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For Those Who Interface, Build, and Apply Micros

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Editor's Page

How To Learn About Micros

Now that almost everyone has a word processor, a spreadsheet, and a database, there is a lot of interest in applying micros to control things in the real world. Not every home needs a microcomputer to write letters and balance the checkbook, but there are numerous applications for micros in measurement and control. Of course, not every homeowner is going to want to know how to interface a micro, but a market will develop for those who can design and build these systems. Many of these applications will be specialized systems produced in low volume with the program in ROM and won't even look like a micro because they may be a black box without a keyboard or screen. These few-of-a-kind markets won't appeal to the large companies, but can be a nice niche for the computerist entrepreneur.

We get a lot of letters asking how to go about learning to interface microcomputers and control things in the real world—this is an area which is being neglected by the industry as they race to market more elegant systems which are less suitable for the experimenter. There is no one book that will make you an expert, and it is not something that you can learn by next week, but there is a very simple answer.

Get Your Hands Dirty

I feel very strongly that the only way to learn how to do anything with computers is to roll up your sleeves and get started. Of course you have to start at a level suitable for your experience. Regardless of how little you may know, there is some project simple enough that you can do it, yet still learn something to apply to a more advanced project. You say that you don't want to start with something as simple as a 555 timer breadboard project because what you really want to do is to design and build the complete on-board computer for a radio controlled robot? Sorry my friend, but things just don't work that way. You either pay someone else who has invested the hours in developing the experience to design the project for you, or you start at the beginning and learn how to do it yourself. It's good to have a future goal in mind to give you a sense of direction, but you have to start by learning the simple building blocks.

Start With Something Simple

There are a lot of easy-to-construct starter projects which can be built at low cost in order to learn the fundamentals. Good examples are the DC motor controller by Bungard in this issue, and the numerous circuits in Johnson's series on Optoelectronics. These can be built with readily available components from Radio Shack, Jameco, Digi-Key, Priority One, and others, and by using a solderless breadboard system the circuit can be easily changed and the components reused for another project. Many of the starting projects don't even require a computer, and a DIP switch can be used to simulate the parallel eight bit signal for static testing where needed. You can usually substitute similar parts in these non-critical circuits, and the experience gained in comparing spec sheets while looking for substitute parts will help you to better understand the use of the components.

Acquire Reference Material

Reading is the route to knowledge! Many experts predicted that television would make books obsolete, and that the computer would bring about a paperless society. That has not happened yet, and as things stand today the only way to acquire the necessary knowledge is by reading. There are many good books available, but there are also a lot of general audience books which do not contain the specific detailed information you need. It is difficult to tell you which books you should get because it depends on what you want to do. Everyone's needs are different. As a minimum I would suggest at least two books on the language you want to use, two books on your comupter's operating system, plus several books on digital logic, interfacing, and control. You may have noticed that I recommended two books on the same subject. That's because I find that while reading a book on any topic, another book by an author with a slightly different outlook helps to clarify some of the difficult sections. Once you have the books pick out a project and get started. It is only by doing that you will learn! ■

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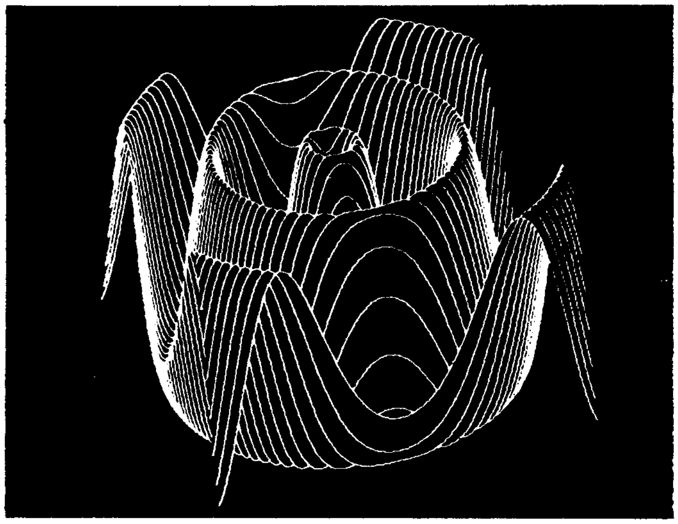
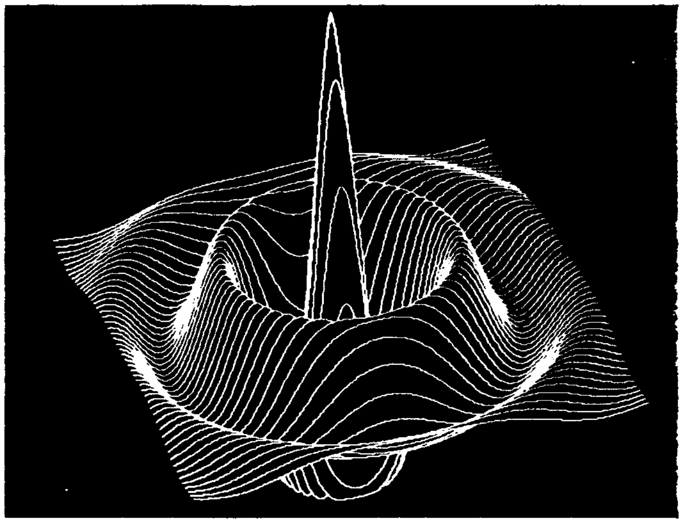
Build a High-Resolution S-100 Graphics Board

Part One: Video Displays

by Lance Rose, Technical Editor





Introduction

In the last eight years or so since the microcomputer phenomenon has been with us, graphics capability of micros has remained pretty much unchanged. We are still using the techniques of character graphics or, at most, "block graphics" where each character position is broken up into a 2x3 "cell" with each 1/6 of the cell individually addressable. While there have been exceptions to this (the North Star Advantage is one), most micros that advertise "high-res" graphics are limited in the vertical direction to around 240 lines or so. This stems from the use of non-interlace video techniques, which I will touch on a little later, to keep the screen flicker to a minimum. With some long-trace phosphors available in some video monitors, it is possible to use a full-interlace video technique to essentially double the vertical resolution of the image to 480 lines, thus bringing the vertical and horizontal resolution into line with each other. Horizontal resolution of 640 dots is easily achievable already.

The graphics circuit I will describe later in this article can be easily built by anyone familiar with wire-wrapping techniques and offers a very cost-effective way of adding high-resolution graphics to your S-100 system. The characteristics of this circuit are:

(1) Low cost. You can build this board for around $200 worth of parts. (Commercial products with similar features typically retail for $500 or more).

(2) Simplicity. The board uses no exotic parts whatsoever. The most expensive single item (other than the blank prototyping board) is a 6116 RAM chip which sells for $4-$5. All other devices are 2732 EPROMS or commonly-available LSTTL chips, resistors, capacitors and the like.

(3) I/O-mapped addressing. The board is usable in both 8 and 16-bit systems even though it has 38K of its own video RAM. This RAM is accessed through a set of 4 address-selectable I/O ports (only 3 are actually used) and takes up no space in the system's main memory.

(4) True addressing at the bit level. Any single bit in the array of 307,200 bits can be turned on or off individually.

(5) Synchronized processor accessing. Many inexpensive video circuits allow the CPU to read from or write to the video RAM at any time. If the video circuit is in the process of scanning a line of information and displaying it when this happens, a "tearing" effect can be seen, particularly when the accessing is repetitive. This circuit "interlocks" the processor access with the scanning so the display is smooth and undisturbed at all times.

(6) Easy bit-mapping. The display is addressed very similarly to a character-oriented graphics board with the zero-location of screen memory in the upper left-hand corner and the memory addresses increasing from left to right on the first line. The next address is the first bit at the left-hand side of the screen on the second line and so on. The highest address (95FFH) contains the last 8 bits on the last line at the bottom right.

(7) "Smooth" curves. The curves or circles plotted with this resolution come as close to being "round" as possible without resorting to very expensive ultra-high-bandwidth monitors and graphics circuits.

(8) This circuit can make use of your current video monitor (with some exceptions). Most monitors with a picture tube having a P31 phosphor or longer (this includes a large percentage of the green-screen variety) will show full-interlace video images with a minimum of flicker. Monitors with a longer P39 or P42 phosphor (I use an Apple III monitor which has P39 phosphor) will display full-interlace

images with virtually no flicker at all. (See below for a more complete discussion of phosphor ratings and the causes of flicker.) Most current monitors have sufficient resolution to use this board although the higher bandwidth types will show a sharper, clearer image, particularly at the corners of the screen.

Incidentally, on the last point mentioned, if you don't already have a monitor and are contemplating buying one, if at all possible try to look at the monitor in operation before you buy. When choosing a monitor to use with this board, I tried out several types before making a choice (there aren't too many choices here in Kalispell to begin with). Beware of specsmanship! One of the monitors I tried which was advertised as having a 20 MHz bandwidth was actually fuzzier than another one which was rated more conservatively (and realistically) at 15 MHz. There's just no substitute for A-B comparison shopping so if at all possible, don't buy an untried monitor mail order if you can help it.

Now that the caveats are taken care of we can proceed to the description of the graphics circuit. But before delving into the actual hardware, it is necessary to have a reasonably good understanding of just how raster scan (television) graphics actually work.

Understanding Raster Scan Graphics

Without worrying about the actual hardware, we need to understand that a raster-scan display consists of two sweep circuits (circuits that cause the electron beam inside the picture tube to move) operating simultaneously. The horizontal sweep moves the beam (and hence the visible dot) in a left-right direction and the vertical sweep moves it in a top-bottom direction. While in theory both of these can be operated at any desired rate and direction (such as in a "vector graphic" display), in TV they are both interrelated and locked to the power line frequency (60 Hz).

Referring to Figure 1 we can see a diagram of the dot movement for a non-interlaced display, the type found in most video display terminals and graphics devices. Assume that the beam starts its display in the upper left hand corner of the picture tube screen. The scanning of a horizontal line is accomplished at a rate of 15,750 Hz in standard TV receivers that use the U.S. television standard (this varies in some countries). What this means is that a signal applied to the horizontal deflection yoke (electromagnetic coil) around the neck of the picture tube causes the beam to traverse the screen from left to right in approximately 63.5 microseconds. At the end of this left-to-right trip, a sudden impulse signal of opposite polarity causes it to jump quickly back to the left-hand edge of the screen. This sweep signal which, by the way, is generated inside the TV itself (as well as the vertical one) is in the shape of a sawtooth waveform.

Now, if this were going on with no vertical sweep applied, all we would see is a single scan line at the top of the screen being retraced every 1/15,750 second. While this might be good for meditation and the like, it isn't very useful for displaying a full screen of text or graphics information. If, at the same time as the horizontal sweep is operating, we also apply a sweep signal to the vertical yoke we can cause the beam to move downward. In normal TV this is done at a 60 Hz rate so as to allow easy synchronization to the power line frequency. With both sweeps operating simultaneously, the appearance of the screen will be as in Figure 1, a set of lines which are nearly horizontal (remember the dot is moving down constantly). The time it takes the beam to jump back over to the left side of the screen after reaching the right side is so short that no appreciable downward movement takes place during that time. At the bottom of the screen after the last line, a vertical retrace occurs, similar to the horizontal one, which causes the beam to move back up to the top of the screen and start over again. This vertical retrace occurs over the interval of several horizontal scans and is not as fast as the horizontal retrace. The blank screen of scan lines resulting from these ongoing processes is called a "raster".

From the ratios of the sweep frequencies, we can see that in a single vertical sweep (or "field") there is enough time for the horizontal sweep to operate 262.5 times. Don't worry about the half line yet. It stems from the fact that each TV image (or "frame") in a full interlace system is composed of two fields for a total of 525 complete lines. As far as non-interlaced diplay goes, the video monitor doesn't have to have sweep frequencies that are exactly what I listed above. If the rates are typically within a few percent of the nominal values, the sweep generating circuitry can lock onto them and display a raster with no adverse visual effects. If the timing information in the signal that we feed into the monitor is much different than the nominal values, we will begin to see one or more dark horizontal lines superimposed on the picture (known in the TV business as "hum bars"). What this means is that if we want the horizontal and vertical rates to be related by an exact ratio such as 262 or something close to that, the receiver will lock onto the signal just fine.

Since most video monitors begin and end their sweeps off the edges of the screen ("overscan"), we typically can't use all the 262 or so lines for displaying information. Further, after a vertical retrace it takes a few lines for the sweeps to get resynchronized so a few lines at the top will be distorted anyway. The most common practice is to actually use 240 of the lines for display purposes. It isn't just coincidence that most terminals display 24 lines of characters. They use 10 actual scan lines for each character line. If the electron beam can be turned on and off at the proper rate during the horizontal scan, we can get a series of on/off dots to be

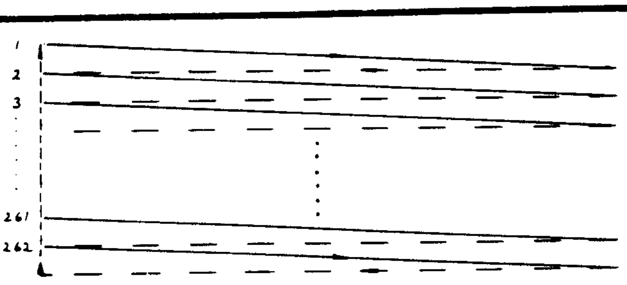


Figure 1: Non-interlaced video display.

displayed on each line. Most monitors can display 640 horizontal dots without fuzzing one dot into another which results in a typical 80 character horizontal diplay on terminals (8 dots per character position). This also allows for blanking out a certain portion of the horizontal sweep at the left and right edges of the screen. You may have noticed that the display from some video boards won't fit on all video monitors without adjusting the monitor. Both quality boards and quality monitors have adequate adjustment to overcome this. With the 240 × 640 pixel (short for "picture element") display, we can have an 8 × 10 matrix in which to display each character.

I mentioned just now turning the beam on and off at will. This is one of the functions of the video signal fed into the TV receiver or monitor. The actual signal is known as a "composite video" signal because it must perform several functions at the same time. First of all, it must carry the horizontal and vertical sweep frequencies with it in order to allow the monitor to synchronize its sweep waveforms. Secondly, it must tell the monitor when to "blank" the electron beam out. This is done during horizontal and vertical retrace to prevent the text or graphics we're displaying from being overwritten by a bunch of zig-zag lines as the beam finds its way back to the left side or top of the screen. If you turn the brightness all the way up on many sets, you can actually see these lines. Finally, the video signal must carry with it the information of what we want the brightness at each point on each horizontal line to be as the scan proceeds. In TV pictures this information can vary linearly over a certain range from black through numerous shades of gray to white. (Forget for now that there are such things as color sets or green or amber screen monitors.) For character or graphics displays, it is sufficient to tell the video monitor whether each particular pixel is "on"or "off"("white"or "black"). Thus we have a digitally encoded signal.

Figure 2 shows a typical composite video signal for a single scan line. Beginning at the left there is a portion of

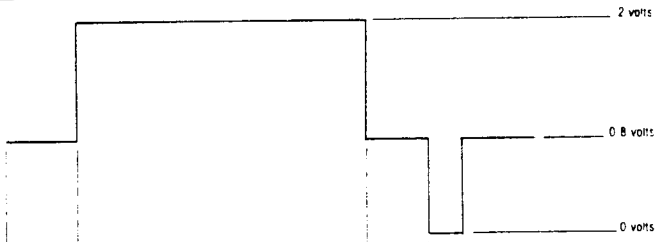


Figure 2: Typical composite video waveform of a single scan line.

the signal that is blanked. Then follows the portion of the line that is to be displayed followed by another blanking interval at the right-hand edge of the screen. Finally, there is a "sync pulse"which causes the beam to retrace back over to the left side of the screen. Typical signal levels and timings are shown in the figure.

