The Small Computer Magazine

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May 1978 / Issue #17 / $2.00 / DM 7,50 / Sfr 8,10 / Ffr 16,0 / UK £2



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# PET's First Report Card

## *an objective evaluation*

*Photo 1. A family portrait: PET, center, with granddaddy, Jolt, left, and proud father, KIM, right.*

A year and a half ago I wrote an article for *SCCS Interface Magazine* comparing the eight personal computers I had bought, built, designed, redesigned and debugged (or failed to debug). At that time, the PET was only a gleam in its father's (Chuck Pettle) eye. Now I have one.

At the end of October my PET arrived, three and a half months after the usual "$800 cash-up-front" type order that most of the others required. Although two weeks tardy, it had a better record than any of the others, except the Scamp and Tarbell, which arrived on time. I've come to accept late delivery as a way of life for newly announced equipment, but I find that most people entering the exciting and mobile field of personal computing balk at it—especially compared to today, when you can walk into a computer store and get products from maybe a dozen suppliers on an off-the-shelf basis. Furthermore, you pay for them next month on a credit card.

I continually hear the query, "Is it worth it?" It is. The day after I received my PET I took it to a meeting of the Valley Computer Club and was barraged with similar questions from people who already had their own computers. How does it stack up?

This "report card" is an attempt to answer some of these questions on an unbiased basis (I'm not selling anything). I have personally built or bought and modified three 8080-based, five 6800-based, three 6502-based and one SC/MP-based microcomputers, so the PET has a lot to live up to.

### Background

In December 1977, Commodore had never advertised the PET, but the magazine articles, television exposure and convention displays made it a pre-production marketing phenomenon. In fact, I assume the reader has already been exposed to its fundamental specifications. In case you haven't, just pick up nearly any back copy of any computer magazine starting last July (e.g., Sheila Clarke's article in the September 1977 issue of *Kilobaud*).

Right up to the present time the big question has been: Can Commodore produce what they claim for the quoted price and still make enough money to stay in business? To get some official answers from them, I wrote a two-page letter and received a one-sentence reply that contained an honest admission to "crummy documentation." After this article was half written, I had a chance to chat with Chuck Pettle, but the opinions herein expressed are my own, derived primarily from personal PETting and augmented by the published references and conversations with sales representatives.

To start with, I'll dive into the deep end of the pool of controversy and say that, in my opinion, they're *going* to make it—and make it big! Not with the model I received (serial 171), but because of *vertical integration* and forward-thinking management.

### Setting the Stage

Let's review some history to get a perspective of the pros and cons of grading the PET #171. In a sense, this is more of a mid-term interim report card because the PET's true potential has not yet been adequately documented. I've spent most of my time trying to find out (the hard way) just what I bought. There is a gnawing feeling in the pit of my stomach that they are going to follow in Radio Shack's footsteps and *not* tell me much more than I already know.

From my point of view, the PET is really the third product from MOS Technology, preceded by Jolt and KIM (see Photo 1). Although the Jolt is produced by Microcomputer Associates, its debut was a result of their synergistic relationship with the then almost-unheard-of MOS Technology. It was the first microcomputer to really take advantage of read only memory (ROM) to reduce hardware.

Of course, others, such as Dataworks, with its 5K of operating PROM, preceded the Jolt (and Altair) by nearly a year—but the accent was on a firmware operating system, not a hardware trade-off. The 6530 mask-programmed chip, which combined ROM, RAM, COUNTER and I/O, was, in my opinion, almost as big a milestone in large-scale integration (LSI) progress as the microprocessor itself . . . not so much as a technological breakthrough (competing devices had similar technology), but as a practical adaptation of an emerging technology to take a giant step forward on the path of progress.

Instead of needing a single board for a Teletype port (as on my Altair 8800), the whole Jolt took up less than half the real estate. The forever-drifting adjustments of the Altair were replaced by a ROM/I-O, which measured the speed of my TTY and adapted itself! But the real value of the TIM (or Demon) 6530 was the *documentation*. Here were 1000 bytes of I/O and

**"PET gets As in three categories—vertical integration, good engineering and advanced technology."**

operating system available at power-up, and documented in such a way that its subroutines could be (and were) used in every program I wrote. It also served as a workbook for learning practical usage of the 6500 code.

The Jolt had one big disadvantage—for practical purposes: I had to have a $1000 TTY for a $300 microcomputer.

**Enter the KIM**

Vertical integration started with the KIM. KIM used two 6530s to double the firmware and utility. It preserved the TTY I/O of the Jolt but eliminated the total dependence on the TTY. It had its own hexadecimal keyboard, hexadecimal readout and cassette storage to replace punched tape. The single board (plus power supply) KIM outperformed three or four boards in my Altair and Imsai.

It was the end of the octal-binary (switch, LED, front panel) I/O era. Toggling data one bit at a time with lever switches was popular in the late 50s and early 60s. With data in the 3-bit *octal* format, the numerical readouts, keyboards and printers of the late 60s and early 70s became popular. Although my PRO-LOG preceded KIM by a couple of years in adopting hex (hexadecimal), it cost nearly ten times as much and used a 4-bit word.

The obsolete formats aren't dead, yet. Heath took (in my opinion) a step backward with Octal I/O; my new Motorola Educator II uses the single-bit format. All in all, KIM was indeed a big step forward in its time.

At the time KIM was introduced, several other I/O developments were also emerging. The highest impact devices were the full keyboard and TV display. The pioneering laurels for bringing the digital TV display out of the high-priced range (over $1000) and down to where you and I could afford it belong to Don Lancaster, who literally wrote the book on the subject. As the demand for low-cost full alphanumeric keyboards produced larger volumes, the cost came down.

