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C-64: A DESIGN CASE HISTORY

By TEKLA S. PERRY and PAUL WALLICH

In January 1981, a handful of semiconductor engineers at MOS Technology in West Chester, Pa., a subsidiary of Commodore International Ltd., began designing a graphics chips and a sound chip to sell to whoever wanted to make "the world's best video game." In January, 1982, a home computer incorporating those chips was introduced at the Winter Consumer Electronics Show in Las Vegas. By using in-house integrated-circuit-fabrication facilities for prototyping, the engineers had cut the design time for each chip to less than nine months, and they had designed and built five prototype computers for the show in less than five weeks. What surprised the rest of the home-computer industry most, however, was the introductory price of the Commodore 64: $595 for a unit incorporating a keyboard, a central processor, the graphics and sound chips, and 64 kilobytes of memory instead of the 16 or 32 that were then considered the norm.

When the chip-development project started, the Commodore 64 was not at all what the designers had in mind. MOS Technology was a merchant semiconductor house. Its LSI Group, headed at that time by Albert J. Charpentier, had been responsible for some of the chips that went into Commodore's VIC-20 home computer, but that project was already well into production. "We were fresh out of ideas for whatever chips the rest of the world might want us to do," said Charpentier. "So we decided to produce state-of-the-art video and sound chips for the world's next great video game."

Charles Winterble, then director of worldwide engineering for Commodore, gave the go-ahead for the chip effort, and Charpentier's group worked fairly independently until both chips were finished in mid-November 1981.

At a meeting with Charpentier and Winterble late that month, Jack Tramiel, then president of Commodore, decided not to proceed with the video game. Instead, he decided, the chips would go into a 64-kilobyte home computer to be introduced at the Consumer Electronics Show in Las Vegas the second week of January 1982. The computer had yet to be designed, but that was easily remedied.

In two days, the engineers laid out on paper the machine's basic architecture. Just before the new year, they completed five working prototypes. In the meantime, enough operating-system software was copied and rewritten from the VIC-20 to give passable demonstrations of what the new machine could do. Following its enthusiastic reception at the Consumer Electronics Show, the Commodore 64 was rushed into production; volume shipments began in August 1982 and have continued unabated.

Despite complaints about quality control and the industry's slowest disk drive, the Commodore 64 has been an unparalleled success, pushing a number of its competitors out of the market. Part of the reason for its success is the price, which keeps falling--from $595 at its introduction to $149 currrently, for which the consumer gets graphics and sound equal to or better than that provided by machines that cost five times as much.

In the late 1970s, MOS Technology was a successful semiconductor company; its engineers had designed the popular 6502 microprocessor, and it manufactured several other solidly selling products. Commodore, a West Coast company at the time, took over MOS in 1976--causing many of the MOS engineers to quit when their stock was bought at 10 cents on the dollar--but MOS was allowed to operate fairly autonomously.

In 1979 and 1980, recalls Charpentier, MOS Technology developed the 6510 microprocessor--a minor revision of the 6502 with an additional input-output port, the 6526 peripheral controller, a lot of read-only memory (ROM) chips, and a 4-kilobit random-access memory (RAM) chip. At that time, MOS was supplying equipment to Atari, Inc., General Electric Co., Hewlett-Packard Co., and a number of other clients, as well as to Commodore.

When the decision was made to design the latest in superior graphics and sound chips, the first step was obvious: to find what the current high-quality chips could do. In assembling his design team, Charpentier recruited Robert Yannes, a young engineer who had joined MOS in 1979 and had designed the VIC-20 at home, from a spare prototype board. The team spent about two weeks researching comparable chips industrywide.

"We looked heavily into the Mattel Intellivision," recalls Winterble. "We also examined the Texas Instruments 99/4A and the Atari 800. We tried to get a feel for what these companies could do in the future by extrapolating from their current technology. That made it clear what the graphics capabilities of *our* machine had to be."

The MOS designers freely borrowed ideas that they liked--sprites from the TI machine, collision-detection techniques and character-mapped graphics from the Intellivision, and a bit-map from their own VIC-20. They then packed as many of those ideas as they could into a predefined area of silicon.

"Al [Charpentier] was given the freedom, within a certain die size, to put in everything he could,

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REPORT FROM M.A.R.C.A.

By LARRY PHILLIPS

MARCA, the Mid Atlantic Regional Commodore Association, held its second annual conference and computer show in late July in Philadelphia. Attendance was estimated at 6-7,000, a figure that caused some disappointment for many of the exhibitors. For those that did attend, the show offered a wide variety of exhibits and talks by well known authorities on Commodore equipment.