Since the vertical retrace occurs every 1/60 second and since both fields contain the same information we say that the screen is "refreshed"at a 60 Hz rate. We have to realize here that after the electron beam passes by any point on the screen and (if the beam is on at that point) it will excite the phosphor on the screen and cause it to glow. Once the beam is past there, the glow will continue for some time. This time is a function of the "persistence"of the phosphor. A short-persistence phosphor will decay rapidly and the image will disappear quickly. While not the best thing for our purposes, these short persistence phosphors are useful in oscilloscopes and regular TV sets where each displayed frame is expected to be different from the last. If the persistence were too long, the previous frame's information would still be visible on the screen when the current frame was being displayed. This would result in the moving objects being followed by a "trail"on the screen.

For the display of text or graphics information that isn't moving rapidly, the best thing is a long persistence phosphor. Without such a phosphor, by the time the electron beam came around to refreshing a dot on the screen again, the dot would have faded to a much dimmer value than it had when it was first excited by the beam. This cyclical intensity variation shows up as a flickering image and is very hard on the eyes if you stare at it long enough.

Picture tube phosphors are rated by their "P-number"which is normally stamped on the label attached to the tube if you want to look and see what you have. The higher the P-number the longer the persistence of the phosphor. Oscilloscopes usually use a P1 phosphor since they are often displaying very fast waveforms. Black-and-white TV picture tubes are approximately a P5, and a lot of integrated display terminals use a green-screen P19 phosphor tube. Many separate monitors are available that use a P31-P42 phosphor green-screen tube. (Amber screens are most typically P19 although some longer trace ones are also available). For monitors with short-persistence tubes but otherwise good electronics, replacement tubes are available with a variety of colors and persistence characteristics. (One source is Langley-St. Clair Instrumentation Systems, 132 W. 24th St., New York NY, 10011.) While a P39 or P42 is nice, very acceptable results can be obtained with a P31 tube even with full interlace video, especially if the brightness is kept low. Even a P19 type is usable with low illumination as the flicker gets worse with brightness. The 60 Hz refresh rate of non-interlaced displays is more than fast enough to fool the eye into thinking that the intensity is constant, even with moderately fast-decaying phosphors. Flicker is minimized and this is probably the most important reason for using non-interlaced video displays. The negative part of course is that we are limited to only 240 pixels in the vertical direction. Graphics displays of this sort are not terrible by any means but the difference in resolutions between the two directions is quite obvious.

In a full interlace display, the first field of the frame is pretty much like the non-interlaced version. The differences begin at the end of the first field. Figure 3 shows the line sequence for a full interlace display. After 262 full lines, the

continued on page 15

SYSTEM INTEGRATION

by Bill Kibler

Introduction

Over the last few years I have been involved with the integration of several systems using CP/M. These integrations usually used components, purchased from swap meets, which were generally not intended to work together. To date, I have dealt with the following manufacturers: IMSAI, Micropro, Micromation, California Computer Systems (CCS), SD Systems, Altair, Compupro, DC Hayes, TDL, Ithaca Audio, Cromemco, Radio Shack, Star Micronics, Big Boards I and II, Coex, Teletek, Altos, and Processor Technology (SOL). Previous to my experience with microcomputers, I spent over 20 years maintaining systems in broadcasting, geophysics, and industrial environments. With this background I will attempt to provide enough information to assist those who are considering buying used equipment. Most of the information will also be of considerable help to those buying off-the-shelf systems.

What is Important?

When considering the purchase of any type of computer system, price is generally thought to be the most important aspect. In reality, it should be the least. My normal charge for integrating a system of used parts is $600 (full 64K, dual 8", in S-100 bus cabinet, monitor extra). Although this is cheap, it is still money wasted if the system is not usable. When considering a purchase, most people (including myself) have only one thing to base their decision on: DOCUMENTATION. In fact, documentation is actually the most important part of any system. A system without documentation is no bargain at any price. Let's review a list of the main things to consider in any purchase, with the most important point first:

a) Documentation: without this it can be impossible to do anything. The manuals should be complete, easy to use, and designed for different levels of expertise.

b) Hardware: does the system have sufficient hardware abilities to perform the tasks for which it is intended? Do not overlook hardware incapabilities.

c) Software: does an operating system exist or will I have to reinvent the wheel? Are listings and ASM files included for modification?

d) Support: is the manufacturer still alive, and if so, does he support mixed systems? If the company no longer exists, is there a considerable amount of information available?

e) Adaptability: this is a consideration of the hardware and software interfaces with an eye on the possibility of upgrading (different from making the system work).

f) Repairability: can I do it myself or can repairs be made only at the factory?

Undoubtedly, there are some additional points that you might consider important, such as color, size, weight, expense, or what your friends use, but these are mostly personal preferences that change with each user. The six which I have listed are the most important considerations in choosing a system. Now let's look at each point more closely.

Documentation

Documentation has probably been discussed more than any topic in the computer industry. It is still most unfortunate that some manufacturers do not support the consensus. One leader in providing good documentation is Compupro. Their manuals are not excessive in size, but do cover the subject completely. I recently purchased an Interfacer 4 and was quite surprised by the quality of the documentation. There is an index and a page for those who would rather try it than read about it first. There are adequate discussions of how it works, an explanation of how to interface the software (with listings), and good readable schematics. A good disk controller manual is the one which comes with the CCS 2422. There is one book for the hardware and one for the software. The hardware book has a listing of the PROM, detailed port usage tables, and a section on theory of operations. The software manual is set up for beginners and will guide you through the steps for adding special functions to the BIOS.

Some companies that do not provide good documentation are SD Systems (more about them later) and the Big Board II, whose manufacturer expects you to have a Big Board I since they are still working on a manual. What mistakes did these two (and others) make? It is usually the same one—misjudging the users' needs. All users require the same information at one time or another, and to meet their needs, a good manual should:

a) provide complete specifications of the product—what it can and cannot do.

b) give intended configuration and interface specifications for the product.

c) provide all known hardware facts, drawings, and schematics (current and past versions).

d) present all software considerations, with well-documented sample listings.

e) be written for different skill levels, including enough information for the advanced user, but written so that the beginner can understand it.

f) be indexed, cross referenced, and have plenty of appendixes.

g) include manufacturers reprints of special ICs and devices.

If the manual does not include this information, you can expect to have a lot of problems bringing up or modifying the system. My system cost would be three to four times the cost of the equipment if the time spent on deciphering poor documentation was taken into account.

Hardware

When considering the hardware, there is more to think about than whether or not it works. You must also look at the system size, its I/O capabilities, and, with S-100, whether or not it meets the standard. When looking at the overall system, a good understanding of your current and possible future needs is necessary. Check with friends, go see dealers, and read a lot of magazines until you have clarified either in your mind or on paper just what your needs are—then buy. A good choice for used equipment is the S-100 line of products, which abound at swap meets. The S-100 standard is rather tricky; currently the makers are using several ways to describe products that are close to the standard but may not work in all cases. When in doubt, call the manufacturer. If they cannot guarantee that it will work for your intended use, assume that it will not. The S-100 standard now calls for some rather precise timing windows that should eliminate many headaches, but assume that all previous boards were intended to work with their own family of cards. For example, the CCS products are not fully S-100 compatible and in fact, if you call the company, as I did, they will tell you that the CCS 2422 ver. 0.001 is to be used with the CCS 2810, and the CCS 2422 ver. 0.002 is for the CCS 2820 only. The company does not support any use other than that. This also points out how versions of the same product may in fact be quite different. For an S-100 compatible SD System product be sure it has the "meets IEEE-696" label, which means that it has been brought up to current specs.

Another thing which may bother the user of older equipment when he tries to upgrade it is VLSI design. The most current problem is disk compatibility which has become more of a problem as new controller chips emerge. I started out using non-VLSI type controllers, and am returning to them after trying several VLSI types. NEC upd 765 is a good device but it has one flaw that keeps me from using my old drives. The device tests the drives at all times for status information. Some old drives are not capable of meeting this need, possibly forcing you to buy new drives. In hot climates, enough heat is generated by the steppers on eight inch drives that the system has been known to shut down. This is a problem experienced with the Teletek Systemaster board when the combined heat of the stepper and the regulator affect the NEC 765 which is mounted above the regulator heat sink and requires the board to have forced ventilation. The WD (Western Digital) products appear to be OK. However, there is some incompatibility between their WD1771 and the WD179X series, although I have read eight inch single density CP/M from one type to the other without problems. My other problem with the VLSI chips is their inability to read a sector should an error occur. Complete track reads are needed to get around this design parameter. With non-VLSI type controllers the software (if all the documentation is available) can always be changed to meet formats or uses you may want, although this is not a task for novice programmers. If you are buying new drives and use only standard disk formats, the VLSI type controllers are preferred.

The last comment on new hardware problems concerns the increasing use of PROMS and PALS. Both units are programed by the manufacturer to allow several functions to be performed by one chip instead of many. This has decreased the amount of real estate needed, and has increased functions while keeping cost down. For the integrator and repair person, this is not a very good situation, as we can no longer change or modify at will. In fact, most manufacturers are not supplying the codes needed to burn your own PALS or PROMS. Not only are you now forced to buy from them when they feel like supplying the part, but in some cases not enough information is available for independent technicians to repair the system. When buying used equipment, avoid units with PALS or PROMS at all cost, (especially from defunct companies) unless you intend to use factory repair services.

Software

When looking at the software for a new system, the major points to study are:

a) compatibility; is it CP/M?

b) simplicity; is the system so involved that I can't work with it?

c) ASM files; are all the ASM files present on the disks?

d) documentation; is there any?

e) disk format; will I be able to read it? Does it have SD or DD disks?

f) are all the non CP/M utilities provided (eg. format program)?

You should also be aware that with new systems,such as CP/M 3, there may be little technical help available. This lack of free support will change with time, but for now think of anything hot off the presses as too hot to handle. When dealing with older systems, and used ones, a local computer club will generally be the best support group around. When I was bringing up the SD Systems VF II, a fellow club member provided a BIOS for CP/M 2.2 that had me running with new I/O routines in 30 minutes.

Some of the signs of bad software are: utilities that assume special terminal codes and then do not supply ASM files to change them (Big Board II's format program), incomplete CP/M disks (SD Systems CP/M 3.0 is not complete), and BIOSs that cannot be assembled without special assemblers and may force you to buy more software. (Teletek's BIOS is in Z80 code and needs M80 and L80 to change. Morrow Decision I BIOS is another.) The most common current problem is the double density only system disk, which is OK if it works, but cannot be modified without a running system (Big Board II will need the Big Board I's CP/M to bring it up). Teletek and Morrow Decision One are also DD only.

The next biggest hassle for novice to imtermediate programmers is CP/M 3.0. It is all in MACROS (more on this in part 3), and some systems also use interrupt driven BIOSs

(Teletek, SD Systems SBC300). Presently, there are several good books on working with CP/M 2.2, but little detailed information on the insides of CP/M 3.0, or how to deal with interrupts. Understanding your limits as a systems programmer can keep you from looking at a straight jacket from the inside out. With time, the last two problems will not cause much grief, but if you are just starting to get into assembly language programming, try to stay with simple straight-forward systems running CP/M 2.2.

Manufacturer Support

This can be the biggest headache of them all and yet is sometimes the most important consideration in choosing a system. If the manufacturer believes in supporting his products, the three previous discussions may seem unwarranted. However, I have found more bad supporters than good ones. In industrial environments it is commonplace to be able to call the manufacturer and talk with someone who knows the product and can help you out. The microcomputer industry is not yet up to industrial standard, and in fact, it may not be out of the dark ages. I feel confident in making that statement after working for Teletek as their sole technical support person. This short period of time gave me a good insider's view of the industry. The term "time is money" appears to be the main motto, and spending time with users is usually considered money lost.

Many manufacturers, including Teletek (I'd say SD Systems also, looking at their documentation) want to be OEMs (original equipment manufacturer) only. Unfortunately for users of used equipment, this position can be nothing but trouble. OEMs make and sell their products not to end users but to other manufacturers who are responsible for support and documentation. The lure of selling a few extra boards on the side, however, has gotten a lot of OEMs into the position of supporting a product poorly.

There are some companies that are really trying hard to support their products. Compupro is the leader. Their guarantee is simple: "if it fails, call us". They will try to help you, and if not sucessful, will ship a board to you. Returning the bad board will keep you from having to pay the cost of the replacement. This is a much better practice than that of most companies, who will not supply loaners. Others take three to six weeks before boards sent in for repair are even looked at, let alone fixed. In the case of new units like IBM you may need to have purchased a service contract from the dealer first, who will, in turn, send it to a service center when it fails. For those of us who do their own work, documentation is our mainstay and talking with the factory is a last resort. Having talked with several companies, I would say that technical support people are unemployed more than anyone else in the industry. SD has been the only company so far to have the same support person after six months of dealing with them.

What to expect when calling a company:

a) to be given to the wrong person at least three times.
b) to be put on hold for 15 minutes (all long distance, too).
c) to find out that the person just went home (after 15 minutes wait).
d) to be told he will call back (if you believe that, I have a bridge to sell you!).
e) you call back but have forgotten the person's name (goto a).
f) you finally get the person, only to stump him with your problem.
g) you are told you will be called back in 15 minutes with the answer (goto d).
h) you are given an answer which you find out does not work.
i) you now get the stock answer, "send it in and we will look at it."

The last time I called CCS, I got a secretary who took my question and did call me back with an answer ("can not help you"). To sum it up, don't call. If you must, get the name of the person you talked with and talk only with him. Tell him what you want and expect from him (don't gossip), have your facts ready and be prepared for hassles (most companies think everything is a trade secret). When faced with big problems expect to talk to a VP of marketing, because in most companies, technical support is a division of sales and not engineering.

Adaptability

Adaptability, a unit's ability to fit some future need, is what I look for when buying used equipment. Although this is not a critical point for most users, it may mean the difference between having to get another board and just adding a chip to the existing board. A sample of adaptability is the use I made of 16K Altair boards. These cheap boards are now running 256K for less than $200 in cost and a half hour of work. Although a lot of development time was spent in this project, it would never have been possible if the product was ill-designed and unadaptable. For more information on this project, see the article "Cheap Memory" in the Dec. 1983 issue of *Microsystems*. Do not overlook magazine articles as they may contain information which can save you many hours of development time.

Repairability

Like adaptability, repairability is not important to everyone. However, when you are doing your own work, good quality boards are a necessity. If a foil surface is so thin that it comes off at the touch of an iron, repair can be a nightmare. Good solder masks are essential, and sockets are much easier for replacing bad chips. PALS and ROMS detract from repairability and were a major failure item in the past (the PALS were not being burnt properly). Software problems can be impossible to solve without the ASM files and may still be unsolvable when not fully documented. Assuming that the listings in the manuals are correct may lead you down the wrong path. (Quite often the listings are old and not completely debugged—get the most current listings from the factory.)

It is important to keep in mind that the current complexity of systems can require complex test equipment. A 50 to 100 MHz scope and a digital voltmeter are the

continued on page 15

OPTOELECTRONICS

Part Three: Optocouplers and Fiber Optics

by Roger Johnson

This installment will conclude the series on optoelectronics and design. Several areas will be covered including optocouplers, fiber optics and simple geometrical optics. While each subject in itself could be the basis for a book, we will introduce the essentials and disclose applications, techniques and sources of materials.

Optocouplers

A cousin of the optocoupler or optoisolator was introduced last time when we discussed the optical switch. In this device an open slot or gap exists between the LED and phototransistor, allowing a piece of material in the form of a flag to pass through the gap for speed, timing or non-contact limit switch applications. The optocoupler's component parts remain the same, except that the gap is gone and the whole device is sealed from external light. So all we have is an LED positioned about 1mm away from a phototransistor in a sealed package. This lets us control or command a circuit simply by turning the LED on or off.

Why is this useful? It turns out that in the real world of electronics there is all sorts of noise. This noise can be from motors, solenoids, heavy current switching, and lighting or radio interference. Since an optocoupler only communicates via light, there is no way that noise from one part of the circuit can affect the optocoupled part.