A third development was also underway—BASIC. High-level languages (including BASIC) had been around for a long time, but, without full alphanumeric I/O, the computer hobbyist had to work on the bit, octal or hex level. This meant working *only* in machine language if you had the minimum computer configuration, such as KIM, Scamp, etc. It took only a few hours of "bit-banging" with op-code conversion to realize that there had to be something better—probably BASIC or an alphanumeric assembly language.

Even if you could afford the extras to interface the necessary keyboard and CRT (around $1000 a few years ago), there were other problems. On the hardware side, you needed memory—lots of it. You could use RAM, and wait and wait to load BASIC or an assembler. Or, you could pay and pay ($425 for my ALS-8 assembler on PROM) to get a resident assembler, BASIC or both. An even more expensive memory alternative was, and is, the floppy disk, with magnetic bubble devices warming up in the bull pen.

On the software side, BASIC has been evolving. Spurred by the San Francisco community, in general, and Tom Pittman, in particular, the old original Dartmouth BASIC was first freeze-dried to miniscule proportions and then extended. But what is more important is the cost of good software. In the late 60s, even moderate software sold for thousands of dollars per program, with additional hundreds to adapt it to your system. Contrast this with Tom Pittman's Tiny BASIC at $5, Chuck Crayne's 6800 Assembler or Ed Smith's Trace/Disassembler in the $10-20 bracket, and the stage is set for mass usage of computer power. Mask-programmable ROMs could utilize this software at reasonable prices, but only if high-volume sales could amortize mask costs.

The time has come for an affordable computer that does *not* require the fervent learning and application of hardware and software skills heretofore required of a hobbyist.

**Enter the PET**

The third entry from MOS Technology (a fourth is on the drawing boards) is another significant step forward for its time. At the time I paid my deposit of $800, the closest competition providing similar specs cost more than twice as much. The Radio Shack TRS-80 is squarely in competition with Commodore's PET, and the factor of vertical integration is likely to keep the field small. Only a few companies, such as Texas Instruments (with their wristwatch and calculator mass production-marketing technologies), have the high-priced chips to pay the entry fees into such a marketing race. Let's take a look at what vertical integration has done for the PET.

MOS Technology started as an independently financed splinter group from Motorola's 6800 development program, with associated legal problems (now resolved). The resultant 6502 microprocessor started as a "cheap" 6800. It uses most of the 6800 instruction set, but is (in my opinion) severely hampered by its lack of a double-byte accumulator. This deficiency is somewhat offset by page zero double-byte indexing capability, which I've never really been able to master. Others have, however, and the 6502, which seemed to come out of nowhere, burst onto the scene in the Jolt as a showstopper at the 1975 WESCON show.

I personally feel that the real innovation was the mask programming of the MOS Technology 6530 I/O chip. In any case, MOS Technology was off and running, nipping at the heels of the well-established Intel 8080 and Motorola 6800.

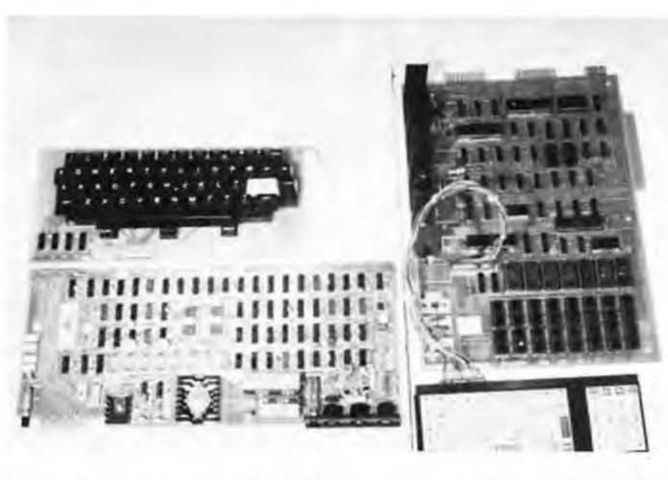

*Photo 2. Front-runners: TRS-80 CPU and keyboard, left. PET's CPU and keyboard, right.*

As the price of 8080s and 6800s fell under $30, the 6502 lost its price advantage, but it was staying ahead in other areas—primarily the KIM. Intel's Intellec and Motorola's Exorcisor development systems ran into thousands of dollars; KIM was less than $300. Although it didn't do nearly as much as the "biggies," KIM, with its superb documentation, was an entry into the world of microprocessors for the smaller electronics manufacturer.

Until very recently, the lack of a good, cheap assembly language and trace has limited my use of the 6502. The availability of Chuck Crayne's assembler for use on the Sphere 6800 and Processor Tech's ALS-8 for the 8080 has diverted my attention from the 6502. My biggest disappointment with my PET is the virtual nonexistence of the advertised "system monitor." It might have filled this 6502 assembler void.

Initial forays into a new field, such as microprocessing, are usually on a small scale, so the KIM filled the bill admirably (and still does). 6502s were designed into new products, and MOS Technology grew. It added memory chips to its line, which included character generators as well as the 6502 family.

The Jolt and KIM were both blockbusters when they were announced . . . but what do you do for an encore? The Apple-II and Ohio Scientific Machines had pushed the use of ROM operating systems and hardware/firmware trade-offs right up to the state of the art for 6502. Something radically different was needed.

**Enter Commodore**

As an early front-runner in the pocket calculator revolution, Commodore faced the same overproduction, price cutting and market-saturation problems that had left a worldwide trail of corporate corpses. Mits was almost one of these, and we all know what saved them from disaster.

The microprocessor originally evolved from calculator technology—the field in which MOS Technology also started. Today, the calculator field is headed in two directions: the $5 cheapy and the $600 wristwatch-calculator and/or the sophisticated programmable printing calculator with long-term memory. How could Commodore compete with TI and others who had vertically integrated to produce everything "in-house," from LEDs and keyboards to LSI chips? You guessed it—they bought MOS Technology. Commodore is still in the calculator business, but you have only to look at their stock-market history during the last year to see where the action is, or isn't.

