hold circuit described in the January 1984 issue could be helpful here, but if you want to measure the highest voltage reached, you will need to act quickly to press the button at just the right moment! In these circumstances a Peak Voltage Detector can be of great help. As its name implies, it detects the maximum (or peak) voltage fed to its input during a period of time, and shows this value on the meter as a steady reading. The circuit is shown in Figure 3.

Essentially it consists of the unity-gain voltage follower described in No. 4, with the addition of a diode (D1) and capacitor (C1). This circuit uses a 531 op-amp which has a very high 'slew rate'; this is the maximum rate at which output can change. For the 531, the slew rate is

Figure 3. Another simple circuit; Peak Voltage Detector.

12V/us compared with 1V/us for the 741 op-amp. When a rising voltage is applied to the non-inverting input (pin 3) the output at pin 6 rises rapidly. It continues rising so as to bring the voltage at the inverting input (pin 2) to the same value as that at the non-inverting input. The feedback to the inverting input is by way of the diode D1, so the voltage actually fed to the inverting input is approximately 0V6 lower than output voltage at pin 6.

These positive swing of the output continues until the output is 0V6 less than the voltage across the meter, and at pin 2, is exactly equal to the input voltage. Now, as the input voltage continues to rise, the output rises correspondingly and the capacitor becomes charged to that voltage, but the voltage is indicated on the meter only if the rate of rise is slow enough for the needle to follow it.

If the input voltage now falls, the output from pin 6 also falls, but because of the diode this can have no effect on the

Figure 4. The component layout, viewed from the top; track cuts are marked by a circled "X".
More Pop Amps

Voltage across the meter. The capacitor retains its charge more-or-less without loss for a period of several tens of seconds and, during this time, the meter needle has a chance to catch up with voltage changes, displaying the peak voltage that was reached. If the input voltage then increases and exceeds the previous maximum, the needle will show the increased peak reading.

Following a peak input, the charge slowly leaks away from the capacitor and the meter reading slowly falls. The rate at which this happens depends mainly on the current taken by the meter itself. If the meter has a 20kΩ/V coil and is on its 10V range, and if the peak voltage reading is +5V, the leakage current through the meter is 25μA. To this must be added a leakage of about 8μA through the capacitor, if it is an aluminium electrolytic type. Reverse leakage through the diode is less than 0.01μA and so can be ignored; a further 0.25μA leaks away to the inverting input. At this rate of leakage, a reading of +5V will have dropped by approximately 0.33V at 1 second after the peak. This sounds rather rapid, but it is quite easy to see the value to which the meter needle rises before it begins to fall, and a usefully accurate reading can be obtained — after all, the pulse that initiated the reading may have lasted for only a few milliseconds. However, ways of reducing leakage will be discussed later.

Resetting

The rate of fall of the needle becomes reduced with time, and may take several tens of seconds to return to zero. It is convenient, therefore, to fit a Reset button, SW2. When this is pressed the capacitor is immediately discharged and the meter reading returns to zero. Capacitor C2 is the frequency-compensating capacitor, needed with this op-amp to maintain constant gain over a wide range of frequencies.

Using The Circuit

Switch on the power and select the voltage range required on the meter. Join the input terminals together; the output should read 0V — if not, adjust RV1. Now the input terminals should be connected to the appropriate points of the circuit to be monitored. The meter indicates the maximum voltage attained during the period of monitoring. To begin a new period, press the Reset button briefly.

Reducing Leakage

Although the circuit is perfectly adequate for most purposes there may be occasions when you want to have plenty of time in which to carefully read the peak value. As the discussion above showed, the greatest leakage is through the meter coil. The obvious way to eliminate this is to replace the meter with the complete Very-High-Impedance Voltmeter circuit described in Pop Amps No. 4. At a 5V peak, the leakage to this circuit will be only 5μA, assuming you are using a CA3140 operational amplifier in the very-high-impedance circuit. With 531 as peak voltage detector followed by a CA3140 as high-impedance voltmeter, the rate of fall from a 5V peak is only 0.08V/s, giving you plenty of time in which to take your reading. The only serious leakage is through the capacitor, especially if it is old. If you find that the rate of fall is still too great, try replacing the capacitor with a new one or, better still, replace it with a tantalum bead capacitor (100μF, 10V). When using two amplifier ICs they can share the +9V and -9V power supply; the complete inter-board wiring is shown in Figure 5.

**Figure 5.** Better performance is obtained by using the Peak Voltage Detector together with the High Impedance Voltmeter.

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The same sort of sensor head can be used for measuring rotational speeds and counting the number of revolutions. In this case, possibly the best course to take with the electronics is to have a pulse-generating circuit after the Hall effect device, so that the pulses can either be counted or fed to an analogue meter (to get a rate of revolution indication).