When heavy currents are flowing in parts of the circuit, this type of noise is called "ground loop". Figure 1 shows how it arises. In this simple example, the ground loop is due to a large voltage drop in the supply lines. A cure is obvious: either increase the wire diameter (or trace width on a PC board) or separate the grounds. This is where optocouplers come in. It should be pointed out that optocouplers also have the nice advantage of being able to control something that "floats" hundreds of volts higher than your circuit. This is called the isolation voltage of the coupler, and for most, it ranges from 1000 to 7500 volts. You can see how incredibly useful such a device can be. There are times when you would use couplers just to be safe. As an example, say you wanted to connect your computer to another peripheral. Even if both pieces of equipment operated from 5 volt logic, you could use an optocoupler to isolate your computer from the peripheral. If the peripheral had a problem and shorted, caught fire, and smoked, your computer would be protected because the only medium of communication between the computer and the peripheral is light and not copper wire.

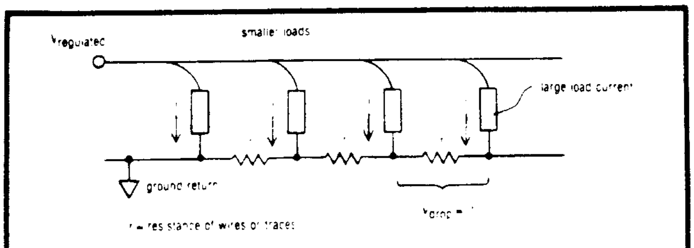


Figure 1: Ground Loops. When large currents flow, appreciable IR drops will occur. The load can cease to operate, or draw voltage away from other portions of the circuit. If the load draws heavy current intermittently, the problem becomes worse, because it is random. The solution is to use heavier wire or separate the loads

You don't have to know anything about optoelectronics in order to use optocouplers, but to use them properly you have to know a bit about how they work. See Figure 2. When the LED is turned on, it will cause collector current to flow in the phototransistor. Just how much collector current flows will depend on the optocoupler you have. This current is set by the coupler's CTR or current transfer ratio. CTR is defined as the ratio of output current to input LED current times 100 per cent. The higher the CTR, the easier it is to drive a low load impedance. High CTR values also mean higher prices.

The other aspect, sort of a secondary one, is that the CTR of a coupler degrades with time. So if you're going to design a piece of equipment for sale or for use in a remote area where the cost of repair could be high, you have to design with the manufacturer's estimates on how the CTR varies with time. Also, it is best not to overdrive the LED. LED life goes down with larger currents. While some data sheets show that the LED can be operated at 50ma continuously and even take short duty cycle bursts of 500ma current, it is usually best to operate the LED at 10 or 20ma of forward current.

Let's take a look at how we use a typical optocoupler to drive a standard TTL gate input. The coupler is a generic one called the 4N25. It is manufactured by all the companies that make optoelectrical components, such as Texas Instruments, Monsanto, General Electric, Motorola, Hewlett-Packard, Litronix and Honeywell. The CTR curve for this opto is shown in Figure 3. It has a CTR of 20% at an LED current of 10ma.

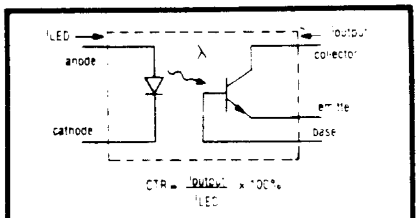


Figure 2: Optocouplers. Optocouplers come in a light-tight, hermetically sealed package. Sometimes the base of the phototransistor is brought out for biasing. Usually it is not used. CTR (Current-Transfer Ratio) is defined above.

We first pick the

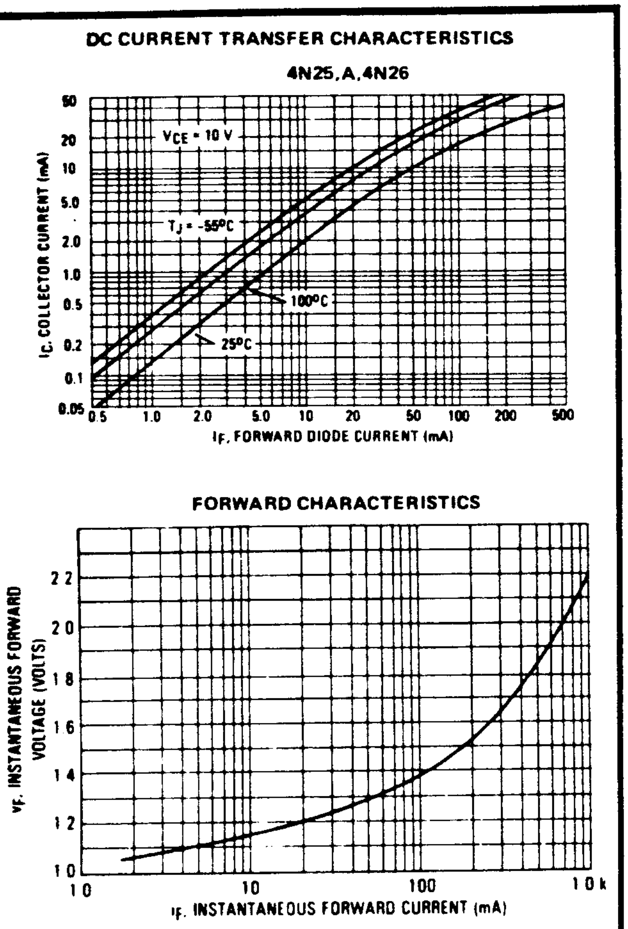


Figure 3: CTR curve for the 4N25.
courtesy of Motorola, Inc.

LED series resistor which will give us our desired LED drive current. Ten milliamperes of LED current will give us 2ma of collector current. We need 1.6ma to sink the TTL input to the low state. This doesn't provide much room for CTR degradation so we pick 16ma of LED current. This also provides a long life for the LED, and is the maximum sink current of TTL. Of course you can change the numbers for whatever logic family you have. We see from Figure 3 that 1.2 volts lies across the LED at 16ma of current. R must be:

R = (5 – 1.2)/16ma = 240 ohms, a standard value.

The collector resistor Rc will see any excess current minus the 1.6ma of the TTL gate imput sink current. The total current in the collector leg is the CTR value times LED current. This is 20% × 16ma or 3.2ma. In Figure 4 we see that the rest of the current which flows in the collector resistor is 3.2 – 1.6 = 1.6ma. Since we assume the phototransistor is on and saturated, it has a Vce drop of 0.2 volts. Hence the value of the collector resistor is:

Rc = (5 – 0.2)/1.6ma = 3000 ohms

3.3K ohms is the nearest standard value.

That is all there is to it. Note that a low on the gate driving the LED produces a low to the input of the gate we are driving. This circuit does not invert the signal. If we wanted to do so, we could add a transistor or use a spare NAND gate.

Most optocouplers come in 6 pin DIP packages. For prototyping work you can insert 2 per standard 16 pin IC socket. And more than just transistors exist on the controlled side of the optocoupler. There are opto-SCRs, optotriacs, optodiacs, and optodarlingtons for huge current magnifications. The circuits in Figures 5 through 8 are tried and tested. The author has designed and used them. These digital circuits solve a variety of problems and have applications in using microcomputers to control huge loads easily. Figure 9 shows a linear application where the output voltage is proportional to input LED current. This circuit is very useful in analog or audio applications that require isolation.

Fiber Optics

Before we can understand how fiber optics work and how we can use them, we have to learn a little bit of optics. A more lengthy and rigorous explanation can be found in a high school physics book, but I think we can explain light wave propagation well enough here to get on with fiber optics and their applications.

We all know that the shortest distance between two points is a straight line... or is it? Let's say you were standing on a beach and someone in the water was yelling for help. To save them from drowning you would want to get to them quickly. Now, for the sake of this scenario and the later disclosure of the fundamental equation of fiber optics, we will assume that you can run faster on dry sand than you can swim in the water. The question then is: How do you get to the person in the least amount of time? Now let's look at the actual geometry of the situation at the moment you decide to take action (see Figure 10). You could actually run and swim all in a straight line. Or you could run to the shore directly opposite the person and then start to swim. If you actually take these two paths and calculate

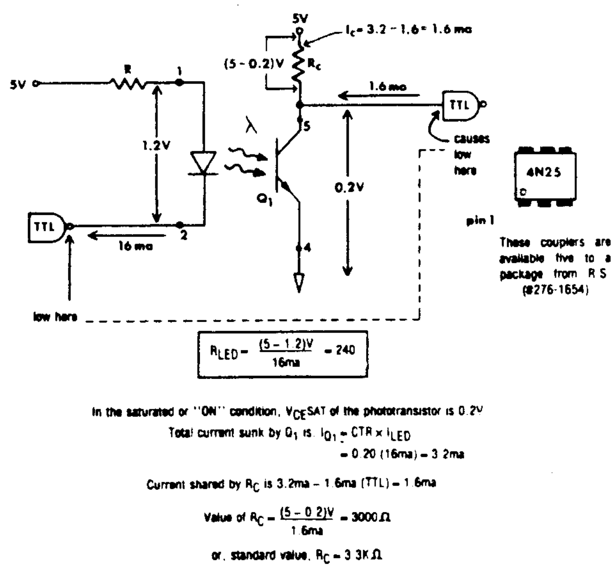


Figure 4: TTL to TTL opto interface using a 4N25.

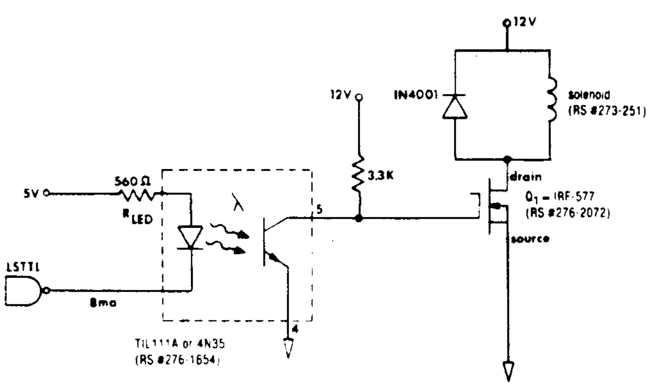


Figure 5: Solenoid actuator with N-channel MOSFET driver. This coupler has a CTR of 100%. It can easily be driven from LSTTL. The solenoid can be used to run valves, switches, robot parts, etc. The MOSFET has an "ON" resistance of only ½ ohm.

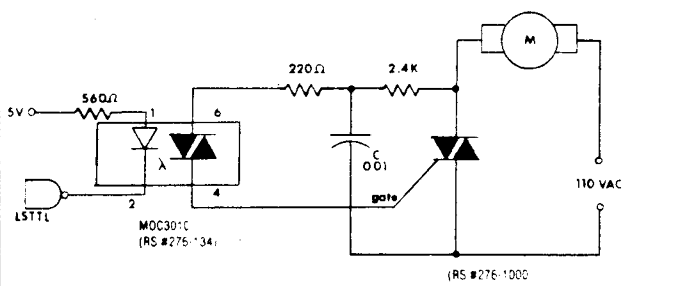


Figure 6: 110VAC motor (or any inductive load) control. The MOC3010 is an optical DIAC. The DIAC conducts in either portion of the AC cycle and triggers the TRIAC. The C is to keep the TRIAC from seeing too high a dV/dt figure (slew rate). This circuit will control loads up to 6A max. Since inrush currents to motors are often 5 times running current, keep the size of the motor to below ½ HP.

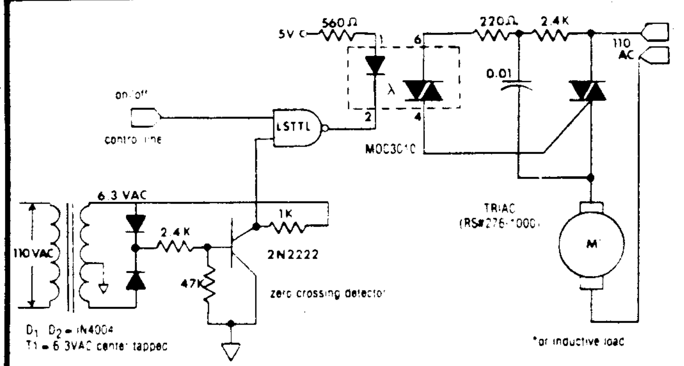


Figure 7: Zero crossing TRIAC driver. This circuit also controls a TRIAC. The extra hardware fires the TRIAC on the positive-going portion of the AC waveform as it passes through zero volts. This always turns the controlled device on at zero volts. It never sees an instantaneous 155V (2 x 110V) signal at turn-on. This will increase the life of the load and TRIAC. It will also minimize the radiation of electromagnetic noise to the surrounding environment.

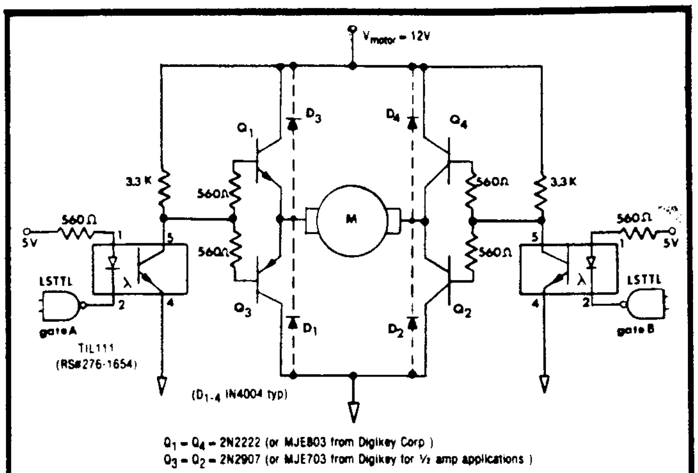


Figure 8: Bi-directional DC motor controller. This isolated motor driver is perfect for motion control applications. Two control lines from gates A and B provide start/stop and forward/reverse control as follows:

gate A	gate B	Mode
0	0	stop*
0	1	forward
1	0	reverse
1	1	stop (w/braking)*

*Depends on the direction of rotation. One mode will provide dynamic braking, the other a regular coast down stop. D_{1-4} will protect the transistors, but will not permit dynamic braking action. (Dotted lines show their placement.)

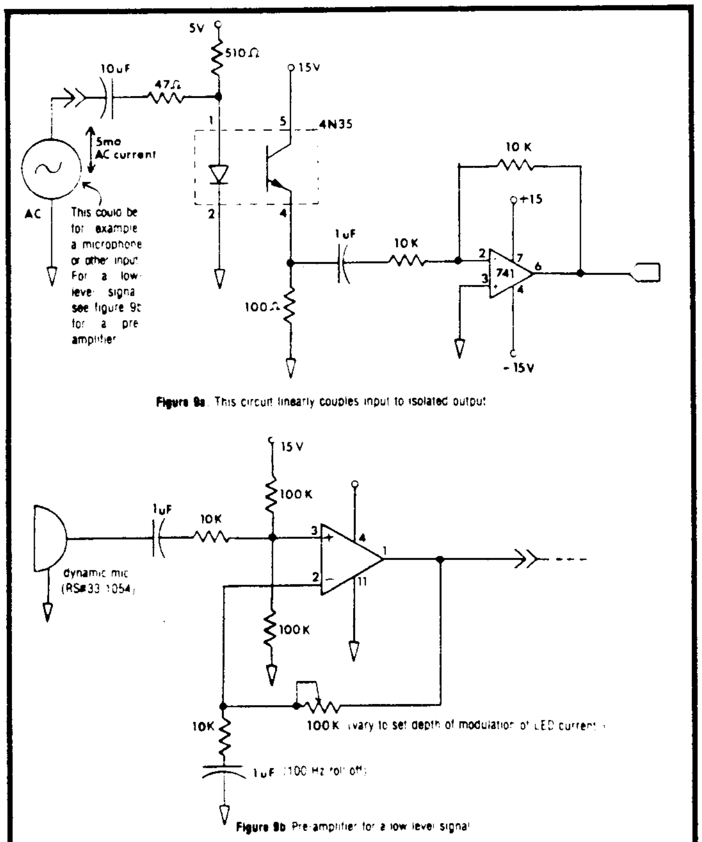


Figure 9: Linear optoisolation with AC source.