When Commodore acquired MOS Technology (and Chuck Pettle), the PET was inevitable. The pieces fell into place. The major expense items for an inexpensive computer were no longer the microprocessor chips (less than $10 in quantity) nor the I/O chips, but rather the I/O devices. The TV headed the list, followed closely by the keyboard and cassette recorder. The next generation of microcomputers would require all of these . . . but was it practical?

There was the spectre of Sphere. Note the marked resemblance between the brand new PET and my two-year-old Sphere in Photo 3. The resemblance is more than skin deep. The built-in TVs and dual keyboards are obvious; not so apparent are the following: a 10K ROM operating system in the Sphere (14K for the PET); 36K RAM for Sphere (8K for PET); PIA, dual cassette, TTY and modem for Sphere (dual cassette, IEEE, PIA and TV for PET). Making allowances for cost of RAM, PROM, etc., a Sphere that was roughly equivalent to my PET would have cost about three times as much. The problem lies in the fact that Sphere Corp. *went broke* about the same time the PET was being announced.

The 4K PET was originally priced at $500, which promptly rose to $600, then to $800 for 8K (the only model delivered, so far). Even at $800, the question in my mind (particularly after shelling out the money) was, "Can Commodore really do it?" Judging from the reaction of people I spoke to and the articles I read, the consensus of opinion was that they *couldn't.*

When the promised delivery date came and went (with the same lame excuses I've heard time and again, starting with my first Altair) I, too, began to wonder. As of December 1977, Commodore was slipping even further behind in deliveries. Does this mean that they're following in Sphere's shadow? Will my PET become another Sphere-like orphan—the Edsel of personal computers? I think not, and here's why: PET gets As in three categories—vertical integration, good engineering and advanced technology. Let's see how PET measures up to competition.

*Vertical integration* is, perhaps, the greatest asset. The PET combines the past experience of product development (Jolt and KIM) with the LSI semiconductor design and production expertise of MOS Technology and the "offshore" subassembly production and aggressive marketing methods Commodore developed for its calculator line.

PET's competitors have equal or greater assets in one or more of these three categories, but none can match the vertical integration of Commodore-MOS Technology. Radio Shack's TRS-80 comes closest. They have the best mass sales setup in the world. They also have the only foreign supply expertise that can rival Commodore's. This is perhaps the most important prerequisite for a cost-effective end product.

The highly priced components of a computer *system* are: TV monitor, memory, CPU (central processing unit), keyboard and cassette recorder. Competition and mass production have forced the costs of CPU production down to a point where, even if you're making your own microprocessor (MOS Technology's PET, Motorola's Educator II, etc.), only small reductions in end-product pricing can be realized.


*Photo 3. Now-defunct Sphere, right, is very similar to PET, left. Note the combined keyboard, TV, CPU, integral dual cassette controls and number pad. PET's cassette is built in.*


*Photo 4. PET's controversial "calculator" keyboard, with quasi-standard key placement and conventional calculator number pad. Note variety of graphic symbols available with shift. Lowercase is also implemented (see text).*

All the other items involve the purchase of devices and/or sub-assemblies made abroad.

The biggest item is the TV monitor. Most hobbyist computer manufacturers gloss over this item with phrases like, "Use your own television set with adapter (not supplied)." A reasonable frequency for your TV set mathematically limits the readability of characters to 16 lines, 32 characters per line, caps only.

Most hobbyists soon find that this limitation, plus competition for time on the family TV, leaves little choice but to purchase a monitor. A commercial TV monitor with adequate bandwidth for lowercase, long-line displays can cost almost as much as the computer (before it "grew"). In fact, I'm using monitors that cost as much as my PET. Inexpensive but adequate TV electronics come from Japan, Korea, etc. So does another major accessory—the cassette recorder.

The competition now takes on an international flavor, and International is Commodore's middle name. Most of Radio Shack's line of Realistic products are also imported, including the TV monitor and cassette recorder, which account for *one-third* of the cost of the TRS-80 system. PET's keyboard is also imported (more on that later).

Speaking from personal experience, I can say the business of getting production quantities of proprietary-designed high-technology hardware from overseas is a major accomplishment. Delivery and quality control require on-site monitoring, which necessitates a truly *international* organization with established operations in the Orient.

Both Commodore and Radio Shack can do this . . . but, can anyone else? This is probably the most important factor in vertical integration—it separates the men from the boys in low-cost, high-volume production. It's possible that these two leaders could produce more cheap personal computers in 1978 than all their competitors combined—and make money at it. Even with years of calculator experience, however, Commodore is having overseas production delivery problems (as of December). On the other hand, the TRS-80 is having problems getting its full BASIC underway.

PET's vertical integration includes LSI production by MOS Technology, and when the dust settles down, this may well be the deciding factor. Initially, the TRS-80 had an edge because it was designed with LSI already in high production from second-sourced suppliers. MOS Technology has had to cope with the learning-curve problems of getting their new LSI RAM and ROM chips into overseas production. These two items account for most of the costs of the respective CPU boards (see Photo 2).

As the learning curve progresses, the tables should turn and give the PET a clear-cut advantage over all comers. PET's in-house volume base for the 6550 (4K, 5 V, static RAM) could even make this chip a dark-horse contender in the 4K memory field. In fact, I'm so impressed with its performance (despite four defective chips) that I'm designing it into a 6800-based controller system.

The third factor in vertical integration is marketing. In this area, the small (often garage-type) computer company is going to have a very, very rough time in the next year or two. Radio Shack, with its massive string of franchised outlets, has a clear-cut advantage, and its parent company (Tandy) is opening a string of computer stores.