On the exhibit floor were many vendors and manufacturers of software and hardware. Commodore was there in strength, showing off the new 128 along with new peripherals that are not on the market yet. The most notable peripheral was the RAMDisk, a RAM expansion that brings the total memory of the 128 up to 512K. The demo was a small (20 line) BASIC program that loaded data from the 1571 and put it into RAMDisk. The data was then transferred to the screen in sequence, producing a 'faster than life', hi-res rotating world globe. The smoothness and speed of the animation was astonishing, and though it was being produced by a BASIC program, the actual data transfer was taking place at about one million bytes per second. For the curious, the data transfer is handled by a DMA controller chip. Also shown was the optional 'mouse'. Possibly the most exciting thing shown by CBM was their new Quantumlink service. Modelled after Playnet, indeed using software leased from Playnet, they plan to offer many online services, including chat, an encyclopedia, financial quotes, etc.

Fiscal Information was there with their 10 Mbyte hard disk. The unit appeared well designed and was extremely fast. They claim a data transfer rate of about 30K bytes per second, and I saw no reason to doubt the claim. In order to maintain compatibility with the operating system and 1541 operations, they have even decided to keep some of the 'features' (bugs?). All in all, it looks like a very nice machine, though the $1500 US price tag will severely limit its market.

Even Canada was represented, the most well known exhibitor being Transactor magazine. Richard Evers, Chris Zamara, and Karl Hildon represented the magazine, and you will probably get the chance to read about the show from their point of view. It should be interesting to see if they go through with their plans to blast the Sheraton hotel for their silly dress codes. A small software firm run by David Eisan, a high school student in London Ont. showed their new disk utility/copy program called Facsimile. I wandered past the booth and stopped to have a look at it, and shocked him when I told him that I already had the program, and that it was written by a friend of mine. Turns out that Kevin Pickell had indeed written the program, and sold it to Exceptional Software Industries.

Among the speakers were many names prominent in the Commodore community. Ryo Kawasaki spoke on interfacing and timing synthesizers, Jim Butterfield spoke on a few diverse subjects, and Dick Immers spoke on 1541 techniques. Dick's talk was especially interesting in light of the way he has been treated by Datamost, who published 'Inside Commodore DOS'. To date, he has only recieved about $700 on estimated sales of over 100,000 copies. This has made him somewhat bitter toward publishers in general, and Datamost in particular. His descriptions of some of the escapades of himself and 'the Bandit' are hilarious, and I fear Datamost have unleashed a monster. I think they would have been better off paying for what they got.

For COMAL fans, there was a lecture by Borge Christensen, the inventor of COMAL. He demonstrated a very nice teaching program that could be used for teaching all levels of programming, from beginner to very advanced. The nice thing about it was that the program included a procedure to hide all lines of the program not written by the student, enabling the instructor to set up finite 'universes' for illustrative purposes. I very much enjoyed meeting him. As COMAL is my favourite language, I also hung around and helped out at the COMAL booth on occasion. There was a great deal of interest in the language, partly due to a couple of small demos that included an automated assembly line and a washing machine made from LEGO, and interfaced to the 64. They were under complete control of a simple COMAL program.

The only disappointment to me was that CBM declined to exhibit the Amiga. I felt that this was an opportuntity for CBM to show the machine off to people from all over the continent, and that they missed the boat. The people tending the booth were shocked by the amount of interest that Amiga has generated among non business users. They seem to think that it is priced out of reach of the home market, and I feel they are in for a big surprise when they find out where the real market will be.

In total, I thoroughly enjoyed the show. Let's hope there's an Amiga at the Pacific Coast Computer Fair.

TSDS: "Full-featured in every sense of the word"

By LARRY PHILLIPS

Kevin Pickell, the author of such winning software as SSI's Gemstone Warrior, has released his Total Software Development System through a small company called PirateBusters. PirateBusters' primary product is protection schemes, but surprisingly enough, TSDS is not protected at all. You are encouraged to make a working copy immediately and to store the original disk in a safe place. They do ask that you not give away the program, and I feel that this attitude should be encouraged. The value of an assembler or compiler is much reduced if you can't put a copy on each working disk.

TSDS is loaded with a fast load routine, coming up with the title at the top of the screen. This is followed by the automatic execution of an 'EXEC' file. This allows you to use your own EXEC file, with the same name, to set up any defaults and KEY functions you are most comfortable with.

At this point the editor is active, and you may proceed to enter, load, save etc., either BASIC programs or assembly language source code. The editor is very powerful, and is actually Commodore's normal C64 screen editor enhanced by a wide range of commands.

The extra commands make for easy file editing, and include such niceties as FIND and CHANGE, each with a wide range of options to allow selective operation. There is Auto numbering, Renumber, forward and backward scrolling LIST, LIST by label (instead of line number), and Delete (range of lines or label-label). Disk oriented commands, in addition to the normal wedge functions include Change disk number, display blocks free, append files, file verify (for SEQ files), Load a program at any address you wish, list to screen from disk, display the start/end address of a PRG file, and of course PUT or GET SEQ files. A command or string of commands may be assigned to any key, allowing many complex functions to be performed by a single keystroke. Some of my favorites are: Cursor to bottom left, PUT current file to disk (using file name contained in first line), and erase to end of line. More complex jobs may be performed with the EXEC function. All that is necessary is to create a SEQ file containing all the commands you want performed, and then EXEC (Name of file), and all the commands will be performed, just as if you were typing them in manually. The command ASM will assemble the named file, and, at your option, list the assembly to printer, generate a program file, etc.