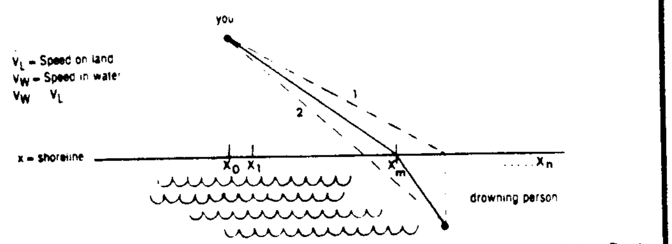


Figure 10a: Your task is to get to the drowning person quickly. Paths one and two seem like good choices, but there is one optimal path.

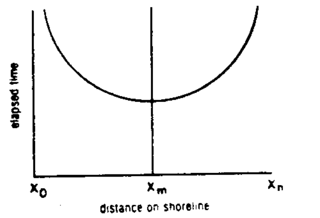


Figure 10b: Graph demonstrates Fermat's Principle. If you search long enough you will find an x value such that any other path will take longer to reach the victim.

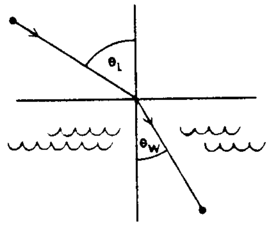


Figure 10c:

$$\frac{\sin \theta_W}{V_W} = \frac{\sin \theta_L}{V_L}$$

your elapsed time depending upon distance traveled and at what speed, you will come up with two different numbers. If you choose some path in between these two, you will come up with a smaller elapsed time. Now if you start an exhaustive mathematical search for the elapsed times for paths every millimeter further along the shore, you will eventually find the minimum time. You have just discovered Fermat's Principle. This is a very powerful tool in lightwave propagation, yet was discovered thousands of years ago.

So we find that the fastest path between two points is not a straight line, but one which takes the least time to travel. Going back to Figure 10, you would find, after some study and observation, that a geometrical relationship exists between your running and swimming speeds, and angles to the shoreline. What you would find is:

$$\frac{\sin\Theta_L}{V_{land}} = \frac{\sin\Theta_W}{V_{water}} \quad \text{(see Figure 10b)}$$

This is powerful. We can predict the shortest time between two points by knowing velocities and angles. In optics, nothing travels faster than light in air or in vacuum. We assign such a transmission medium a number called an index. We assign both air and vacuum an index of 1. Water is about 1.33 and glass is about 1.5. Diamond is 1.8. By dividing the speed of light, c, by the index, we can calculate how fast light travels in that medium. In optics we always use indices rather than the absolute values of these velocities—it's just easier. Also, we never really use actual distances like we did in the beach example. We always use the angles measured from the perpendicular of the interface between the two materials. We then get a corresponding equation called Snell's Law. It states:

$$n_1\sin\Theta_1 = n_2\sin\Theta_2 \quad \text{(see Figure 11)}$$

This is also called the refraction equation and it totally describes how light travels in any medium. This is the fundamental equation of optics and also of fiber optics. The two angles Θ_1 and Θ_2 are usually called the angle of incidence and angle of refraction respectively.

Armed with this equation, we can generate another important one. Let's say that our light started out in the higher index medium, in this case, water. Well, Snell's Law doesn't care which direction the light comes from and we would find that the light gets bent away from the perpendicualr as it emerges from the water. This is sometimes called "optical reciprocity" which is a fancy way of saying that light obeys the same equations traveling in either direction.

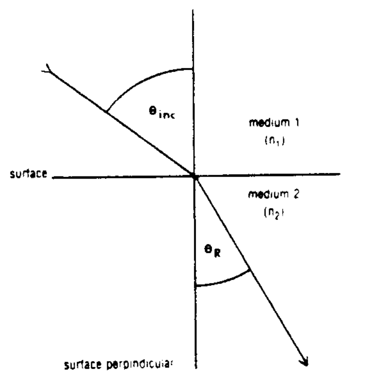
But now let's take a flashlight we have submerged in water and increase its angle of incidence. Pretty soon we will have the emerging refracted rays of light bent at 90 degrees. What happens if we increase the angle of incidence just a little bit more? Mathematically we can't have the sine of an angle greater than one. What we observe is that the light gets reflected off the surface of the water back into the water. This is known as total internal reflection. It is what keeps the rays of light bundled in the fiber as they propagate down the fiber. The critical angle, at which total internal reflection (TIR) occurs, is found by setting the refracted angle to 90 degrees. We then have:

$$\Theta_C = \sin^{-1}(n_1/n_2)$$

TIR can only happen when light goes from an optically higher index to an optically lower index. TIR will then occur at the interface, if the angle of incidence is greater than the critical angle.

Let's calculate the critical angle for TIR of a glass fiber in air. The index of air is 1 and glass is 1.5. So we have as the critical angle:

$$\Theta_C = \sin^{-1}(1/1.5)$$
$$\Theta_C = 41.81°$$



Light is refracted at the interface between the two surfaces. The angles of incidence and refraction are measured with respect to the surface perpindicular. We can tell here that medium 2 has a higher index value than medium 1 because the angle of refraction is less than the angle of incidence.

$$n_1 \sin\theta_{inc} = n_2 \sin\theta_R$$

Figure 11: Snell's Law of Refraction.

In use, the fibers of cables are polished or cleaved smooth. Light is launched in the fiber end by a small lens, a nearby LED, or the end of another fiber. In any event, because of TIR only a cone of rays will be accepted. Figure 12 shows how this cone angle is calculated. A common fiber optic figure of merit is the so-called numeric aperture(NA) of the fiber. The NA of a fiber is defined as the sine of the acceptance angle. The higher the NA, the more light it can accept from a source.

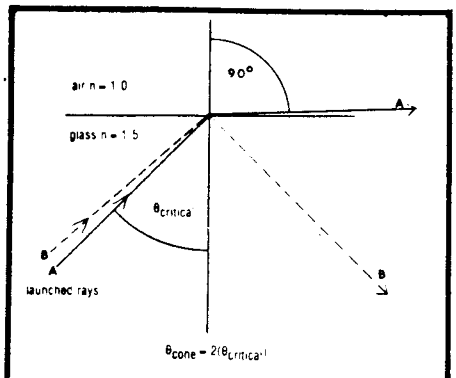


Figure 12: Total Internal Reflection. Illustration of critical angle in an air-glass interface. Ray A gets refracted at 90°. Ray B has a launch angle a tiny bit larger than A and undergoes total internal reflection (TIR). This shows how light is propagated down a fiber.

The problem with high NA fibers is that they permit a lot of rays to propagate down the fiber. The ones traveling close to the critical angle take longer to reach the end than do the ones which are traveling at large angles of incidence. This is simply due to the length of their paths. The fact that some of the rays have a longer travel time than others results in signal dispersion and is the reason that repeaters have to be installed every so often in fiber optics communications links. As Figure 13 shows, an uncoated or unclad fiber's NA can be calculated by setting $n_2 = n_1$ in the general equation which is derived in that figure. When this substitution is done, we find that the NA of a single index fiber is 1. This means that it accepts all light launched into it. In some instances this is good, but in communications technology using fiber optics, it has the above mentioned problem of transmitting too many "modes" and results in signal dispersion problems.

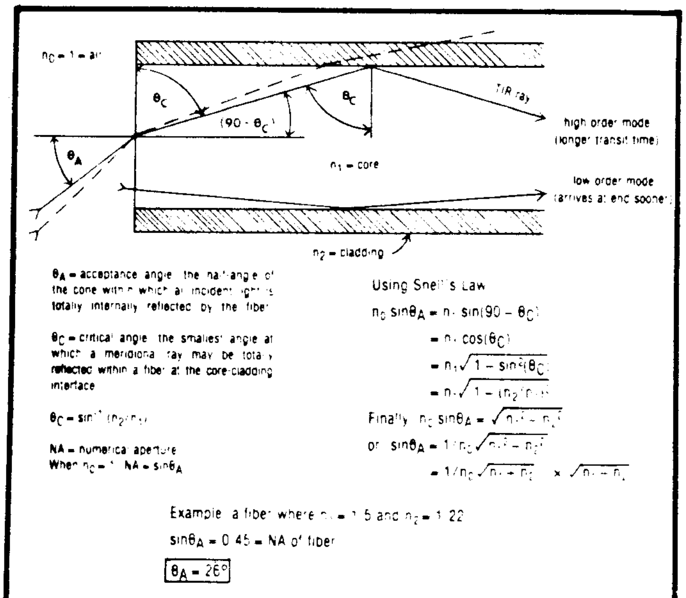


Figure 13: Modes and NA of Fibers.

The solution to this is to add a coating or cladding whose index is less than that of the core. This controls and hence limits the NA of the fiber. Manufacturers can make the fiber so small and the NA value so low that only rays traveling straight down the fiber, hugging its axis, are permitted to propagate. In the parlance of the fiber optics community, this is a low order or core mode. It is traveling in a single mode fiber which is called a step index fiber because a plot of its index of refraction as a function of radius has a step in it.

The rays that get refracted into the cladding are called the cladding rays. These rays are then said to be propagating in the cladding mode. This thin circular cladding does not support the propagation of cladding modes. These rays are "skew" to the optic axis and get attenuated and absorbed quickly. In fact, they decay exponentially. What rays are left then, are the core rays. These propagate extremely well.

The best solution arrived at for large NA and single mode propagation is the graded index fiber. This is a fiber whose index of refraction profile is parabolic. It is high in the middle and falls off quadratically to some lower value at the boundary of the fiber. Additionally, some graded index fibers also have a cladding. This type of fiber is manufactured by doping a fiber continuously with phosphate ions as it passes through a flame. The thermal gradient established is just the right one to fix the parabolic profile. Once the fiber cools, just seconds later, it has this profile frozen into it forever. Graded index fibers act on all launched rays in an interesting manner. A ray launched at a steep angle gets refracted more than a ray launched at a shallow angle. The result is that all rays travel at the same speed. As a result, graded index fibers have both high NA values and are single mode. They are also the most expensive fibers available today. See Figure 14.

Fiber optics today have their main application in telephone communication links. There are some uses such as medical instruments and dental tools, where the main purpose of the fiber or fiber bundle is to deliver light or an image. But today the main use is in comminications. It is true that a single fiber operating at a visible light wavelength can theoretically carry about a billion phone conversations. As the price of copper wire shoots skyward, fiber optics, which are made out of sand, the most abundant substance on the Earth's surface, will be the main method of communication in the future.

There are four main losses that occur in FO (fiber optic) systems. The first three are a mismatch type of loss and the fourth is the basic attenuation of the fiber to a propagating lightwave.

•NA loss

$$\text{NA loss in db} = 20 \log_{10} \left(\frac{\text{NA of source fiber}}{\text{NA of receiver fiber}} \right)$$

This occurs if the NA of the receiver is smaller than the exit NA of the source.

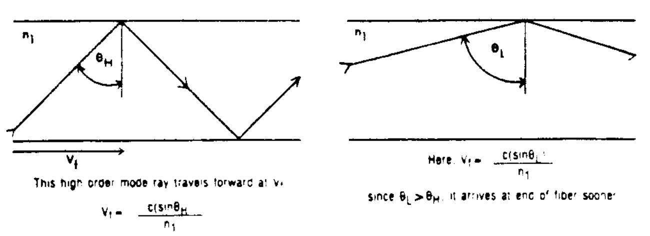


Figure 14a: This variation in velocities results in signal dispersion: all rays start at the same time, but arrive at different times.

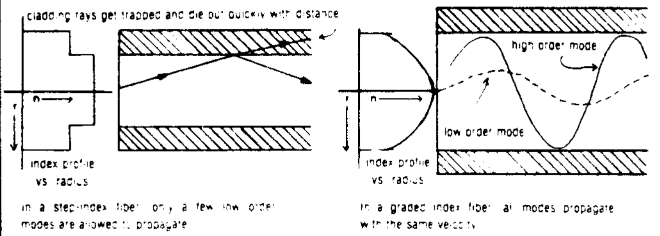


Figure 14b: Two fiber types permit only certain modes to propagate. Step-index fibers let only low modes travel, while graded-index fibers bend high mode rays more than low mode rays. Graded-index fibers (GRIN for short) also have a higher NA.

•Area loss

$$\text{Area loss in db} = 20 \log_{10} \left(\frac{\text{Diameter of Source}}{\text{Diameter of Receiver}} \right)$$

If the receiver fiber has a larger area than the source, power is wasted.

•Fresnel loss (pronounced fra-nel')

$$\text{Fresnel loss in db} = 10 \log_{10} \frac{(n_1 + n_2)^2}{4n_1n_2}$$

When the indices of refraction of two fibers are different, there is some reflection at the interface. Note that the loss is zero in this equation if n1 = n2. The core indices of the two different fibers are n1 and n2. This is usually expressed in db per kilometer.

glass = 1 to 10 db/km
plastic = 100 to 2000 db/km.

Glass has less attenuation than plastic, and early fibers had poorer transmission figures than current fibers. Today, the average glass fiber has less attenutaion per mile than a quarter inch of window glass!

The components that you need to make connections and splices with FO components are expensive. One of the main reasons is that the end of the fiber has to be polished. There have been some successes with diamond point cleaving of fibers, which leaves a smooth end. Also, some firms are investigating connectors which have a lifetime supply of index matching fluid in the connector shell. This couples one fiber to another and also lessens the requirements for a well polished end.

Another reason for the expense of components is mechanical alignment of fiber end to fiber end. Since some fibers are 100 microns in diameter, fiber end placement repeatability should be 10 microns or better, which places incredible demands on the connector manufacturer. However, there are some plastic low-cost connectors and splicing kits available from Amphenol, ITT/Cannon and Honeywell, and I expect some mail order houses to offer them soon. See Figure 15 for some typical fiber preparation details.

Until the components for using glass fibers become readily available, you can experiment with and learn a lot about FO technology by using plastic fibers available from Edmund Scientific. They offer many different diameters and also have polishing rouges and diamond coated papers for fiber tip preparation. With that in mind, let's move to a field of FO that is rapidly expanding and is quite exciting. Here, the fibers are not used in signaling applications, but in the measurement of physical quantities. This is the field of Fiber Optic Sensors.

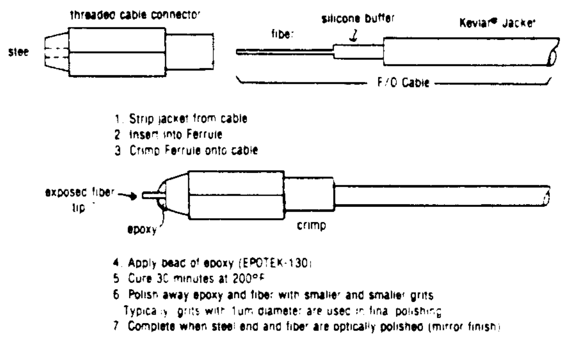


Figure 15a: Typical Fiber/Connector Preparation

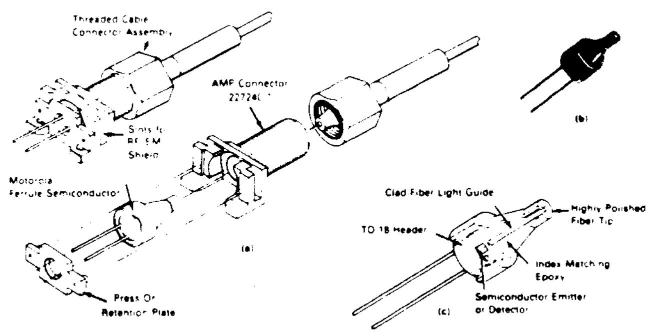


Figure 15b: Typical Optoelectronic to Cable Interface.
courtesy of Motorola, Inc.

Fiber Optic Sensors

FO sensors use the fiber itself to measure almost any physical, chemical, magnetic, or electrical parameter. Temperature sensors have been built that have a response time of two milliseconds! Other devices such as magnetometers, PH sensors and accelerometers are being presented daily. What we shall do here is to investigate FO sensors by building a FO Pressure Sensor, a FO Guitar, and a FO Remote Optical Switch.