In marketing, the PET is a phenomenon, so far. The Commodore calculators survived in a cutthroat marketplace; so this, along with KIM, gives the PET a solid foundation. It's been further augmented by bringing in experienced personnel from competitors in the field. Any newcomer will think twice before going up against this kind of marketing competition—the blue chips in this game are expensive.

Another factor—the concept of utility—sets these contenders apart from their predecessors. They are not aimed at the hobbyist computer-addict market (although the impact will probably hit 7 on the Richter Scale).

### The Keyboard, Graphics and "Extras"

Both the PET and TRS-80 have recognized that the family appeal requires electronic game appeal. This makes a TV and keyboard graphics mandatory and brings up the problem of keyboard and/or joystick input. Although both have graphics capability, neither has a joystick (as does the Dazzler or Apple-II). I'm sure that this will become available in the future since both have expansion capabilities to support a joystick.

There is a basic difference in the use of graphics in the PET and TRS-80. The TRS-80 splits each character block into a decoded matrix like the Cromemco Dazzler, Apple, etc. The PET goes a different route; it gives a unique graphics symbol to virtually every key on both keyboards. This provides a very large selection of fine-line picture elements not achieved through the older techniques. It also provides unique game-playing symbols, such as the card characters of hearts, clubs, spades and diamonds. Descending lowercase characters (with shift) for all alpha characters and reversing white-on-black to black-on-white are also provided.

All this flexibility poses several keyboard concept and design problems, since each letter key must display six different characters. How can it


*Photo 5. My Sphere's original alpha keyboard was replaced as shown. Note pasted editing and control labels on fronts of keys. Specialized timing controls at far left are not standard.*

be done economically? PET's solution was, of necessity, a compromise. By using two calculator-type keyboards (for which Commodore tooling was probably available) and changing the artwork on the anodized caps, they got an inexpensive (probably the cheapest in the world) alphanumeric keyboard. The alpha key arrangement is only quasi-standard, but the separate calculator numeric keypad is standard. It is also small enough for the cassette mechanism to be mounted alongside it and still fit a minimum-size case.

Both keysets are mounted on the same cost-effectively designed passive motherboard. Since the keyboard matrix plugs into the CPU with a single cable (see Photo 2), it would be possible to use a standard-spaced keyboard in parallel with, or instead of, the calculator board.

The most commonly criticized feature of the PET is the key placement of the keyboard. Keys are more closely spaced than normal, the middle row isn't staggered, and the feel of a calculator key isn't the same as that of a typewriter (it's more like a Teletype). I was told (by a TRS-80 booster) that it is impossible to touch-type on the PET. He was wrong; however, it does take a relearning period, much like going back to a stick shift after driving an automatic for years.

When I returned to my full keyboards on the Sphere and Imsai, I realized that I've always used the hunt-and-peck method for number pad entry, multiple key-control character and special character entry. Unlike touch-typing, most of my programming is really hunt and peck, and the PET is just about (but not quite) as easy to use as the Sphere (see Photo 5). A programmer friend and one of our keypunchers both claim that PET's keyboard drives them up a wall. But then, how many PET customers are professional data processsors?

I understand that the next model PET will have a full keyboard, but will cost a lot more. I could easily wire a $40 keyboard to replace the original —in fact, the original lousy alpha keys on the Sphere shown in Photo 5 have been replaced, just that way. Then what would I do about the 70 graphics and special characters that aren't available as standard key tops? In short, PET's keyboard isn't great, but neither are the practical alternatives.

Another quirk of the PET is that its graphics and lowercase display modes are mutually exclusive. It initializes to the graphics mode, and requires a POKE 59468,14 to convert the display to lowercase. A POKE 59468,12 returns to graphics. This is accomplished by some mysterious hardware/software manipulations involving a PIA and ROM that I haven't deciphered, yet. You can't mix lowercase and graphics. Changing modes changes *every* shifted character on the screen, but not in memory. It can create some weird effects that I used to change graphics each second in an experimental STOPWATCH program. PET didn't list its lowercase capability in specifications at the time I bought it, so it came as a pleasant surprise—one of several "extras."

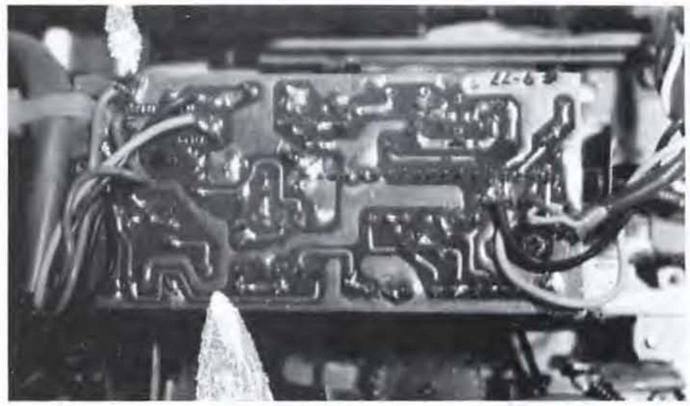

*Photo 7. All of the cassette record, playback and erase electronics are on this single small PC card.*

**"Except for the TRS-80 and PET, cassette recorders are a hidden extra expense of personal computing."**

A real-time clock is another of these extras. It doesn't do as much as an S-100 real-time card, but it doesn't cost an extra $130, either. It outputs a six-digit, 24-hour clock word, e.g., TI$ = 235959 = 23 hours, 59 minutes and 59 seconds. At 240000 it resets to 000000 and is software presettable. It also outputs JIFFIES, which are 1/60 second counts accumulated from 000000. JIFFIES are about as fast as anything you could use with any program written in BASIC. The clock runs off of the 8 MHz crystal.