When fitted to a vehicle wheel, such a system could have a further important use, namely in an anti-skid braking system. In this, the electronics would detect when the wheel was not turning while the car was still moving. The system would then momentarily reduce the brake force to the wheel so that it would turn again and control would be restored, after which full braking force would be restored. This has the effect of pumping the brakes — but be warned, it's not easy to construct such a system, and we strongly recommend not trying!

Hall effect devices can be used to detect linear motion; Fig. 11 shows a simple pressure switch. Coupled with a push-button, this sort of arrangement is common in keyboard switches. A similar application is as an acceleration detector, and Fig. 13 shows how this can be done. In this, acceleration forward or backward, causes the magnet to move nearer to one of the two Hall devices. Conversely, the tilt sensor in Fig. 13 works by detecting when the magnet moves away from directly above the Hall device.

As transducers go, Hall effect devices can give a relatively large switching capability, being capable of sinking ample current to interface directly with TTL. Fig. 14 shows a suitable circuit for interfacing to CMOS devices.

Fig. 15 shows a handy buffer circuit that can be used to drive larger loads, such as a 12 V relay coil. In Fig. 14, when the magnetic field is strong enough, the output from the Hall device will be low and the transistor will be off. Hall devices can drive reed relays directly, provided that they do not pass too much current, and provided that a transient suppressing diode is connected across the coil to prevent the back-EMF from destroying the Hall device (the diode cathode should go to the positive terminal of the relay coil). If a Hall device, such as the UGN-3030T, is required to control a triac such as the RCA 40669, which can handle up to 8 A RMS, a transistor amplifier stage is required between the Hall device and the triac as shown in Fig. 16. When the Hall device conducts, a current of 9 mA flows from the base of the PNP 2N5811 transistor, which in turn supplies 80 mA to the triac gate to turn on the load current. It should be noted that the Hall device is connected to one side of the power supply; this could be avoided by the use of an opto-coupling device between the Hall IC and the triac circuit.

Rotational systems, as described above, have a very wide range of use in engines and machinery. One that many readers will have first-hand experience of, is in car ignition circuits, where the contact breakers are replaced. This leads to the ignition timing being a once-and-for-all setting, as there is no wear, and this can only help improve fuel economy and lower exhaust pollution.
CAR FAN CONTROL

by J.N. Swanson

If, like me, you own an old car with a conventional fan, driven from the engine, a worthwhile improvement can be obtained by fitting an electric fan in its place. These can readily be bought from a scrap yard. The advantages gained are better fuel consumption and lower engine noise particularly at high revs.

A problem arises in finding a suitable switch to operate the fan at the required temperature. Most of the switches fitted to cars are fitted in a threaded hole in the side of the radiator, which means that most scrap yards are unwilling to separate the two. For this reason I have designed a circuit to switch on the fan using the existing temperature sensor for the temperature gauge.

The voltage regulator on the car usually works by interrupting the supply so as to provide an average level of about 10V. Because of this, a fair bit of smoothing is required in order to stop the fan switching on and off with the regulator. A zener diode provides a 10V supply for the op-amp and the reference voltage. The 470k and 100k resistors provide a certain amount of hysteresis and the two diodes prevent the transistor turning on due to offset of the op-amp. The fan may run for a few seconds when the ignition is initially turned on. This may be prevented by increasing the 100uF capacitor to a few thousand uF, but I find this useful as otherwise in winter the fan may not run for weeks on end.

DE-LUXE AB BOX

by Marcus Valentine

This Audio line signal routing device was designed for one of those guitarists who feel insecure unless they are surrounded by numerous effects boxes, but who wish to have more control over them collectively. It has two modes: single and dual.

In the single mode, depression of the footswitch noiselessly re-routes the signal path from going through chain A, to chain B, a chain being either a straight jack to jack lead, an effect, or a series of effects.

In the dual mode, the signal is re-routed through chain A followed by chain B, and on depression of the footswitch (here's the clever bit) is re-routed to chain B followed by chain A.

The two LEDs indicate the chain selected in the single mode, and in the dual mode the first chain.

The flip-flop built around N1 and N2 ensures that the bilateral switches used change state cleanly and quickly, and, more importantly, at the same time.

Current consumption, which is set mainly by the LEDs, is low enough to allow a 9V battery to be used as power. The LEDs were considered essential for ease of use.

The device can be conveniently constructed in an aluminum box measuring 10x10x4 cm, with the input socket arranged so that the input plug connects the negative supply.

By using various combinations of sockets, the device can be utilized in many more audio signal rerouting applications, e.g. by using the A and B return sockets and output only, (with a dummy plug inserted into the input socket to provide power) the box can be used as a single selector.
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