Figure 16 details the construction of the pressure sensor. It works by microbending the fiber. When this occurs, more light gets sent into the cladding. Since the cladding modes are rapidly attenuated with distance, they are completely gone after about a meter of fiber. The power that is left in the core is therefore modulated by externally applied

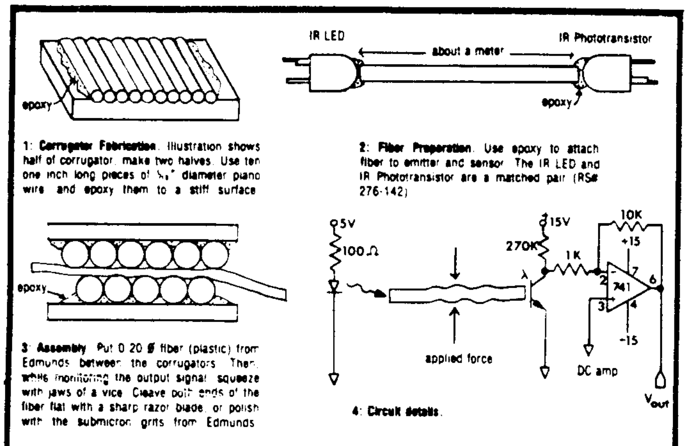


Figure 16: Fiber Optic Pressure/Force Sensor. Microbending occurs in a fiber when it is wrapped around a cylinder whose radius is on the order of or smaller than the fiber diameter. Here, $Ø_{wire} = 0.063$ and $R_{wire} = 0.031$. The fiber $Ø = 0.020$. This is close enough to start the effects of microbending.

pressure. This microbending effect was discovered early in FO use by observing that signals were affected by motion of the fibers. You can make the corrugator as simple or as complex as you desire. It provides the basis for a good sensor. There are even FO microphones which are built by tightly winding hundreds of turns of fiber onto an aluminum drum. When the drum is struck by acoustic energy, the diameter of the drum changes enough to alternately stretch the fiber, thereby modulating the injected light.

Figure 17 shows how a fiber optic based guitar works. Here microbending does not take place, but rather a change in polarization of the injected light. The result is the same though—a modulation in the light power. A benefit here is that the guitar picks up no AC hum, which has always been the bane of electric guitars. Also, no shock hazard exists.

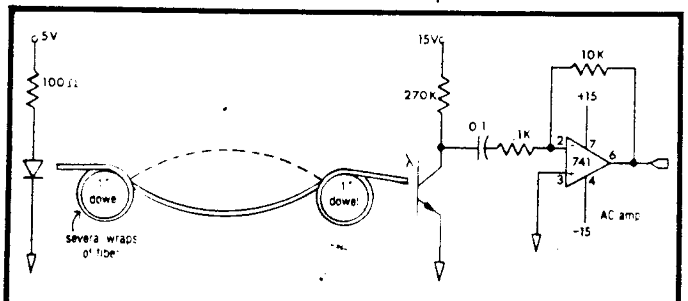


Figure 17: Fiber Optic Guitar. Using the same prepared fiber as before, direct the signal into the AC amp as shown. Use tape to anchor the several wraps of fiber onto the two wooden dowels. In this experiment, the strain induced in the fiber by vibration changes the polarization of the propagating light. It still results in intensity modulation at the output end of the fiber.

The remote optical switch in Figure 18 uses a beam splitter to focus and launch light onto the fiber and also to analyse that which returns. If a reflective plate or mirror is brought close to the fiber end, then light is reflected back into the fiber where it travels backwards and is redirected by the beamsplitter. Here another lens focuses the light

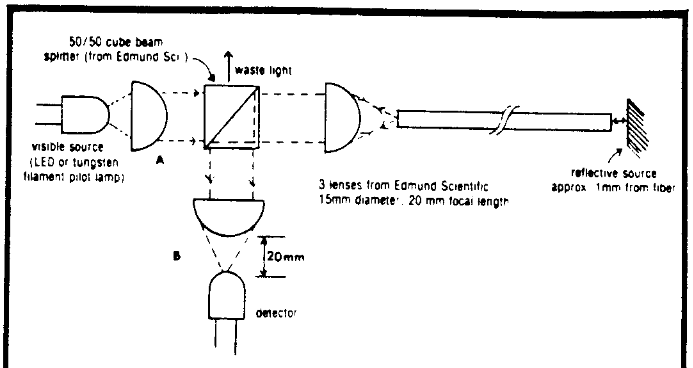


Figure 18: FO Remote Optical Switch. This device uses the same sensing electronics as in Figure 16. It should operate in near darkness. By adding filters at A and B, you can increase its ability to reject ambient light. These filters are also purchased from Edmunds. The source and detector should be positioned one focal length away from the lens. This configuration produces collimated, or parallel light.

onto a detector. This type of on/off sensor is valuable in explosive environments, since no electrical power is ever present at the sensor end. It is also cheap, easy to maintain, and not affected by electrical noise.

Some Simple Geometrical Optics

In working with fiber optics you will encounter lenses. Figure 19 depicts some simple lens formulas you can use. One of the more interesting ones is the equation relating the focal spot size of a lens given wavelength and F number. This is useful in determining spot sizes when focusing onto a fiber tip. This is also the equation used by designers of video disks. A laser beam is focused down to some minimum spot size and this determines the ultimate storage density of the disk. The laser is modulated by changes in surface reflectivity of the disk which were burned in when the disk

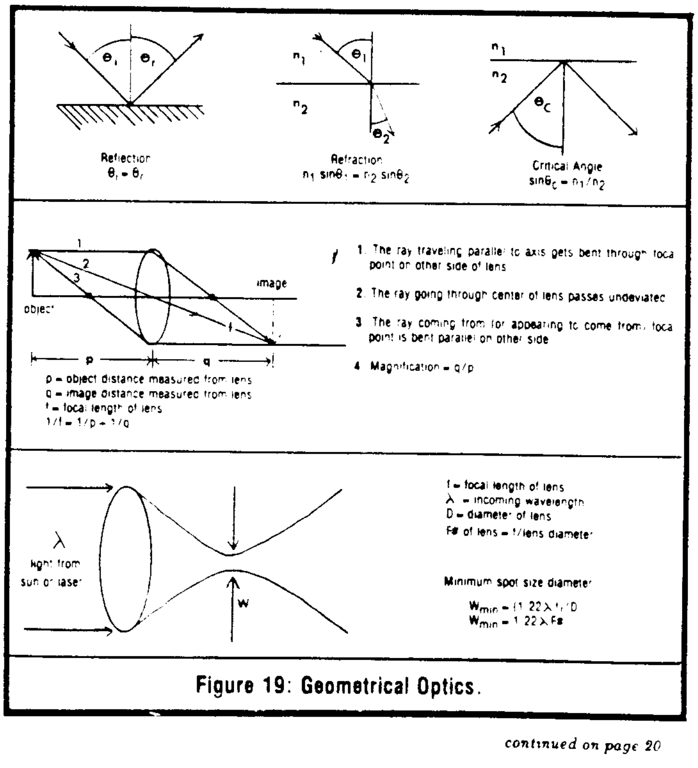


Figure 19: Geometrical Optics.

continued on page 20

was duplicated.

Conclusion

There is a lot to cover in the field of optoelectronics. I've purposely avoided the subject of lasers. As of this writing, lasers are not yet within the price range of the experimenter. Typical low power helium-neon lasers of 1mw output power cost about $600. Because of this, the fields of holography, optical computing, laser lithography, and interferometry have been left out. The price will drop and then articles about these subjects and ways to use the laser will be written. For those who are interested, the following free catalogs are full of designs, theory and applications with regards to lasers, optics and electronics.

Melles-Griot................................lasers, optics
Designers Guide I & II
1770 Kettering St
Irvine, CA 92714
714-556-8200
Hewlett-Packard..............electronics, optoelectronics
Optoelectronics Designer's Catalog
640 Page Mill Road
Palo Alto, CA 94304
213-970-7500
Motorola.................................optoelectronics
Optoelectronics Device Data
Box 20912
Phoenix, AZ 85036 ■

System Integration, continued from page 7

minimum equipment needed, and for more complex interfacing problems a $10,000 digital analyzer may be the only solution. Using other systems to check operation of a card can confirm whether the problem is hardware, software, or interfacing. In fact, bringing up some systems is not possible without having a running system at your disposal.It is important to know your limits in this area, as well as having the test equipment and the skills to use it.

Review

In review, you should remember that most of the problems mentioned in this article will cause you headaches for only a short period of time. Yes, it did take over six months of daily work to get my CCS 2422 to work with an 8080, but that unit is now running faultlessly. Before buying used parts, check out the market fully and be sure you know what you are getting into. At swap meets the same type of boards are usually for sale and may be even cheaper at the next visit. Researching the product with friends, magazines, and other club members may save you from wasting a lot of time. Building systems from non-compatible used equipment is a challenge and a learning experience that can move you from the intermediate to the advanced level of system integrator.

In part 2, expect a more detailed discussion of SD Systems Versa Floppy II/696 and their implementation of CP/M 2.2.■

Build a Graphics Board, continued from page 4

additional half line is scanned before the vertical retrace begins. After vertical retrace, the second field in the frame scans a half-line before beginning its own 262 full lines. The end result is that the lines in the second field are interleaved between the lines of the first field thus doubling the vertical resolution to 480 pixels. However what we have done is to accomplish this at the expense of the refresh rate. Since the dots in the first field have to wait until the second field has been displayed in order to be refreshed, we have cut the effective refresh rate down to 30 Hz. Hence the need for a long-persistence phosphor in the video monitor used.

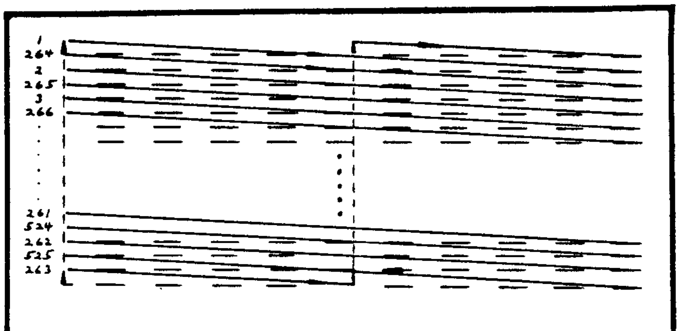


Figure 3: Full-interlace video display

As a concession to those of you who know a lot about TV circuitry let me say that the exact means of accomplishing the vertical retrace is a bit more complicated than I have shown in Figures 1 & 3, however the end result is as pictured. Until I designed and built this graphics board, my own knowledge of TV sweep circuits was just about zilch. For those interested in learning more about raster scan displays, read Chapter 8 in the "TV Typewriter Cookbook"by Don Lancaster (available from *The Computer Journal's* Bookshelf). There are also many other sources of information dealing with conventional television receivers.

Next month, after letting you digest all this about how the video monitor functions, I will describe how to go about implementing the hardware that can send the composite video signal to the monitor and with it the information stored in the 307,200 bits of the video RAM. ■

COMING NEXT MONTH...

- •Heuristic Search in Hi-Q
- •Build a High-Resolution S-100 Graphics Board, Part Two: Theory of Operation
- •Muti-user, Part Four: 3COM's Etherseries
- •System Integration, Part Two
- •A 555 Timer Breadboard Project

CONTROLLING DC MOTORS

by Neil Bungard

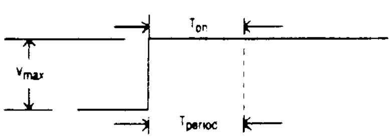
Introduction

There are a number of applications in areas like robotics, astronomy, and solar collection technology where controlling the speed and the direction of an electric motor is desired. Futhermore, microcomputers are playing an increasing role in these control applications. Microcomputer control is becoming popular because much of the design work is eliminated by the use of a personal computer as part of the control circuit. This allows design changes to be made in software without actually modifying any circuits, so that control applications which were difficult in the past have now become relatively simple interfacing tasks.

In this article we will look at a simple method for controlling motor speed and motor direction with a microcomputer. The method described in this article is called Pulse Width Modulation (PWM). PWM gives the designer much more control over the motor than the on/off method, and is easier to implement than DC servo control techniques. Following a description of PWM techniques, a PWM motor control circuit which gives the builder computer control over his motor will be described. Also, interfacing details will be presented so that the motor control circuit can be utilized with a number of different personal computers.

Pulse Width Modulation

Pulse Width Modulation is a technique for applying various DC voltages to a motor for the purpose of controlling the motor speed. With PWM, constant DC voltages are not applied to the motor; instead, the motor's maximum voltage is applied as a succession of pulses. The actual voltage felt by the motor is an average voltage, and is dependent upon the duty cycle of the PWM's waveform. The duty cycle is defined as the ratio of the motor's "on" time (in one pulse period) divided by the time of one pulse period (see Figure 1). The speed and the torque of the motor are dependent upon the average voltage and thus the duty cycle of the waveform from the PWM. If the motor is to be run at full speed, a duty cycle of 100% is required. A duty cycle of 100% looks like:



The average voltage, in this case, is equal to the maximum motor voltage according to the expression:

$$V_{ave} = V_{max} \left(\frac{T_{on}}{T_{period}} \right)$$

If the motor is to be turned off, a 0% duty cycle is employed. In this case the average voltage would, of course, be equal to 0 volts. Any motor speed between fully off and fully on is obtained by producing a duty cycle between 0% and 100%. Figure 2 shows the speed, waveform, and average voltage relationships for three typical motor speed conditions.

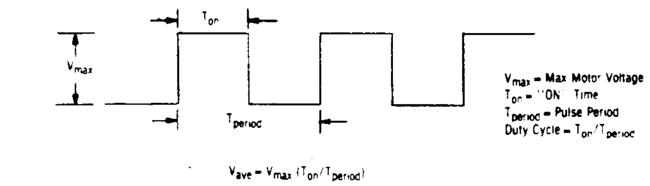


Figure 1: Waveform example.

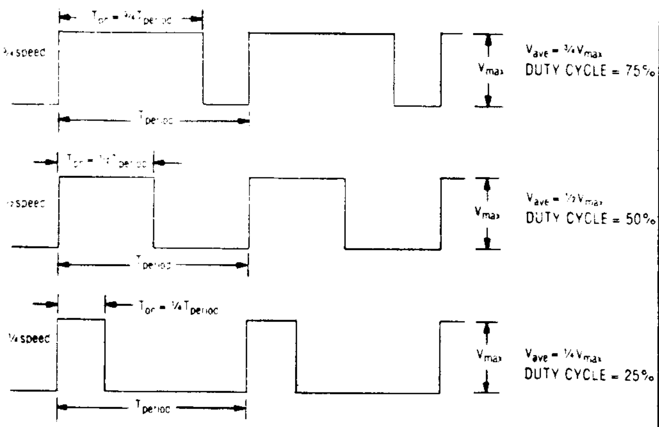


Figure 2: Three PWM Waveforms.

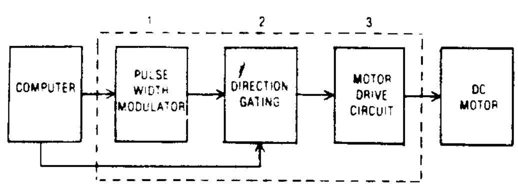


Figure 3: Block Diagram.