The assembler itself contains many desirable features. Full MACRO facilities, conditional assembly, symbol table sorted numerically, alphabetically, or in the order they were defined. .FIL and .LIB functions allow for very large and versatile assemblies, and may even link between files on different diskettes.

Compatibility has been considered, and the directives .ASC and .BYT are both supported, along with a new one (at least to me). The .POK (poke) directive is identical to the .BYT, but instead of generating ASCII values, it will generate the screen POKE values so that you can easily create strings to be transferred rather than PRINTed to the screen.

During the assembly process, and as an adjunct to the conditional assembly functions, the assembler directives .INV and .INB allow the programmer to input values to variables, in numeric or Boolean form respectively. The .INV accepts a value, and .INB accepts a 'y' or an 'n' to be tested with the conditional statements, which include .IFE, .IFN, .IFP, and .IFP. (Equal, Not equal, Plus, Minus) Printer controls include page definition, titling, page numbering, etc. The .SKI and .PAG directives skip lines or an entire page. Printing may be enabled or suppressed throughout the assembly at will.

In keeping with the PirateBusters' avowed purpose, there are directives for encoding programs. Code may be EORed or ADDed to during assembly. The programmer must of course remember to decode to the proper form before executing. You may also set checksums on all or any part of a program in order to ensure data integrity (read: you can tell if someone has messed with it).

The assembler uses standard MOS 6502 mnemonics, and suports all addressing modes, including the ability to force absolute addressing mode. Ex/, !, and . (boolean OR function). Labels may be redefined during assembly, and labels within MACROs are considered local unless specified otherwise. All in all this is a full featured assembler in every sense of the word.

In the words of the immortal TV mail order salesmen, "Now how much would you pay?... But wait...".

As an added bonus, the disk also contains translators to convert source files to TSDS format from PAL and MAE format, an unassembler, a couple of handy EXEC files, and the best sprite editor I have ever seen. The sprite editor supports hi-res and multicolour sprites, and uses the standard cursor and screen editing keys or a joystick. You can overlay up to 6 sprites, animate up to 255 sprites at varying speeds, and even copy a sprite image with or without rotation. It is completely menu driven, easy and fun to use, and is alone, nearly worth the price of the package.

Now for the price. I'm sure you are all cringing at this point, waiting for the bad news. Well, the news is good. TSDS is available for $50.00 from:

PirateBusters
#268 - 7493 140th St.
Surrey, BC Canada V3W 6G5
Tel: Voice...(604) 590-0517
BBS...(604) 590-0518

DESIGN CASE HISTORY

(From Page One)

working backward within the size we planned. When he ran out of registers he stopped," said Winterble. "We defined in advance the silicon size that would give a yield we were willing to live with; at that time, a die size that was reasonable in 5-micrometer technology was less than 200 mils. Then we prioritized the wish-list from what must be in there to what *ought* to be in there to what we'd *like* to have, so the decisions that were needed at various points became fairly automatic."

For nine months, Charpentier worked with two draftsmen and one computer-aided-design operator on the graphics chip while Yannes worked with two other draftsmen and one CAD operator on the sound chip. They lacked completely the sophisticated design tools of today's engineering workstations, but they had one readily available design tool found almost nowhere else in the home-computer industry: a chip-fabrication line on the premises. With this, Winterble explained, a circuit buried deep inside the chips could be lifted out and run as a test chip, allowing thorough debugging without concern for other parts of the circuitry. David A. Ziembicki, then a production engineer at Commodore, recalls that typical fabrication times were a few weeks and that in an emergency the captive fabrication facility could turn designs around in as little as four days.

The cost of developing the Commodore 64? No one knows. "I had no formal budget accountability," said Winterble, "other than Jack [Tramiel] watching me. Jack said that budgets were a license to steal." Because MOS Technology's fabrication facility was not running at full capacity, the equipment used for C-64 test chips and multiple passes of silicon would otherwise have been idle. "We were using people who were there anyway," said Ziembicki. "You waste a little bit of silicon, but silicon's pretty cheap. It's only sand."

Although custom chips are usually considered expensive, the C-64 chips were not. Not only were development costs absorbed in company overhead, but there was no markup to pay, as there would have been if the chips had been built by another company. And yields were high because the chips were designed for a mature semiconductor-manufacturing process.