Although it isn't immediately evident, the real-clock function is an excellent example of the aggressive design policy that makes the PET a technical step forward, regardless of price. I haven't figured out exactly how they did it . . . but what I've deciphered so far indicates an impressive utilization of the latest LSI capabilities from MOS Technology (more vertical integration here, and a valuable feature not available from their competitors). Among other things, the TI (time) function is a fundamental building block in automated home programming. Since it runs on interrupts, it will keep the time of day as long as power is left on. But, unless you trim the oscillator, you'll have to keep readjusting the readout.

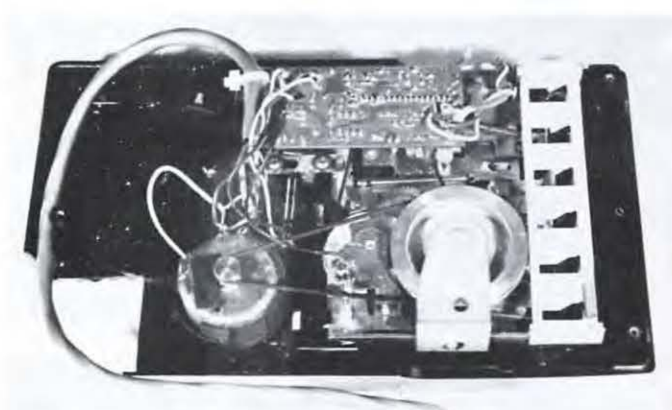

*Photo 6. Gutted cassette is probably a stopgap measure. Note absence of usual electronics, speaker, jacks, etc.*

#### The Recorder System

By now it should be evident that the PET's low price was not achieved by making a cut-down, stripped version of older technologies. Take the built-in cassette recorder, for instance (Photo 6). In all my other systems, built-in recorders are not provided. Except for the TRS-80 and PET, cassette recorders are a "hidden" extra expense of personal computing. The garden-variety cassette recorder isn't optimized for digital recording. It sacrifices signal-to-noise for low harmonic distortion and ignores phase distortion. Its electronics are an overkill, including automatic gain control which prevents full-level recording.

PET's cassette takes a radical departure. All the erase-record-play electronics are on the single card shown in Photos 6 and 7. Obviously, the gutted mechanism in the current models is a stopgap solution to overseas delivery problems, and the eventual recorder should be produced at a significant savings over competing systems.

The recording method is a compromise between dc saturation digital recording and the frequency-shift-audio techniques currently in vogue. Dc erase is used, and square waves are fed directly to the record head. The record current is limited to prevent complete saturation and biased for centering. On my unit this results in about 8 db better signal output on playback with improved phase distortion characteristics. My unit also had two dry-joint solder intermittents.

To find these, I had to create a schematic. I also needed the information to find out why my PET played back its own tapes flawlessly, but couldn't copy from one cassette to another as I've been doing with my Sphere, etc. The problem was in the reduced record level and phase distortion. It worked most of the time, and might even be practical for short programs, but it certainly isn't good enough for longer ones or file storage. PET got some demerits when I found that several playback errors were *not* caught by the double-recording check. I'm sure that a mass cassette duplicating operation will eventually duplicate digital tapes in this format, but my copy of the first one on the market (*not* Commodore) was a disaster.

I asked Chuck Pettle if PET was designed that way on purpose to give Commodore an edge in the prepackaged software field. He was surprised at my difficulties, and assured me that the intention was to provide a truly interchangeable format for all PET users. There is no problem in interchange of original recordings, only duplicated copies.

I really notice the absence of a counter on the cassette recorder. Unless you restrict your tapes to two or three per side, you wait forever for the playback to find the right program. In desperation, I use a separate recorder to find the approximate start position with a counter and then transfer it to the PET—a real pain. Although the baud rate is high (1100 baud), a long preamble, double-buffered recording scheme and a motor stop between files slow down the file handling to a snail's pace, compared to a Tarbell. The second cassette port is fully implemented on the CPU but, as yet, no recorder is available to make use of it. I hope it will have a counter.

Another nice added "extra" is the *verify* mode. After recording, you can rewind and verify the tape playback against memory. Since I've eliminated the intermittents in the recorder, it's a bit redundant because there has *never* been a playback error.

Another extra is the unrivaled simplicity of loading a program—turn on power, insert a cassette and press RUN. It tells you to play the recorder, displays the label of the first thing it finds, tells you it's loading and if it loaded OK and runs the program. Even a very small child can do it. An A rating. If children are to realize the maximum educational potential of personal computing, this approach will be very helpful. If you specify a label, it will display each label it finds until it gets the right one—then loads it.

The PET's recording format is unique, like those of most of the new computers . . . it looks as though the Kansas City standard will bite the dust. The PET maximizes the hardware/software trade-off. It uses almost a bare minimum of analog devices (room for design improvement here), a couple of PIA ports and no UARTs or other serial I/Os. It's the most cost-effective digital recording system I've analyzed, although the Educator II is a close second. It's an A+ example of saving money with design ingenuity.

### The TV Board

All of the other competing computers with CRTs use off-the-shelf monitors or TV modifications. In this instance, as with the recorder, PET breaks with tradition, gaining improved cost/performance by replacing hardware with firmware. The complex sync signals, which use up hardware in both the traditional character generators and monitor, are generated by firmware and the very powerful 6522 I/O chip. The video, horizontal and vertical drives are also available on the rear user terminal. Because the video board doesn't need to decode sync or amplify video, it's simpler (and cheaper) than competing models. Since the screen is built in close to the operator's eyes, it can be smaller than a separate monitor (such as the TRS-80) and still provide the same legibility—another saving.

There is only one external adjustment: contrast. My PET needed vertical centering. It was done with the black tabs on the neck of the CRT. A small pot at the rear adjusts the height. So far it has been very stable and provides a steady picture with a superior bandwidth, another A-rated example of cutting costs with creative system design.