Circuit Description

The DC motor controller block diagram, shown in Figure 3, consists of three distinct sections. The first section, the Pulse Width Modulator (PWM), is responsible for varying the speed of the motor. The second section, the direction gating, is responsible for establishing the desired rotational direction. The third section, the motor drive circuit, is actually responsible for converting the TTL level signals,

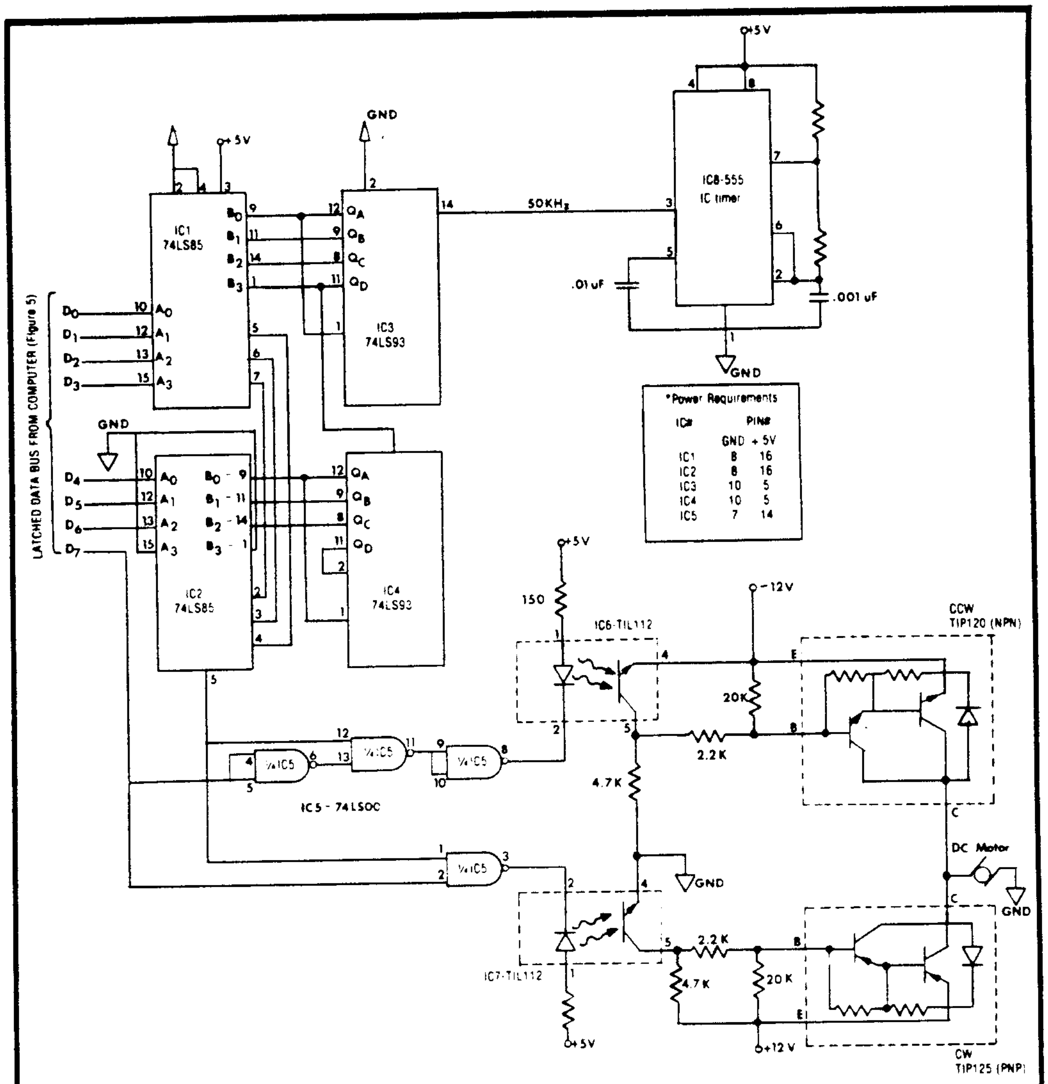


Figure 4: Schematic drawing.

from the PWM, to plus and minus 12 volts signals for driving the motor. In addition to accomplishing a TTL-to-plus and minus 12 volt conversion, the driver circuit utilizes a high current solid state device (a Darlington transistor) to provide the required current to the motor.

The Pulse Width Modulator

Pulse Width Modulation techniques can employ either analog or digital techniques to generate the desired pulse width duty cycles. Since the PWM is to be controlled by a microcomputer, digital PWM techniques were used. In the schematic diagram of the motor control circuit (Figure 4), the PWM section consists of two 74LS85s and two 74LS93s (IC1, IC2, IC3, and IC4). The 74LS85s are four bit magnitude comparators and the 74LS93s are four bit binary counters. Each 74LS85 has two four bit ports (port A and port B). The values of these two ports are tested and, depending upon the port magnitudes, condition flags are set. The condition flags, which can be set by the 74LS85s, are A > B, A < B, and A = B. A similar set of flags are also available on the 74LS85s as condition flag inputs. This allows the comparators to be cascaded so that any number of bits can be compared. In this particular circuit the highest order bits of the cascaded comparator (pins 15 and 1 of IC2) are grounded, configuring the 74LS85's as a seven bit comparator.

The information on port A of the comparator is applied by a microcomputer. Notice in Figure 4 that only seven of the eight data bus bits from the microcomputer are used as comparator inputs. The highest order bit (D7) from the microcomputer is used for controlling the motor's direction and is not used for speed control. Details on exactly how this bit controls the motor's direction will be discussed in the section on direction gating. Once the seven bit word is placed on port A of the 74LS85's, comparisons with port B automatically begin. Port B is connected to the outputs of a set of binary counters which are configured to continuously count between 0 and 127. The duty cycle of the PWM is determined by the value applied to port A of the comparator. Consider the case when a value of 0 (decimal) is output by the microcomputer to port A of the comparator. As the binary counter cycles between 0 and 127 on part B, port A is always less than or equal to port B. The PWM output (A B, pin 5, IC2) is never true (logic 0). The duty cycle is consequently 0%, and the motor is off. When a 127 (decimal) is applied to port A by the microcomputer, the PWM output is always true (logic 1), representing a 100% duty cycle. (Actually 100% minus the time when port A = B. This time is small and is ignored.) With a duty cycle of 100% the motor is always on and is at full speed. With a 0 (decimal) representing a 0% duty cycle and a 127 (decimal) representing a 100% duty cycle, the port A value required for any PWM duty cycle can be calculated by the following expression:

$$(128) \times (\text{duty cycle}) = \text{port A value}$$

The microcomputer used to command the motor control circuit can be anything from a single chip computer, like the Intel 8748, to one of the inexpensive personal computers, like the Sinclair ZX81 or the VIC 20. Interface circuits for several different personal computers are shown in Figure 5. Software to drive the personal computer interfaces is simple; output a byte to the latch on the data bus. The value of the byte output by the computer directly determines the speed and the direction of the motor.

Direction Gating

The direction gating circuit controls the rotational direction of the DC motor. Refering to Figure 4, the direction gating consists of IC5 (a 74LS00). The highest order bit of the data bus from the microcomputer enters the gating circuit on pin 2 of IC5. A logic "0" on pin 2 turns the clockwise (CW) gate off and the counter clockwise (CCW) gate on. With the CCW gate turned on, the signal from the PWM is allowed to pass through the gate to the motor drive circuit. If a logic "1" is applied to pin 2 of IC5, the CCW gate is turned off and the CW gate is activated. The PWM signal will now pass through the CW gate to the drive circuit. The inverter between the CCW gate and the motor drive circuit is required to ensure that the CW and CCW drives circuits respond similarly to the PWM phase. The inverter is necessary because the CW driver is a PNP device which requires a logic "0" to turn on the driver. The CCW driver is a NPN device which requires a logic "1" to activate it.

There are four possible states which can be decoded by the direction gating circuit. They are ON-CW, OFF-CW, ON-CCW, and OFF-CCW. Let's consider these four possiblities and see how each state affects the motor drive circuits.

Motor Drive Circuit

The motor drive circuits amplify the voltages and the currents to drive the DC motor. Plus or minus voltages are applied to the motor to control its direction, according to the state of the direction gating circuit. The first state we will consider is the ON-CW state. In this state the PWM input (pin 1, IC5) and the control input (pin 2, IC5) are at a logic "1". The gating circuit's outputs (pin 3 and pin 8, IC5) will both be at a logic "0". Look at the CCW drive circuit in Figure 4. A logic "0" on pin 2 of the optical isolator (IC6) turns the isolator's transistor on, which applies −12 volts to the base of the TIP120 and turns the TIP120 off. With the TIP120 turned off, the motor will not be driven in the CCW direction. In the CW drive circuit, a logic "0" on pin 2 of IC7 turns the isolater's transistor on and applies a ground to the base of the TIP125, turning the TIP125 on. With the TIP125 turned on, +12 volts is applied to the motor and it will be driven in the CW direction. In the second state (OFF-CW) the PWM input goes to a logic "0" and the control input remains a logic "1". The CCW gate output (pin 8, IC5) is unchanged and the TIP120 remains off. However, pin 3 of IC5 switches to a logic "1" which is applied to pin 2 of IC7. This turns the isolator's transistor off and applies a +12 volt signal to the base of the TIP125, turning the TIP125 off. Now the motor is not being driven by either circuit and it comes to a stop. The two remaining states (ON-CCW, and OFF-CCW) operate in a similar manner to the CW states. In the ON-CCW state, TIP120 is turned on and TIP125 is turned off. This condition drives the motor in the CCW direction by applying a −12 volts to the motor. The OFF-CW state turns both the TIP120 and the TIP125 off and the motor stops. The TIP120 (NPN) and the TIP125 (PNP) are the actual current driving elements in the motor drive circuit. These devices are Darlington transistors, and are capable of delivering more than enough current to drive the 12 volt motors.

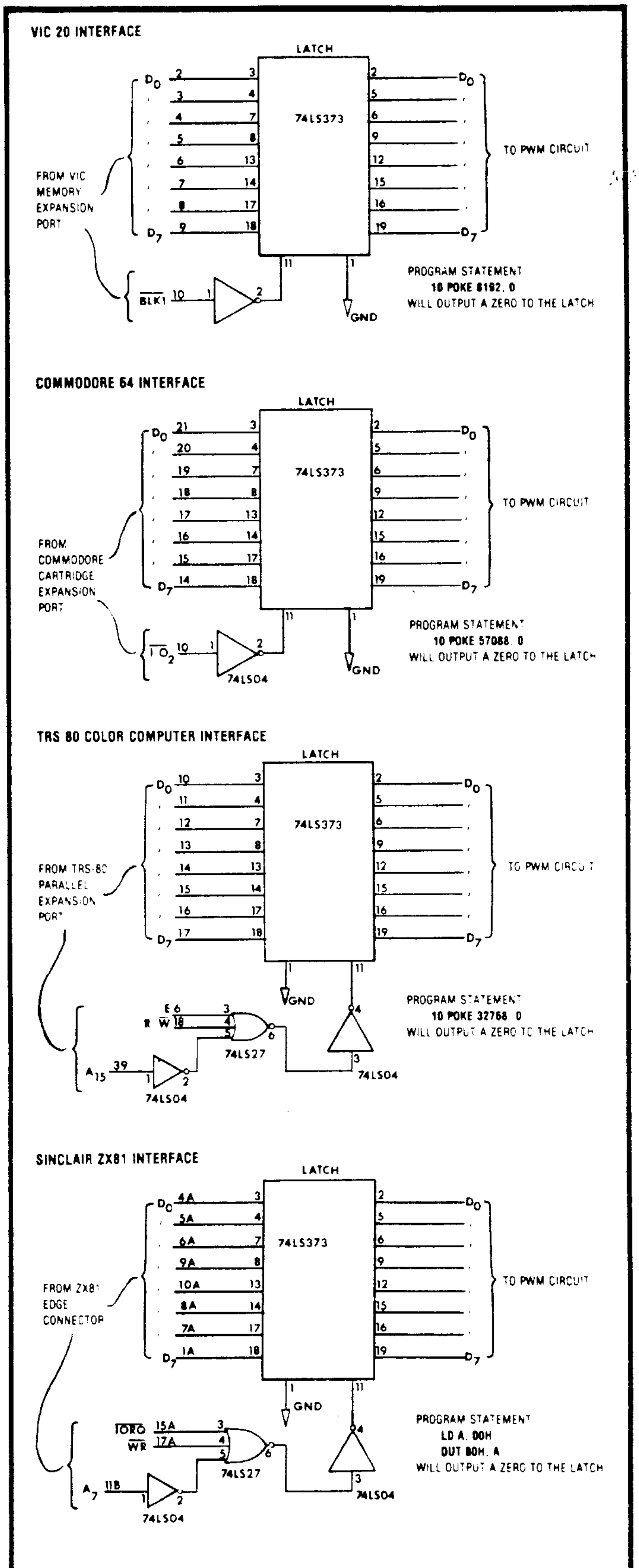


Figure 5: Interface examples.

Multi-user

A Column by E.G. Brooner

In earlier columns we talked about the differences between time-sharing, multi-processing, and networks. We noted that time-sharing computers require all of the users to share not only peripheral equipment but also memory and the CPU itself. Multi-processor, multi-user systems (MP/MU) share only the peripherals; each "user" has unto his or herself a dedicated CPU and memory. They can operate in a completely independent manner except when accessing the disk system or printer. This is a significant improvement, at only a slightly higher cost, but there are also some limitations. In many cases the limitations don't matter.

But sometimes they do matter, and that's where networks come into their own. The distinction between networks and the other multi-user systems are not superficially apparent, but the distinctions that do exist open up all kinds of possibilities for the users.

In the first place, there is really no practical limit on the number of users that can share a network. Networks (depending on the design) can accomodate from 64 users (some of the smaller systems) to several thousand users. There is also no meaningful limit on the quanitiy of printers or the amount of disk storage that can be distributed around the system and made available to all users.

The most severe limit set on networks is the distance over which such a system can be distributed. This is ordinarily on the order of a few thousand yards or a very few miles. For this reason the correct term for such computer systems is "Local Area Networks" (LAN). Individual users could, of course, go outside the network via modems and telephone lines, but in that kind of mode they are not operating as part of the net.

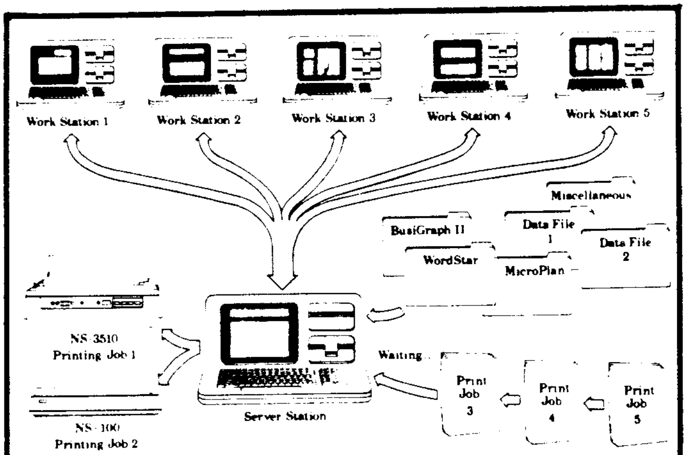
One valuable network feature not available with other multi-user methods is direct communication between the users. This can take the form of the so called "electronic mail" as well as permitting the direct transfer of programs and data files between users.

The key to any Local Area Network is its high-speed communication capability. Time-sharing and multi-processor systems customarily "communicate" at several hundred or a few thousand bits per second. Networks function at between one million and fifty million bits per second. This high speed is what permits so many users to share a single communication link; it is also the reason for the relatively short end-to-end range to which most of them are subject.

The network's special communication systems also account for thier being relatively more expensive than either time-sharing or multi-processor installations. Imagine, if you will, sending data to a printer at fifty million bits per second. That's many times the speed of your microcomputer's own CPU, and hundreds of times faster than anything a normal printer can accept. The advantage is that it ties up the cable for only a few microseconds, thus allowing scores of users to share the same cable. The disadvantage and hence the cost, results from the interface devices that must be added to both the computers and the peripherals. The printer, for example, has to have a special micro system known as a "print server" attached to it. The server is capable of accepting and storing data at very high speed. It then prints it at normal printer speed; meanwhile, you are free to conduct some other activity at your personal work station. The same philosophy applies to the disk systems within the network.