The sound chip was designed with 7-micrometer technology, scaling down to 6 in places. (By contrast, the custom chip for Atari's Video Computer System, fabricated four years earlier, was built with 6-micrometer technology.) Commodore's video chip was designed with 5-micrometer features.

Because design time rather than silicon was at a premium, the chips were laid out simply rather than compactly. "We did it in a very modular fashion," said Yannes. For example, he noted, "the standard way of building oscillators is to build one and then multiplex it until you have as many as you need. We just built an oscillator module and repeated it, because that was much faster than working out all the timing for the multiplexer."

"What was remarkable," Winterble added, "was that nine months later, when we came out with the first pass, it functioned except for one bad sprite."

In November 1981, the chips were complete. The original intent had been a game machine, but at this point the personal-computer market was beginning to look promising. At a meeting of Charpentier, Winterble and Tramiel, the decision was made to go for a personal computer. The next choice to be made, according to Charpentier, was between a 16-kilobyte and a 64-kilobyte machine, since the custom chips were designed to handle either option.

"Jack [Tramiel] made the bet that by the time we were ready to produce a product, 64K RAMs would be cheap enough for us to use," Charpentier said.

(Continued in next issue)

BASIC CLUB FACTS

The Commodore Computer Club serves the users of all Commodore computers. We are an independent, voluntary, non-profit group organized under the Society Act of B.C. with a large active membership.

The club presently meets twice a month -- once for a workshop, where members are encouraged to bring their own equipment, and once for business and lectures by guest speakers. The workshop meeting is currently held on the first Tuesday of the month at David Thompson Secondary School cafeteria, 1755 E. 55th Avenue (near Victoria Drive and 54th) starting at 7:00 p.m. The "lecture" meeting is held at the Emily Carr College of Art and Design on Granville Island on the third Wednesday of the month at 7:00 p.m. Details about these meetings can be obtained from phoning the club's 24-hour answer phone: PET-3311 (738-3311).

One of the major features of the club is the large library of public domain programs for the 64, VIC and PET, containing hundreds of programs. The 64 library currently contains over 30 disks, while the VIC-20 library consists of 15 disks and 24 tapes. These tapes and disks can be borrowed by members for a reasonable deposit, or in the case of the 64 library, purchased. Membership in the club also entitles you to receive this free newsletter, available at club meetings.

Membership fee in the Commodore Computer Club is only $20 a year, plus $5 initiation fee to first-time members. Applications will be accepted at the Pacific Coast Computer Fair and at all regular meetings of the club.

Again, for information on the club and its meetings, call PET-3311 (738-3311). Or you can write to our mailing address: P.O. Box 23396, Vancouver, B.C. V7B 1W1.

MEETING SCHEDULE

-- Workshop Meetings --
(David Thompson School)
October 1st
November 5th
December 3rd

-- Lecture Meetings --
(Emily Carr College)
September 18th
October 16th
November 21st
December 19th

BATTERIES INCLUDED:

A CANADIAN SUCCESS STORY

By PETER SILVERMAN

(reprinted with permission from Small Business Magazine)

In 1976, 2 brothers and a sister created a summer job for themselves. In time, it turned into one of the most visible software firms in North America, with about 60 employees and gross sales in 1984 of $10 million, expected to increase 35% this year.

Marcie, Alan and Robby Krofchick opened a stand at the Canadian National Exhibition (CNE) in Toronto, selling watches and calculators made by Commodore Business Machines. In 1978, after their third summer at the CNE, they decided to rent 310 sq. ft. of retail space in a downtown retail mall, for $700 a month. To boost sales, they included free batteries with the calculators and watches they sold, so they called their business Batteries Included. It opened in late 1978, and was incorporated as a partnership in 1979.

Alan quit his job and he and Marcie started working full time. Robby soon joined them as vice-president. Marcie is now Secretary/Treasurer. To get started, they went to the Canadian Imperial Bank of Commerce and took out an $18,000 personal loan. "Although we all signed, I had some Consumers Distributing stock for collateral," says Alan Krofchick, President. The 1,000 shares were then worth about $25,000.

First year sales were $120,000. Computers had not yet become a hot consumer item, and most revenue came from calculators. After selling Commodore products for 1-1/2 years, Batteries expanded to take in the 2 neighbouring shops, increasing its total space to 1,000 sq. ft. At about this time, the company cracked the lucrative educational market with the Etobicoke Board of Education.

The Commodore offered both reliability and a good price/performance ratio. This was important to the schools, since the computer teachers were anxious to acquire a lot of computers quickly so their students could get practical computer experience.

At that time, says Krofchick, 20-30 computer retailers were competing for school board business in Ontario. The decisions were made by the schools' computer teachers, not the purchasing agents, so Batteries had an advantage because many teachers had met the Krofchicks through their store. By 1981, Batteries was among the largest Commodore dealers in Canada.