### The CPU Board

Photo 8 shows the CPU board—PET's brain. It takes less than two minutes to remove it. Wiring harnesses cost n ney. Both the PET and t e Ti.S-80 keep them to a minimum. The board plug-connects to the power supply, keyboard, video and recorder. Incidentally, be careful with the keyboard plug. Mine became intermittent after its first replacement. The leaf spring contacts in the female cord connector are easily overstressed and

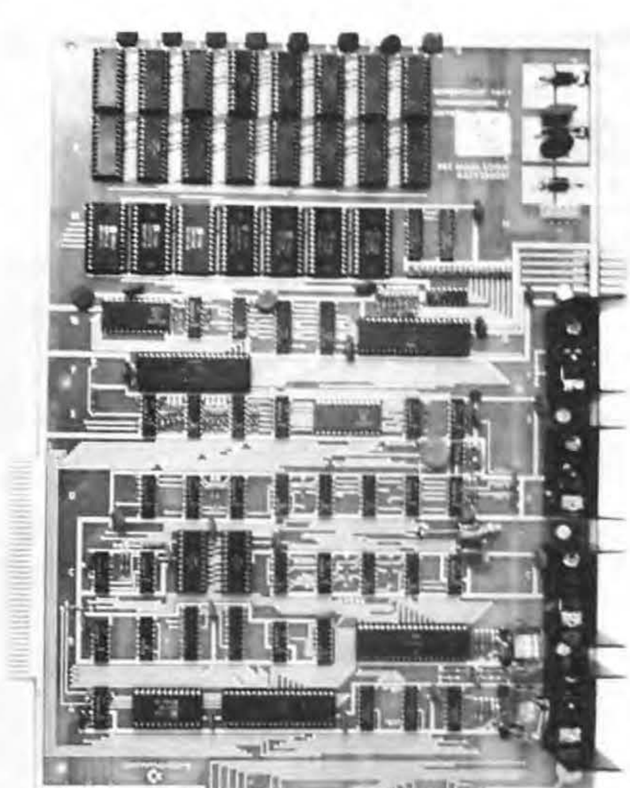

*Photo 8. PET's brain: Top 16 chips are RAM. Seven ROM chips below contain operating firmware. Power supply and cassette #1 are along right side. Output ports are along bottom (rear). BUS and memory expansion are at left.*

may have to be re-formed with a probe.

Note how the four expansion connectors are made directly to the board through slots in the side and rear of the case—a far more efficient arrangement than that of any of my other systems. At this time there is nothing available to connect to them, but when there is, the difference between the utility of the PET and the TRS-80 is likely to give the PET a big competitive edge (see Photo 2).

The long connector on the left-hand side has what the TRS-80 has on its single expansion port. In addition, the addressing is available decoded into 4K blocks. Current plans call for its use in RAM, ROM and PROM (2716) expansion. The monitor and assembly language will probably go into ROM.

The current price of $200 for 4K of RAM makes PET about the highest-priced RAM on the market. When the 6550 moves out on its learning curve, PET should be in a position to provide the cheapest memory around.

The small connector pad in the lower left corner is for cassette #2. You can play the recorder into it. It works, but, as yet, there isn't any recorder available to use with it. If PET doesn't make one available soon, I'm sure someone else will, and I hope they provide a counter. The center connector brings out the aforementioned video feeds and half of the powerful 6522 PIA programmable I/O. It's called a User port and, if documented adequately, could become PET's most valuable asset.

The lower right connector is the IEEE-488 bus. If and/or when the S-100 bus system yields to another format, it's likely to be the 488. This system is supposed to allow your PET to talk with up to 18 peripherals through a high-speed, 8-bit parallel bus. Properly implemented, it can be almost as fast as a motherboard or backplane.

There are more than 200 devices (a lot from Hewlett-Packard) available for use with the 488. However, most of them cost more than the PET and are special-purpose test instruments, not really suited to personal computing. Motorola and others are coming out with LSI chips that should make the 488 system cost competitive with the S-100. This won't happen immediately, but when it does, PET will have a well-established lead over the rest of the pack, particularly in software. PET gets an A here because Commodore's vertical integration should allow them to make inexpensive peripherals that could be used with competitors' microcomputers, as well as with the PET. The TRS-80 (see Photo 2) with its single, unique 40-pin port only rates a D when it comes to this kind of expansion.

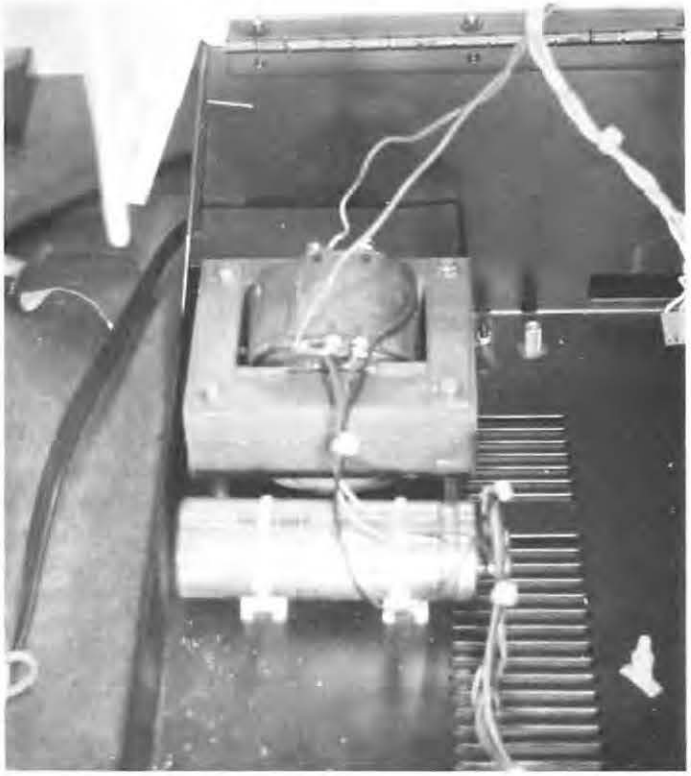

*Photo 9. The power transformer, filter capacitor and 110 ac control are the only electrical devices directly wired to the chassis.*

PET's power supply, see Photo 9, is 5 volts *only* (Sphere uses five different voltages) for the digital equipment. The TV board has its own rectifier-regulators. The CPU board splits the load into three sections with the three 5-volt regulators along the left-hand side. The two power transistors with heat sinks are the motor controllers for the cassette recorders. The regulators are running hot now, so additional loads should be limited.