There are a multitude of ways to accomplish this type of communication, hence we find that there are some 50 to 100 different kinds of network. Progress toward standardization is and will continue to be slow. An ETHERNET and an ARCNET, for example, are completely incompatible with one another. We can only hope that as time passes manufacturers will adopt just a few standards that will make things simpler for the users. Right now, though, certain micros can be used with only certain networks, and vice versa.

This network communication involves both software and hardware. As things develop, the hardware is being placed in a few large chips, drastically reducing the cost. Software usually has to be written for each individual kind of computer operating system, and normally comes on a diskette as does any other system software or application program. Many manufacturers have chosen to build thier network operating system around CP/M or MSDOS, which is a start toward standardizing the whole mess. Using one of these standard systems greatly simplifies operation, too. You might have the sole use of two floppy drives in your



Network with a print server
courtesy of North Star Computers, Inc.

own computer, and be able to access a large hard disk located somewhere else in the network. The operating system, then, would let you treat the remote disk as if it were just another drive that is part of your personal installation.

You might wonder why (even given the high transmission rate of network communications) the work stations do not occasionally interfere with one another's efforts.The answer is something called "collision avoidance." There are many ways to prevent stations from interfering with one another's messages; the two major systems are known as Token-passing and CSMAD (Carrier sensing, Multiple access account for a good part of the cost of networking. We'll go into each one in detail in later issues.

ETHERNET is one of the oldest and most widely used networks. It was originally meant for use with minicomputers and the network interfaces were expensive - in the range of several thousand dollars per user work station. It is now available for the IBM PC in a form known as Etherseries. Etherseries (3COM Corporation) consists of a single plug-in board and a single 5 inch floppy, and sells for $950 per station.

There are other systems, less well known (and perhaps a bit less capable) that sell for half that price. The lowest price we have seen is that of Digital Research's CP/NET. It is almost entirely software, is in fact just an extension of CP/M and MP/M, and is quite simple to install and operate. It also lacks some of the finer features normally associated with networks. It sells for $200. Many other networks use CP/M to similar advantage.

In the next multi-user column we'll discuss Etherseries in some detail, and compare it with some of its competitors. ■

FURTHER READING

For more information on networks see:

Standards and Protocols for Communication Networks, (Carnegie Press, about $60)

The Local Network Book, (Howard W. Sams & Co., about $12)

Controlling DC Motors, continued from page 18

Circuit Assembly and Hints

Although circuit assembly presented no problems, it should be noted that the motor will draw significant current when it is initially turned on. It is suggested that separate +5 volt and (+ and −) 12 volt power supplies be used for the circuits supply voltages to eliminate the problems associated with motor turn-on.

Notice, in Figure 4, that IC8 is a 555 IC Timer which has been configured as an oscillator with an operating frequency at 50 KHz. This operating frequency was determined empirically. I attempted to select a PWM output frequency (with a 50% duty cycle) which would give me the maximum torque on the motor shaft. This was done by first connecting the output of a square wave signal generator to the input of the PWM. A value of 64 (decimal) was then applied to port A of the PWM (to create a 50% duty cycle), and the frequency of the signal generator was increased until the maximum torque could be felt on the shaft of the motor. Once the optimum frequency was determined, the signal generator was replaced with a fixed oscillator (IC8). If your motor appears to have poor torque characteristics, you may want to conduct the same test to tune the control circuit to your particular motor. ■

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DC MOTOR APPLICATIONS

by Art Carlson

There are many types of motors available for use in control and robotics applications. In fact there are so many that it is confusing and difficult to decide which type of motor to use for a certain application. Some of the most important considerations for hobbyist and prototype applications are availability, cost, power requirements, and ease of control.

Advantages of DC Motors

The DC motor is very attractive because:

1) It is readily available at low cost. Low power toy motors can be obtained from many sources and medium powered motors can be salvaged from 12 volt automotive heater blower motors.

2) For low and medium power aplications you can usually use motors which operate at 12 volts or less. These low voltages facilitate operation from batteries for mobile applications, and avoid the chance of accidental electrical shock from touching exposed contacts (let's face it, hackers don't build everything to UL standards).

3) It is easy to control the speed and direction of DC motors.

4) Where space and/or weight is important, the DC motor provides the highest power in a given weight or space

Some Disadvantages of DC Motors

It is easy to control the speed of a DC motor by varing the applied voltage, but the speed is also very sensitive to any fluctuations in the load—even the slight changes in friction caused by the bearings warming up while in use will result in changes in the speed.

When controlling a DC motor (see the article by Neil Bungard in this issue) you should understand that the speed/voltage curve is not linear, especially at the lower voltages (see Figure 1). The motor will not start unless the voltage is above the point where it overcomes the motor friction and the starting torque of the load. You can program control voltages in the lower range, but the motor will not rotate if the voltage is below the critical value. If you program a slowly increasing voltage the motor will remain stationary until the starting voltage is reached, then it will jump up to the running speed at that voltage. If you program a slowly decreasing voltage while the motor is running, it will contine to run until the stall voltage is reached, and then it will stop. Speeds below the starting or stall voltage can not be obtained by adjusting the voltage to the motor. The starting and stall voltages will change with temperature and applied load, which makes this is a very unstable operating region.

DC motors use switching contacts on the rotor (called brushes) to change the direction of the rotor magnetic poles by reversing the electrical current. The high frequency arcing can cause radio frequency interference and ignition of flammable vapors. The contacts are also subject to both mechanical wear and erosion from the electrical arcing, which results in limited life.

DC Motor Enhancements

There are methods to design around some the DC motor limitations, but then it is no longer the simple system we started with.

The most common refinement (and this applies to all motors, not just DC motors) is to use some form of gearing in order to obtain speeds below the speed at the starting voltage. The amount of power produced varies with the voltage, so you would want to operate the motor near its rated voltage if you need the rated power. For a fixed speed application you would normally run the motor at rated voltage and then adjust the gearing to obtain the required speed. This procedure would enable you to find the lightest, smallest, and least expensive motor for the job. The use of gearing optimizes the power over a certain speed range, but there is a problem with fixed gearing if you require an extremely wide range of speeds. For example, consider a car with manual transmission. Imagine trying to start in fifth gear—it would be very difficult, especially with a small engine or in mud or snow. On the other hand, consider starting in first gear and then zipping along the freeway at 75 miles an hour still in first gear! Neither of these is practical because the engine is effective only over a restricted range of speeds in each gear ratio.

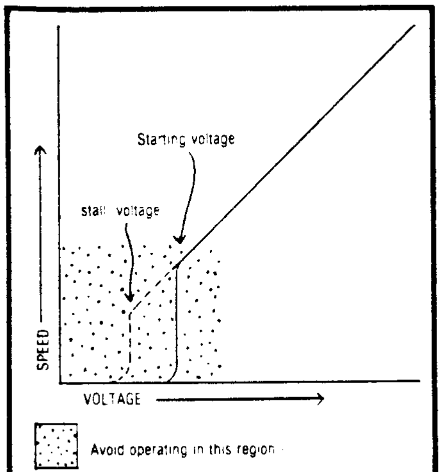


Figure 1: Speed Vs. Voltage. Typical curve showing starting and stall voltages.

The same principle applies to electric motors, and you will have to make trade-offs between motor size and the mechanical complexity of gearing when applying any motor. If the required minimum speed is near the starting voltage of a small motor you can sometimes avoid the use of gearing by using a more powerful motor with low-friction bearings (ball bearings) to reduce starting torque, especially if you add a feedback loop which we'll discuss in the next paragraph. This motor will be larger, heavier, and probably less efficient (requires more electrical power), but may still be a better choice for one of a kind applications. If you absolutely must have precise control over a wide range of speeds, you may have to use a stepper motor.

The problem with controlling the speed of a DC motor by supplying a predetermined voltage for a given speed is that you don't know at what speed the motor is actually turning. This is called "open loop" control because the system controlling the input does not receive any information about what is happening at the output. A great improvement is to measure the output speed and feedback this information to the control system. This is called "closed loop" control, or "servo" control.

The principle of a feedback control device lies in measuring the difference between what is happening and what we want to have happen, and applying corrective action to cause the difference to become zero. The basic idea is simple, but most books on the subject are written on a very high level and use so much heavy math that the average computerist can not get any practical information. There would be a need for this exaustive treatment if you were designing a lunar lander, but it is not necessary for the hacker who wants to learn about simple motor control. Future articles in this series will describe easy breadboard projects to illustrate the fundamentals of motor control. These will be easy to follow, cheap and dirty, "use what you have" projects using empirical methods to learn by doing with a minimum of math or theorical considerations.

The first motor application projects will demonstrate simple methods of measuring the voltage-speed-torque relations of salvaged motors which are available at low or no cost. These bargain motors can be very useful, but specification sheets are usually not available. Another very useful project will be using a calibrated motor to determine the characteristics of a device while operating under load.

There are a lot of confusing terms used when talking about motors, but if you can understand the difference between ROM and RAM you will have no problem understanding motor applications. As with any new subject, the thing to do is to look at one new term at a time and not try to learn everything at once. It is also important to get your hands dirty and to work with the hardware in order to really understand it. ■

THE CONSTRUCTION CORNER

A Source For Odd-ball Parts

Those of us who build microcomputer controlled electro-mechanical devices are always looking for sources of low-cost motors, actuators, gears, racks, and other intriguing gadgets. I collect catalogs of surplus odd-ball parts, because I find that browsing through these catalogs will often give me the inspiration on how to solve a problem.

A very useful catalog is from JERRYCO, 601 Linden Place, Evanston, Illinois 60202, phone 312-475-8440. The current issue runs 48 pages, and contains a wide assortment including:

Variable speed worm drive for $3.25

Solar motor that starts on 0.3 volts for $1.75

Roller chain & sprockets starting at $1.00

Gear driven screw jack for $7.50

A wide assortment of casters and wheels

A full page of fans and blowers

Magnetic clutch for $3.95

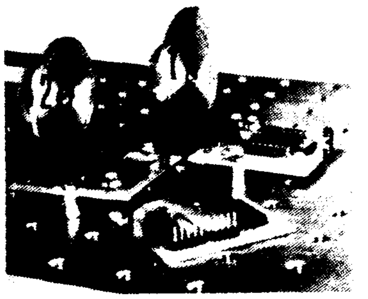
Small stepper and DC pulse motors for $3.75 to $4.50

Ten amp-hr NiCd batteries for $4.50

Piezo disk which converts pressure to voltage and vice versa, 2 for $2.00

Plus a wide assortment of meters, solenoid valves, transformers, motors, gearmotors, and other goodies to numerous to mention.

This catalog is a must if you work with electro-mechanical gadgets, and makes interesting reading for the many other items if you don't. ■



The Computerist's Calendar

April 07C0

SUN	MON	TUES	WED	THURS	FRI	SAT
1	2	3	4	5	6	7
8	9	A	B	C	D	E
F	10	11	12	13	14	15
16	17	18	19	1A	1B	1C
1D	1E					

New Products

Alspa Announces "MC Series" LAN

Four new desktop models of Local Area Network microcomputers, each combining a network master computer, a hard disk drive, and bundled network software, are now available from Alspa Computer, Inc., makers of the Alspa-Net LAN. The new "MC Series," a simplified, all-in-one approach to LAN design, is available with 10, 20, 35, or 50 megabytes of formatted storage.

The bundled software package contians an Alspa-enhanced version of the TurboDOS operating system and the new ConNet-8 electronic mail program. The new line of products is fully compatible with existing Alspa-Net hardware and software and can be interfaced with other brands of computers and terminals as well. Any computer with an RS-232 port can communicate with the network through direct connection or a modem.

Including software, the MC-4010 with a formatted 10MB hard disk costs $4495; the MC-4020 with 20MB hard disk costs $5495; the MC-4035, $6495; and the MC-4050 with a formatted 50MB hard disk, $7495. One master will support up to 255 network nodes, i.e., workstations.

An MC computer uses a Z80A microprocessor operating at four megahertz and offers 64K of internal memory. Every MC model provides these interface connections: two RS-232 serial ports, one Centronics compatible parallel port, one SASI compatible parallel port, and one RS-422 network interface port. The TurboDOS operating system is compatible with CP/M and MP/M applications software without modifications.

For more information, contact Alspa Computer, Inc., 477 Division Street, Campbell, CA 95008. ■

New FORTH Textbook

MicroMotion announces **FORTH Tools**, a new book for the FORTH language. **FORTH Tools** is a comprehensive introduction to the new international FORTH-83 Standard and all its extensions. It gives careful treatment to the CREATE-DOES construct, which is used to extend the language through new classes of intelligent data structures. **FORTH Tools** gives the reader an in-depth view of input and output, from reading the input stream to writing a simple mailing list program. Each topic is presented with practical examples and numerous illustrations. Problems (and solutions) are provided at the end of each chapter. **FORTH Tools** is the required textbook for the UCLA and IC Berkeley extension courses on FORTH.

MicroMotion has been writing FORTH tutorials since 1980, when it published the first textbook for the now outdated FORTH-79 Standard. **FORTH Tools** retails for $20.00 and may be ordered directly from MicroMotion, 12077 Wilshire #506, Los Angeles, CA 90025, (213) 821-4340. ■

Software from BV Engineering

BV Engineering of Riverside California announces the first three programs in their line of engineering software.

PLOTPRO is a scientific graph printing program in Microsoft Basic, which makes graphs on any 80 or 132 column printer. PLOTPRO creates templates of the physical appearance of any graph, and then saves them to the disk files to develop a library of frequently used templates. Data files for PLOTPRO may be generated by any user program in BASIC, FORTRAN, etc., or data may be entered into PLOTPRO manually. Data are transferred to the program in the simple form of (X,Y) pairs in a disk file.

ACNAP is an electronic circuit analysis program which analyzes active and passive circuits with up to 60 components and 21 nodes. ACNAP automatically calculates any circuit's Noise Equivalent Bandwidth, and works with component tolerances to provide Worst Case and Monte-Carlo analysis.

SPP is a signal processing program containing an integrated set of routines which analyze linear and non-linear systems and circuits, and their effects on user specified time domain waveforms. SPP will automatically generate many of the basic time domain signals such as rectangular pulses, sine waves, triangle waves, etc. SPP shares common data files with the ACNAP program and the PLOTPRO program.

SPP is priced at $59.95, and ACNAP and PLOTPRO are priced at $49.95 each. Add $3.00 for shipping and handling. All programs are available for 5.25/8" CP/M, IBM PC, VICTOR 9000, and the TRS-80 models I, III, and IV. ■

Maintenance Guidelines From SAMS

Howard W. Sams & Co., Inc. (Indianapolis), a subsidiary of ITT Corporation, now shows small-computer owners how to dodge the costs and delays of avoidable repair bills in a book that describes simple preventive maintenance techniques as well as do-it-yourself servicing. **How to Maintain and Service Your Small Computer** (ISBN 0-672-22016-4) by John G. Stephanson and Bob Cahill is available for $17.95 (suggested US retail) at participating Sams dealers and bookstores nationwide.

How to Maintain and Service Your Small Computer explains some straightforward maintenance guidelines and procedures that help microcomputer owners prevent service problems from happening. Should repairs and downtime become imminent, easy-to-use flow charts lead users through diagnosis and troubleshooting to isolate the problem area. The entire computer system is covered, including printers, disk drives, and other peripherals.

Some knowledge of electronics, such as how to use a VOM and oscilloscope, is needed for troubleshooting, but no special understanding of digital theory is necessary and no electronics knowledge at all is required to follow the book's preventive maintenance procedures. For more serious problems, there are even guidelines on what to tell service people.

Author John G. Stephenson is a freelance technical writer who has authored a wide range of computer and digital topics. Co-author Bob Cahill is an experienced electronics service technician who is now service manager at a large computer dealership.

For further information, contact Howard W. Sams & Co., Inc., 4300 West 62nd Street, Indianapolis, IN 46268; (317) 298-5400. ■

New Zilog Directory

A new 210-page catalog providing complete information on software offerings for Zilog, Inc., computer systems and microprocessors is now available free from the firm.