A big break came from Batteries' policy of letting computer enthusiasts use the display machines in the store. One was a high school student, Steve Douglas, who soon started working there part time. "That was after I took my paper route money and bought a Commodore for $1,000," Douglas says. At the age of 17, he wrote the first version of Paperclip, word processing software that later hit number 1 on Billboard Magazine's chart, a rare achievement. To date, sales of Paperclip have amounted to about $4 million. Douglas, now 21, is a self-employed computer programmer who is close to being a millionaire from his royalties.

Douglas wrote a rough version of the program in the spring of 1982. That June, Batteries gave samples to teachers to evaluate during their vacations, while the Krofchicks spent the summer ironing the kinks out of the program. School boards snapped it up, largely because the price was right. Its chief competitor was priced at $200-$250, while Paperclip sold for $150 retail. For schools, Batteries cut the price in half.

After a software program like Paperclip is developed and its instruction manual written, it goes into production. In Batteries' leased 8,000 sq.-ft. facility, about 20 workers use disk duplication equipment to transfer programs onto disks that the company buys from suppliers. Commercial printing houses print and bind the manuals and deliver them to Batteries, where they are shrink-wrapped with the disks. Disks, manuals and assembly account for about 10% of the retail price.

In the same facility, Batteries produces its hardware products, a few "cards," which plug into the Commodore 64 computer to give it added capabilities,

(Continued on Page 4)