The 8 MHz crystal clock drives the 6502 microprocessor at 1 MHz. It also provides the TV timing and 60 Hz JIFFIES. The crystal is stable, but the factory feels that plus or minus 1½ minute per day is adequate. If you want greater accuracy, you'll have to trim the driving capacitors next to the crystal. A 6-30 pf variable in parallel with 22 pf did the job for me (see Photo 10). Now I can trim it like my digital wristwatch. The 24-hour clock is counted with interrupts and should be software independent. I've encountered unresolved problems with a program that continuously reads TI$—it speeds up the displayed time.

The 6550 RAMs are 4K, high speed, low power, static, and require only 5 volts. They are pinned as 1K by 4 bits, so they are socket-mounted in pairs along the front of the board. Page 0 is at the left and the high nibble is toward the front. If memory problems occur (I've had four failures), you'll need to play musical chairs, since it's impractical to apply a memory test to the low 1K where BASIC operates its scratchpad. This device gets an A for design and a D for deportment.

The ROMs in the first units (mine included) were not the MOS Technology devices currently being shipped. They are 2K devices and are now being soldered in. Although PET is officially specified for 14K of ROM, 2K of the same ROM is used as a character generator. The PET is currently oriented toward the personal-computer mass market; changing *only* the ROMs and keyboard caps could make it a super development system, smart terminal, dedicated controller, word processor, typesetter or just about anything micros are, or will be, used for. It could happen virtually overnight, and, with the inherent mass-production economics, it would be a price-cutter in any market. (That's awesome when you think about it, since MOS Technology could supply inexpensive masked ROM for any application.)

**Mechanical Engineering**

PET gets a B+ for its metal case. It will probably be replaced by a more durable plastic case, but dies for this size molding are a long time coming. In either case, the PET is utilitarian and its exterior appearance can only be compared to units costing several times more. It even has a prop to hold up the hinged top for servicing. The tooling is a little sloppy and some of the holes are mismatched. My degree was in mechanical engineering (a long time ago), and I appreciate good mechanical design. PET has it. Not only is the case impressive, but so are the circuit-board layout and the overall cost-effective design decisions. Three of the four circuit boards are inexpensive "single sided."

The case of the TRS-80 is a good design job also, but the overall effect looks like a keyboard with dangling wires to a dominating TV, with a cassette and power supply strung around it. The TRS-80 is more attractive than the uncased Jolt or KIM, but, to the average neophyte, it may not *look* like a computer when compared to a PET or Sphere.

**And Now . . .**
**The Bad News**

PET gets low marks in two areas: reliability and service maintenance. I give it a D. At the same time, there is enough room for improvement so that it could go to the head of the class. It worked when I received it. Since then, I've had four intermittents; three were bad solder joints and the fourth was a defective connector. I have also had four memory failures, a glitch in my TV horizontal sweep, drifting vertical centering, undetected read errors, off-frequency crystal calibration and a couple of other weird goings-on that remain unidentified. To put things into perspective, I should add that this behavior is *better* than that of my Mits 8800, Mits 680, Imsai, Sphere, Jolt or SWTP.

Bugs are a way of life when you get the first units off a production line; I expect them. Mits had trouble with bad memory chips on the first 8800 boards . . . worse than my PET's. They wouldn't send replacement ICs so I reluctantly sent the useless boards back. It was four months and $40 extra before I got working memories from them.

The big hang-up with bugs in my PET is that there is no service information provided; furthermore, it's unlikely that I'll see a schematic for a long, long time, if ever. The local distributor doesn't have any more information or spare parts than I do. The 6550s aren't on the market and there are no complete spec sheets available for them. A magazine article had estimated that factory service would require two months, including shipping. If you detect a note of frustration, you're right! It's even worse when you see a little LED on the board and know that it's a part of a built-in diagnostic system that's using up some of the ROM you bought. Neither you nor your local dealer can use it; it's a factory secret. Now what do you do?

First, call the factory. When I called, the girl who answered didn't know what I was talking about, and the fellow who might have known was unavailable. People who went through this with Mits and SWTP in the "old" days (it's changed now) know the script.

After a period of fuming and fretting, punctuated with expletives, I decided that $10,000 worth of test equipment and four years' worth of experience with microprocessors ought to be able to solve the problem without schematics. It did—partially.

I had to write my own memory test program and use a multitrace storage scope to eventually find the intermittents and some of the bad memory chips (also intermittent). Then, another call to the factory. This time I was put through to the right man with the right attitude and right answers—a real gem. Three days later I had replacements and spares, no extra charges, no insistence that I relinquish my cherished PET for an indefinite stay and a lot of good solid advice on how to tackle the remaining problems. He also assured me, as did Chuck Pettle, that most warranty repairs took less than a week, if worse came to worse.

OK, so my PET is running pretty well, but what about the housewife in some boondocks town without a well-equipped laboratory, years of experience or a WATS line? What if she got my #171? Well, as of December, her only recourse would have been to return it to California or Pennsylvania and hope that Murphy's Law, as applied to intermittents, wouldn't require too many return trips. However, by the time you read this, PET could be in the best service position any personal computer manufacturer has ever been in.