The "Winter 1983/84 Software Directory" lists all vendors supplying software products compatible with Zilog's System 8000 family of 16-bit UNIX® -based "supermicros," and with the Z8® , Z80® , and Z8000® microprocessor families.

For the System 8000, the directory lists accounting, financial management systems; vertical applications; development tools; and miscellaneous packages.

For the Z8, Z80, and Z8000 chips, the catalog lists assemblers and cross-assemblers, compilers and cross-compilers, operating systems, real-time kernels, development tools, and miscellaneous packages.

Product data provided includes product description, price, source availability, language in which the software was written, date of first shipment, and number of installations.

The directory lists Zilog's worldwide sales offices and technical centers as well as vendor locations.

The "Winter 1983/84 Software Directory" can be ordered from Technical Publications, Zilog, Inc., 1315 Dell Ave., Campbell, CA 95008, or by calling the Zilog Literature Hotline at (800)272-6560. ■

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Scientific Plotter Enhancements

Interactive Microware has announced enhancements for their Scientific Plotter software, which enables the program to be used with several color plotters, including Hewlett-Packard 7470A, 7475A, or 7220, Houston Instrument DMP series color plotters, Apple color plotters, and Yokogawa color plotters. Another new IMI enhancement uses an Apple][or //e as the host micro to link the Scientific Plotter to the VisiCalc® electronic worksheet and other programs that use DIF file format. Each new Scientific Plotter enhancement may be purchased for $25.

The new Scientific Plotter, Version II is also available for $25. It includes all previous Version I updates, has improved documentation, and uses informative screen prompts which are directly referenced in the manual.

New capabilities include an improved labeling routine for annotating graphs on the Apple's high resolution screen using both upper and lower case characters as well as a host of plotting and mathematical symbols. A new stand-alone utility program is also provided that prints labels on any high-resolution picture; this program is ideal for creating slides and transparencies. Version II is integrated with Smartware's powerful "ADVANCED GRAFPAK" graphics printing utility. Priced at $35, "ADVANCED GRAFPAK" lets one choose among graphic printing modes, including side-by-side and panorama printing of graphic screens. Images may be rotated and printed at any feasible magnification. "ADVANCED GRAFPAK" is exceptionally user friendly and supports virtually every I/O card and printer (both dot matrix and daisy wheel) on the market.

For additional information, write Interactive Microware, Inc., PO Box 139, State College, PA 16804-0139, or call Tim Reddington at (814) 238-8294. ■

Classified

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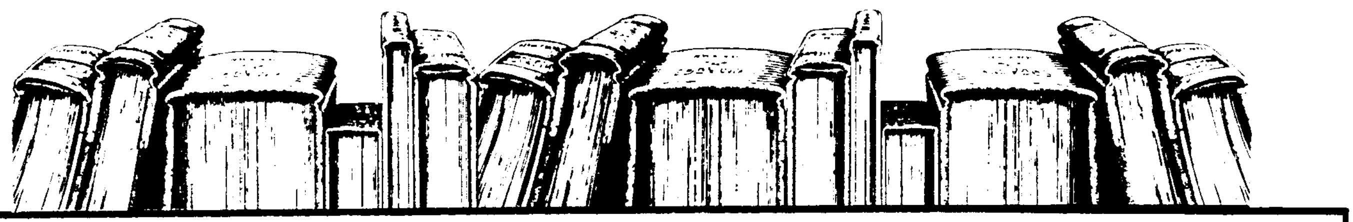

The Bookshelf

TTL Cookbook
Popular Sams author Dan Lancaster gives you a complete look at TTL logic circuits, the most inexpensive, most widely applicable form of electronic logic. In no-nonsense language, he spells out just what TTL is, how it works, and how you can use it. Many practical TTL applications are examined, including digital counters, electronic stopwatches, digital voltmeters, and digital tachometers. By Don Lancaster. 336 pages, 5½x8½, soft. © 1974 .... $11.95

SCRs and Related Thyristor Devices
A comprehensive guidebook to the operational theory and practical applications for silicon controlled rectifiers, triacs, diacs, unijunction transistors, and other members of the thyristor family. Also contains a microprocessor mini-course to help you in inter-facing thyristors with digital control circuits. If you're involved with design, installation, or maintenance of electronic power-control equipment, this is the book for you. By Clay Laster. 136 pages, 8½x11½, soft. © 1981 .... $12.95

Instrumentation: Transducers, Experimentation, and Applications
A laboratory-oriented manual that helps provide you with an in-depth understanding of instrumentation and measurement. By Roger W. Prewitt and Stephen W. Fardo. 224 pages, 8½x11, soft. © 1979 .... $12.95

The Programmer's CP/M Handbook
An exhaustive coverage of CP/M-80®, its internal structure and major components is presented. Written for the programmer, this volume includes subroutine examples for each of the CP/M system calls and information on how to customize CP/M – complete with detailed source codes for all examples. A dozen utility programs are shown with heavily annotated C-language source codes. An invaluable and comprehensive tool for the serious programmer. By Andy Johnson-Laird, 750 pages, 7½x9¼, softbound $21.95

Interfacing to S-100 (IEEE 696) Microcomputers
This book is a must if you want to design a custom interface between an S-100 microcomputer and almost any type of peripheral device. Mechanical and electrical design is covered, along with logical and electrical relationships, bus interconnections and more. By Sol Libes and Mark Garetz, 322 pages, 6½x9¼, softbound $16.95

Microprocessors for Measurement and Control
You'll learn to design mechanical and process equipment using microprocessor-based "real time" computer systems. This book presents plans for prototype systems which allow even those unfamiliar with machine or assembly language to initiate projects. By D.M. Auslander and P. Sagues, 310 pages, 7 3/8x9 1/4, softbound $15.99

Osborne CP/M® User Guide (Second Edition)
A new revised edition which includes expanded sections on CP/M® 86 and CP/M® 80, as well as CP/M®'s relationship to assembly language programming, MP/M® and CP/NET® operating environments. By Thom Hogan, 292 pages, 6½x9¼, softbound $15.95

Discover FORTH
Whether you are a beginner seeking information on this multi-faceted programming language or a serious programmer already using FORTH, this book is a reference that should not be overlooked. Long considered a computer language of building blocks, FORTH has been optimized for speed and requires little computer support. By Thom Hogan, 146 pages, 6¼x9¼, softbound $16.95

68000 Assembly Language Programming
Each of the 68000's instructions is individually presented and fully explained in this assembly language tutorial. For experienced programmers, this book is also a complete reference to the 68000 instruction set and programming techniques. By Lance A Leventhal, 614 pages, 6½x9¼, softbound $18.95

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This book is filled with real-world programming examples, sample problems, and troubleshooting hints that will guide the reader to mastery of this powerful new 16-bit "super chip". The entire Z8000® instruction set is described in detail. By Lance A Leventhal, Adam Osborne, and Chuck Collins. 928 pages, 6½x9¼, softbound $19.99

The 8086 Book
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Microprocessor-Based Robotics
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TV Typewritter Cookbook
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Microcomputer Math
A step-by-step introduction to binary, octal, and hexidecimal numbers, and arithmetic

operations on all types of microcomputers. Excellent for serious BASIC beginners as well as assembly-language programmers. Treats addition and subtraction of binary, multiple-precision and floating-point operations, fractions and scaling, flag bits, and more. Many practical examples and self-tests. By William Barden, 160 pages, 5½x8½, softbound$11.95

Understanding Digital Logic Circuits

A working handbook for service technicians and others who need to know more about digital electronics in radio, television, audio, or related areas of electronic troubleshooting and repair. You're given an overview of the anatomy of digital-logic diagrams and introduced to the many commercial IC packages on the market. By Robert G. Middleton, 392 pages, 5½x8½, softbound.......$18.95.

CMOS Cookbook

One of the best-selling technical books on the market, this cookbook gives you a solid understanding of CMOS technology and its application to real-world circuitry. Explains how CMOS differs from other MOS designs, how it's powered, and what its advantages are over other constructions. The final chapter shows you how to put all preceding information to work constructing several large-scale, working instruments. Includes a mini-catalog of more than 100 devices, with pinouts and application notes. By Don Lancaster, 416 pages, 5½x8½, softbound.......$13.95

SCRs and Related Thyristor Devices

A comprehensive guidebook to the operational theory and practical applications for silicon controlled rectifiers, triacs, diacs, unijunction transistors, and other members of the thyristor family. Also contains a microprocessor mini-course to help you in interfacing thyristors with digital control circuits. If you're involved with design, installation, or maintenance of electronic power-control equipment, this is the book for you. By Clay Laster, 136 pages, 8½x11, softbound.......$12.95

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This book presents an original approach to the terms, skills, and standard hardware devices needed to connect a computer to numerous peripheral devices. It distills technical knowledge used by hobbyists and computer scientists alike to useable, comprehensible methods. It explains such computer and electronics concepts as simple and hierarchical interrupts, ports, PIAs, timers, converters, the sampling theorem, digital filters, closed loop control systems, multiplexing, buses, communication, and distributed computer systems. By Caxton C. Foster, 190 pages, 6¼x9¼, softbound.......$9.95

Interfacing Microcomputers to the Real World

Here is a complete guide for using a microcomputer to computerize the home, office, or laboratory. It shows how to design and build the interfaces necessary to connect a microcomputer to real-world devices. With this book, microcomputers can be programmed to provide fast, accurate monitoring and control of virtually all electronic functions – from controlling houselights, thermostats, sensors, and switches, to operating motors, keyboards, and displays. This book is based on both the hardware and software principles of the Z80 microprocessor (found in several minicomputers, Tandy Corporation's famous TRS-80, and others). By Murray Sargent III and Richard Shoemaker, 288 pages, 6¼x9¼, softbound.......$15.55

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Gives you a look at the hundreds of ways IC timers are used in electronics. Provides a collection of numerous recipes for using the IC timer, including a 555 monostable circuit with auxiliary output, a touch switch, a programmable monostable circuit,and hundreds of others. By Walter G. Jung, 288 pages, 5½x8½, soft. © 1977.......$10.95

CP/M Primer

Helps microcomputer veterans and novices alike find the answers about CP/M in a complete, one-stop sourcebook that's a Sams best-seller! Gives you complete CP/M terminology, hardware and software concepts, startup details, and more for this popular 8080/8085/Z-80 operating system. Helps you begin using and working with CP/M immediately, and includes a list of compatible software, too. By Stephen Murtha and Mitchell Waite. 96 pages, 8½x11, comb. ©1980.......$14.95

Soul of CP/M: Using and Modifying CP/M's Internal Features

Teaches you how to modify BIOS, use CP/M system calls in your own programs, and more! Excellent for those who have read *CP/M Primer* or who otherwise understand CP/M's outer-layer utilities. By Mitchell Waite. Approximately 160pages, 8x9½, comb. ©1983.......$14.95

The S-100 and Other Micro Buses (2nd Edition)

Examines microcomputer bus systems in general and 21 of the most popular systems in particular, including the S-100. Helps you expand your computer system through a better understanding of what each bus includes and how you can interface one bus with another. By Elmer C. Poe and James C. Goodwin, II. 208 pages, 5½x8½, soft. ©1981$9.95

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This book introduces you to the principles involved in transferring data using the asynchronous serial data-transfer technique. It focuses on using the universal asynchronous receiver/transmitter (UART) chip in order to help your understanding of communication chips. Explores operation of teletype-writer interfaces and serial transmission circuits. With experiments and circuit details. By Peter R. Rony. 160 pages, 5½x8½, soft. ©1979.......$7.95

Active-Filter Cookbook

A practical discussion of the many active-filter types and uses, written by one of Sams' most popular authors. Teaches you how to construct filters of all types, including high-pass, low-pass, and bandpass having Bessel, Chebyshev, or Butterworth response. Easy to understand – no advanced math or obscure theory. Can also be used as a reference book for analysis and synthesis techniques for active-filter specialists. By Don Lancaster. 240 pages, 5½x8½, soft. ©1975.......$14.95

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Discusses and explains data conversion fundamentals, hardware, and peripherals. A valuable guide to help you understand and use d/a and a/d converter applications. Includes manufacturers' data sheets. By Walter G. Jung. 576 pages, 5½x8½, soft. ©1978.......$14.95

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Regulated Power Supplies (3rd Edition)

Newest, most comprehensive discussion you'll find of regulated power supplies, including their internal architecture and operation. Thoroughly explains how to use regulation in your designs and projects when the need arises, and discusses practical circuitry and components. A valuable book for any technician or engineer involved in servicing or design. By Irving M. Gottlieb. 424 pages, 5½x8½, soft. ©1981.......$19.95

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Books of Interest

Fiber Optics
Communications, Experiments & Projects
by Waldo T. Boyd
The Blacksburg Continuing Education Series®
Published by Howard W. Sams & Co., Inc.
221 pages, 5 3/8 × 8 1/2 softbound. $15.95.

The combination of Fiber Optics and microcomputers is a very powerful tool with many applications in communications, measurement, and control. We will be using fiber optics frequently for interfacing, sensing, and control, and you will need a good book with practical information to guide you in this rapidly expanding field. See part three of the series on Optoelectroics by Johnson in Volumn 2 Number 1 of *The Computer Journal* for some interesting applications of fiber optics.

Waldo presents the material on a practial level in an easy to read manner with numerous experiments and projects. I feel very strongly that you cannot really understand something like fiber optics without getting your hands dirty and working with the hadrware.
The contents are as follows:

- **Section 1 Fundamentals of Fiber Optics.**
  Introduction To Fiber Optics. Basic Principles Of Fiber Optics. Where It All Started—the development of fiber optics, the usefulness of fiber optics, the nature of fiber optics. The "Nuts and Bolts"—basic light propagation in a glass bar, propagation in a glass rod, and safety precautions. Basic Principles Of Glass Fibers. Simple Systems—basic methods of signaling with light, communication with pulses, mulitplexing, digitizing frequency, simple amplitude modulation, sensing devices, cable TV applications, and booster amplifiers.
- **Section 2 Experiments.**
  Experiment 1—getting acquainted with a "light pipe". Experiment 2—light-beam voice and music modulator. Experiment 3—improved modulator. Experiment 4—LED-driven fiber optic system. Experiment 5—basic digital transmission of data. Experiment 6—multitone modulation of digital transmission. Experiment 7—basic pulse-frequency modulation. Experiment 8—pulse-frequency modulation.
- **Section 3 Projects.**
  Project 1—amplitude-modulation fiber optics receiver. Project 2—amplitude-modulated fiber optics transmitter. Project 3—fiber optics light transmission cable. Project 4—fiber optics light-pen cable. Project 5—single-fiber passive light pen.
- **Section 4 Appendixes.**
  Caution Note. Light. Obtaining Experimental Fiber Optics Supplies. Sources For Fiber Optics Systems, Connectors, and Components—sources, company names and addresses, and sample data. Building Circuits. Terminating and Coupling Optical Fibers—cleaving the fiber, grinding and polishing, and manufactured couplings. Examples of Manufactured Products. Miscellaneous Information—pulses and code tables. Advantages of Fiber Optics—bandwidth, size and weight, signal loss, electromagnetic interference, confinement, safety, and lower cost. Glossary. Bibliography—books, articles in journals and periodicals, reprints, and periodicals.

Many of the experiments use commonly available materials such as water filled plastic tubing so that you can perform the experiments without buying a lot of expensive hard to get material. ■

Erratum

Lee Bradley from Millington, CT, spotted a typo in the article "File Transfer Programs for CP/M" which appeared in Volume I, issue Number 2. We dropped a line during pastse-up in the XMTRC3 routine in listing 1 on page 4, and the correct listing for this routine is as shown below with the added line underlined.

```
XMTRC3: MOV     A,M         ;Get next byte to send
        INX     H           ;Update pointer
        MOV     E,A         ;Save in E
        ADD     D
        MOV     D,A         ;Update checksum
        CALL    XMTBYT      ;Transmit byte
        DCR     B
        JNZ     XMTRC3      ;More in record
        MOV     E,D
        CALL    XMTBYT      ;Send checksum
        PUSH    B
        MVI     C,4
        MVI     E,OOB
```