64 LIBRARY ADDITIONS

```
"CCC LIBRARY DISK" S3 2A
11  "LIST-ME PLEASE"     PRG    2  "INX.D"     SEQ
31  "6510 OPCODES"       PRG    1  "INXQ.D"    SEQ
1   "INST.LIST.PRT"      PRG    2  "INY.D"     SEQ
1   "---DATA FILES---"   SEQ    1  "INYQ.D"    SEQ
10  "D1.W"               PRG    3  "JMP.D"     SEQ
3   "D2.W"               PRG    1  "JMPQ.D"    SEQ
32  "D3.W"               PRG    3  "JSR.D"     SEQ
6   "D4.W"               PRG    1  "JSRQ.D"    SEQ
9   "D5.W"               PRG    2  "LDA.D"     SEQ
58  "INST.LIST.D"        SEQ    2  "LDAQ.D"    SEQ
1   " ---------------"   SEQ    1  "LDX.D"     SEQ
1   "-OPCODE---FILES-"   SEQ    2  "LDXQ.D"    SEQ
3   "ADC.D"              SEQ    1  "LDY.D"     SEQ
3   "ADCQ.D"             SEQ    2  "LDYQ.D"    SEQ
3   "AND.D"              SEQ    2  "LSR.D"     SEQ
3   "ANDQ.D"             SEQ    2  "LSRQ.D"    SEQ
3   "ASL.D"              SEQ    1  "NOP.D"     SEQ
3   "ASLQ.D"             SEQ    2  "NOPQ.D"    SEQ
2   "BCC.D"              SEQ    2  "ORA.D"     SEQ
2   "BCCQ.D"             SEQ    2  "ORAQ.D"    SEQ
1   "BCS.D"              SEQ    1  "PHA.D"     SEQ
2   "BCSQ.D"             SEQ    1  "PHAQ.D"    SEQ
2   "BEQ.D"              SEQ    1  "PHP.D"     SEQ
3   "BEQQ.D"             SEQ    1  "PHPQ.D"    SEQ
2   "BIT.D"              SEQ    2  "PLA.D"     SEQ
1   "BITQ.D"             SEQ    1  "PLAQ.D"    SEQ
2   "BMI.D"              SEQ    1  "PLP.D"     SEQ
3   "BMIQ.D"             SEQ    1  "PLPQ.D"    SEQ
2   "BNE.D"              SEQ    2  "ROL.D"     SEQ
3   "BNEQ.D"             SEQ    2  "ROLQ.D"    SEQ
2   "BPL.D"              SEQ    2  "ROR.D"     SEQ
3   "BPLQ.D"             SEQ    2  "RORQ.D"    SEQ
3   "BRK.D"              SEQ    4  "RTI.D"     SEQ
3   "BRKQ.D"             SEQ    1  "RTIQ.D"    SEQ
2   "BVC.D"              SEQ    3  "RTS.D"     SEQ
4   "BVCQ.D"             SEQ    1  "RTSQ.D"    SEQ
1   "BVS.D"              SEQ    3  "SBC.D"     SEQ
4   "BVSQ.D"             SEQ    2  "SBCQ.D"    SEQ
1   "CLC.D"              SEQ    1  "SEC.D"     SEQ
2   "CLCQ.D"             SEQ    1  "SECQ.D"    SEQ
1   "CLD.D"              SEQ    1  "SED.D"     SEQ
2   "CLDQ.D"             SEQ    1  "SEDQ.D"    SEQ
1   "CLI.D"              SEQ    1  "SEI.D"     SEQ
3   "CLIQ.D"             SEQ    1  "SEIQ.D"    SEQ
1   "CLV.D"              SEQ    1  "STA.D"     SEQ
2   "CLVQ.D"             SEQ    2  "STAQ.D"    SEQ
3   "CMP.D"              SEQ    1  "STX.D"     SEQ
1   "CMPQ.D"             SEQ    2  "STXQ.D"    SEQ
2   "CPX.D"              SEQ    1  "STY.D"     SEQ
1   "CPXQ.D"             SEQ    2  "STYQ.D"    SEQ
2   "CPY.D"              SEQ    1  "TAX.D"     SEQ
1   "CPYQ.D"             SEQ    1  "TAXQ.D"    SEQ
3   "DEC.D"              SEQ    1  "TAY.D"     SEQ
1   "DECQ.D"             SEQ    1  "TAYQ.D"    SEQ
2   "DEX.D"              SEQ    2  "TSX.D"     SEQ
2   "DEXQ.D"             SEQ    1  "TSXQ.D"    SEQ
2   "DEY.D"              SEQ    1  "TXA.D"     SEQ
2   "DEYQ.D"             SEQ    1  "TXAQ.D"    SEQ
3   "EOR.D"              SEQ    2  "TXS.D"     SEQ
2   "EORQ.D"             SEQ    1  "TXSQ.D"    SEQ
2   "FILE NAMES.D"       SEQ    1  "TYA.D"     SEQ
2   "INC.D"              SEQ    1  "TYAQ.D"    SEQ
1   "INCQ.D"             SEQ    3  "MENU.D"    SEQ
292BLOCKS FREE.
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"CCC LIBRARY DISK" S4 2A
70 "PONZO TUTOR 1"     PRG    61 "PONZO TUTOR 6"     PRG
67 "PONZO TUTOR 2"     PRG    60 "PONZO TUTOR 7"     PRG
75 "PONZO TUTOR 3"     PRG    76 "SPRITES TUTOR 1"   PRG
64 "PONZO TUTOR 4"     PRG    31 "SPRITES TUTOR 2"   PRG
67 "PONZO TUTOR 5"     PRG
93 BLOCKS FREE.
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"CCC LIBRARY DISK" S4 2A
71 "GRAPHIC TUTOR 1"   PRG    77 "MICROS'NCHIPS 4"   PRG
23 "GRAPHIC TUTOR 2"   PRG    79 "MICROS'NCHIPS 5"   PRG
77 "MICROS'NCHIPS 1"   PRG    80 "MICROS'NCHIPS 6"   PRG
77 "MICROS'NCHIPS 2"   PRG    83 "PONZO DISKVIEW 3"  PRG
77 "MICROS'NCHIPS 3"   PRG
20 BLOCKS FREE.