The information and special wiring harness should be released so that the built-in diagnostics can be utilized by relatively inexperienced people. Faults could be fixed by identifying and exchanging the offending circuit. Since there are only four circuit boards and a rudimentary power supply, the built-in diagnostics, augmented by test cassettes, should easily bracket the problem.

From personal experience, I'd estimate that most "while-u-wait-repairs" could be done in less than 15 minutes. The ability to do this was obviously a design objective. Currently, there are two flaws in the grand plan. All available parts are being used to try to satisfy a huge backlog of delinquent system orders. There are no spare boards for dealers or servicemen. Also, documentation and test equipment are not yet available in what Chuck Pettle describes as an "acceptable" form.

When I asked him when I would get schematics adequate for servicing the problems with my PET, he told me that only the characteristics of the I/O were going to be released, and the rest would be kept "secret from competitors." In a vain attempt to get him to change his mind, I pointed out that a competent computer engineer could produce a schematic of the whole system in a few days and that any programmer who has written a BASIC interpreter (see "A Tale of Four BASICs," *Kilobaud* No. 13, January 1978) could produce a source listing of the ROMs. In fact, the only firms that possess these in-house skills *are his competitors*! As they say about gun control, "If you make gun possession a crime, then only criminals will possess guns." If PET (or Radio Shack) refuses to supply schematics to servicemen and product designers, then the only people who can get the information are their competitors with skilled manpower.

I admit I'm biased by the many wasted hours I've spent debugging my PET, but I can't help feeling that Chuck is adhering to a shortsighted policy. However, I feel that he's a reasonable man, so I hope someone else will succeed where I failed, and we'll all benefit.

After rereading what I've just written, it's evident that, with the exception of the service and documentation problems (which may not exist by the time this is printed), the PET has been depicted rather positively. As a matter of fact, Commodore could easily drop a perhaps fatal wad on the PET venture. Several local dealers who

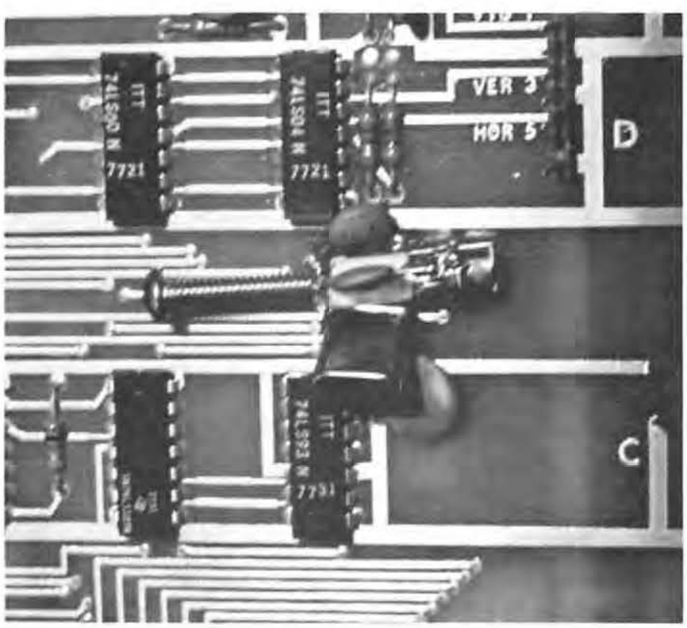


*Photo 10. Author's modification of 8 MHz crystal oscillator with trimmer capacitor trims 24-hour clock to high precision, but software problems remain.*

were pushing PET a month ago are now telling customers to buy something else because "Commodore is going broke." I suspect that delinquent deliveries and "cash-up-front" dealer policies are the real motivation, but how much of this can PET take?

One look at the gutted cassette recorder implies a big problem with overseas supplies. Less obvious, but unmistakable, evidences abound to attest to the probability that my cold-solder-joint intermittents are the result of questionable production practices and relaxed, or inadequate, quality control.

No matter how cost-effective a product design may be or how dynamic the pre-production sales effort, if you can't produce a reliable product on schedule with efficient and minimal after-sales service, you'll lose the ball game . . . remember Viatron? MOS Technology had problems with the early KIMs (mine went back twice), and successfully solved them. I'm betting that PET will have a similar success.

When it comes to software, PET gets a C, with an "incomplete" noted in the margin. The bare-bones listing of Microsoft's latest BASIC makes it difficult to work with, much less evaluate. Someone else will have to do that after the manual is published. So far it's about the same as the Crayne BASIC I've been using on the Sphere and the Mits on the Altair. It's faster, the error messages are better and the files are double buffered, but watch out for commas within quotation marks, such as addresses in FILE programs—they tend to act as delimiters. If you're used to using abbreviated instruction, you'll be disappointed.

> "If PET refuses to supply schematics to servicemen and designers, only competitors can get the information."

The original specs called for a 4K basic operating system. Compared to my Sphere operating system with only 2K of PROM, the PET is a disappointment. There are USR and SYS commands in BASIC, but no facility to load or generate machine code except by writing your own program to POKE it in BASIC. I had hoped that they would at least start where the two-year-old Sphere system left off.

If I were to put the Crayne's Sphere BASIC in ROM along with the current ROM operating system that consists of V3D, PDS, Mason's X-DBUG and Programma Assoc. text editor, it would require 20 percent less ROM and provide many features not found in this version of the PET. This includes utility subroutines such a number-base conversion, multibyte division and multiplication, block moves, hex-decimal-ASCII conversions, etc.

**Conclusion**

After all the pros and cons have been considered, it looks to me as though Commodore's PET has the brightest future of any microcomputer I've ever evaluated. It could graduate *summa cum laude*. Right now it's on shaky ground and could conceivably *flunk out*, as did the Sphere. It could have the short-term success of the *average* microcomputer, such as the Jolt. No matter how history marks its final report card, a new era of *mass* usage of artificial intelligence has been ushered in by Commodore's PET. ■