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"CCC LIBRARY DISK" V1 2A
25 "SPEEDSCRIPT V3.0"  PRG    6  "SPIDER ML"           PRG
67 "S/S INST.V3.0"     PRG    23 "SPIDER BASIC"        PRG
11 "S/S FILE CONVERT"  PRG    20 "GAMELIFE"            PRG
21 "BISSET LETTERS"    PRG    33 "ACROBAT C-64"        PRG
4  "DAZZLE-DO"         PRG    1  "PRINT FILE"          PRG
17 "MEMORY TRAINER"    PRG    19 "SPACE CAVERNS"       PRG
5  "TINYTALLY"         PRG    1  "WARM START FLASH"    PRG
5  "A STORY"           PRG    5  "VERIFIZER"           PRG
23 "ROBOT"             PRG    7  "VERIGEN"             PRG
67 "OREGON TRAIL     " PRG    5  "RND(0) RND(1)"       PRG
21 "SCHEDULE"          PRG    11 "PACHELBEL"           PRG
11 "VANISHING MAZE"    PRG    10 "BUG REPELLENT"       PRG
31 "B.C. SLOT MACHIN"  PRG    11 "BIG PRINT"           PRG
15 "MEMO DIARY"        PRG    17 "HOP AROUND"          PRG
5  "DEVASTATOR"        PRG    6  "C-64 TURBODISK"      PRG
7  "DEVML"             PRG    18 "FLANKSPEED.MOD"      PRG
6  "DEVBASIC"          PRG    4  "TURBODISK.OBJ"       PRG
3  "SPIDERS"           PRG    21 "TURBODISK.CREATE"    PRG
102BLOCKS FREE.
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"CCC LIBRARY DISK" V2 2A
2  "DM-BOOT"           PRG    17 "HAL.ML"              PRG
2  "DM-1"              PRG    100"HALSET"              PRG
15 "DM-2"              PRG    39 "TAX84 MUL-PLN"       REL
10 "DM-3"              PRG    5  "CDNTAX.INSTRUCT"     PRG
32 "DM-4"              PRG    55 "EAGLETERM.C3"        PRG
65 "DM-5"              PRG    7  "TERM.C3"             PRG
1  "DM-6"              PRG    3  "FIRSTDIAL3 BOOT"     PRG
1  "DM-7"              PRG    4  "FIRSTDIAL3"          PRG
2  "DM-8"              PRG    1  "FIRSTTERM3 BT"       PRG
23 "DM-9"              PRG    54 "FIRSTTERM3"          PRG
8  "DM-A"              PRG    46 "FIRSTTERMDOC1W/P"    PRG
5  "DM-MENU"           PRG    33 "FIRSTTERMDOC2W/P"    PRG
131"HAL"               PRG
3  BLOCKS FREE.
```

```
"CCC LIBRARY DISK" W1 2A
59 "RAINBOW"           PRG    15 "SHEET DATA.D"        PRG
25 "MUSICBOX DNCER"    PRG    7  "BARRICADE"           PRG
36 "BACH PRELUDE"      PRG    15 "SLITHER"             PRG
29 "BACH INVENTN08"    PRG    15 "SLITHER 4.C"         PRG
36 "MORNING BROKEN"    PRG    15 "SLITHER DUEL.C"      PRG
35 "FROSTY"            PRG    9  "SHUFFLE"             PRG
9  "LINCOLNSHIRE"      PRG    23 "BARB'S BOAT.C"       PRG
9  "RANDOM MUSIC"      PRG    18 "CRAZY 8'S"           PRG
2  "M/L MUSIC"         PRG    31 "DOCTOR WHO.C"        PRG
19 "SIDMON"            PRG    42 "RECOL"               PRG
43 "MUSIC LESSON"      PRG    41 "BATTLESHIPS"         PRG
34 "FUGUE"             PRG    32 "BAY STREET"          PRG
2  "SHEET MUSIC"       PRG    28 "HANGMAN"             PRG
35 BLOCKS FREE.
```

```
"CCC LIBRARY DISK" W2 2A
2  "MENU"              PRG    4  "HORIZONS"            PRG
5  "COMPUTE!/VIC"      PRG    11 "QUEST/VIC"           PRG
7  "GAZETTE/VIC"       PRG    9  "HI RES DUMP"         PRG
2  "COMPUTE!"          PRG    7  "ZAP/VIC"             PRG
32 "NEW 64 BOOKS"      PRG    7  "NO ZAP/64"           PRG
14 "NEW VIC BOOKS"     PRG    11 "APPLE/VIC"           PRG
9  "VM"                PRG    20 "APPLE/64"            PRG
9  "MN"                PRG    12 "P2"                  PRG
4  "COMPUTECOLOR"      PRG    12 "POOL/VIC"            PRG
4  "COMPUTESCREEN"     PRG    16 "MB"                  PRG
18 "GAZETTE"           PRG    83 "AAC64 AD"            PRG
2  "VICONTENTS"        SEQ    1  "ASTROPANIC!"         PRG
14 "MLX 64 V2.02"      PRG    2  "64 CONTENTS"         SEQ
4  "PROOFREADER"       PRG    3  "MLFB64"              PRG
12 "VIC MLX V2.02"     PRG    1  "METABASIC"           PRG
11 "V2"                PRG    1  "POOL/64"             PRG
15 "PL"                PRG    3  "MLFBVIC"             PRG
2  "TRIPLE 64"         PRG    13 "AP"                  PRG
13 "NUMBER QUEST/64"   PRG
260BLOCKS FREE.
```

```
"CCC LIBRARY DISK" X1 2A
12 "MIND BUSTERS"      PRG    4  "TRIDENT.INST"        PRG
21 "FILE PROTECTOR"    PRG    10 "TRIDENT/49152"       PRG
29 "BD GYS FRM SPC"    PRG    41 "SPACE THIEF"         PRG
56 "DATABASE"          PRG    6  "CUTOFF/49152"        PRG
102"JEDI ADVENTURE"    PRG    2  "CUTOFF LOADER"       PRG
11 "MATH DRAG"         PRG    12 "MOSQUITO"            PRG
41 "TANK 2064"         PRG    50 "AMORT/FEB 18/85"     PRG
3  "SOFTSCROLL64"      PRG    7  "AMORT/REDUC'N/YR"    PRG
2  "EDIT-TIME"         PRG    9  "HI-RES ML(49152)"    PRG
40 "EDIT"              PRG    5  "HI-RES BASIC 1"      PRG
1  "----------------"  SEQ    5  "HI-RES BASIC 2"      PRG
13 "INST64"            SEQ    10 "HI-RES BASIC 3"      PRG
22 "ASMFIX"            SEQ    15 "ATOM HANDBALL"       PRG
17 "MACROS"            SEQ    9  "BIG TIME"            PRG
13 "DISK-O-64 INST."   PRG    4  "KALEIDOSCOPE"        PRG
6  "DISK-O-64"         PRG    9  "DEFLECTION 2"        PRG
23 "FRENCH 64"         PRG    12 "3 OF A KIND"         PRG
4  "ADSR ENV DEMO"     PRG
38 BLOCKS FREE.
```

```
"CCC LIBRARY DISK" X2 2A
6  "SPEED3GD BOOT"      PRG   72 "ALPHADOT"            PRG
14 "SPEEDSCRIPT3X.D"    PRG   25 "MULT QUIZ"           PRG
3  "SPEEDTRANS3.D"      PRG   23 "PLUS/TERM-64"        PRG
31 "UNIVERSAL MODEM"    PRG   10 "P/T.ML/64"           PRG
7  "TERM.C1"            PRG   7  "SHADING"             PRG
7  "TERM.64.NEW"        PRG   1  "SHADINGML"           PRG
26 "TERM MITEY MO 3"    PRG   12 "CHESS64"             PRG
9  "TERM.BL"            PRG   19 "CHESS2"              PRG
3  "CIRCLES"            PRG   23 "CRAZY CLIMBER"       PRG
11 "DRINK & DRIVE.C"    PRG   12 "MOSQUITO"            PRG
33 "ALIEN CITY.C"       PRG   2  "RATS"                PRG
33 "RUN RIKI RUN.C"     PRG   26 "RATS.OBJ"            PRG
72 "ALPHADOT.C"         PRG   4  "TAXMAN"              PRG
25 "MULT QUIZ.C"        PRG   24 "TAX.OBJ"             PRG
3  "THUNDER LOADER.C"   PRG   16 "THINGS IN DARK"      PRG
38 "THE THUNDERER"      PRG   17 "TAG"                 PRG
3  "MINUTE LOADER.C"    PRG   1  "APRIL FOOL"          PRG
34 "MINUTE WALTZ"       PRG   9  "C-64 JUKEBOX"        PRG
3  BLOCKS FREE.
```

```
"CCC LIBRARY DISK" Y1 2A
2  "MENU"               PRG   5  "QUICKSORT/64"        PRG
9  "MN"                 PRG   3  "BS"                  PRG
9  "VM"                 PRG   3  "SB"                  PRG
14 "MLX/64"             PRG   4  "QS"                  PRG
12 "MLX/VIC"            PRG   4  "POWER BASIC/64"      PRG
11 "V2"                 PRG   3  "POWER BASIC"         PRG
4  "PROOFREADER"        PRG   19 "JOG LOG/64"          PRG
18 "GAZETTE"            PRG   17 "JOG LOG/VIC"         PRG
7  "GAZETTE/VIC"        PRG   1  "BUBBLE SORT"         PRG
32 "64 BOOKS"           PRG   1  "SHELL SORT"          PRG
14 "VIC BOOKS"          PRG   1  "QUICKSORT"           PRG
2  "COMPUTE!"           PRG   44 "SID EDITOR"          PRG
5  "COMPUTE!/VIC"       PRG   9  "SQUARES"             PRG
4  "COMPUTECOLOR"       PRG   13 "FREEZE FACTORY"      PRG
4  "COMPUTESCREEN"      PRG   11 "FREEZE/VIC"          PRG
3  "VICONTENTS"         SEQ   2  "ML BEG"              PRG
3  "64 CONTENTS"        SEQ   5  "ASSASSIN"            PRG
83 "ALL ABOUT 64"       PRG   5  "ASSASSINATION"       PRG
10 "ALIEN ARMADA/64"    PRG   8  "RELATIVE"            PRG
12 "ALIEN ARMADA"       PRG   9  "SCREEN-40"           PRG
12 "AA"                 PRG   2  "SCR-40.BOOT"         PRG
1  "JOURNEY"            PRG   1  "----------------"    USR
5  "Y"                  PRG   12 "DOODLE LOADER"       PRG
35 "Z"                  PRG   37 "DDCOMAL CALVIN"      PRG
19 "CHARLEMAGNE/64"     PRG   37 "DDMIDDLE EARTH"      PRG
18 "CHARLEMAGNE"        PRG   37 "DDGRAN PRIX"         PRG
4  "BUBBLE SORT/64"     PRG   5  "RND(0) RND(1)"       PRG
4  "SHELL SORT/64"      PRG
10 BLOCKS FREE.
```

```
"CCC LIBRARY DISK" Y2 2A
8  "1ST.TERM.BOOT"      PRG   40 "2ND.DIAL.DOC2W/P"    PRG
4  "1ST.TERM.DIAL.01"   PRG   1  ">+++----------+++<"  USR
1  "1ST.TERM.DATA.02"   PRG   8  "SCRIPTSAVE 3.1"      PRG
54 "FIRSTDATA3"         PRG   25 "SPEEDSCRIPT.V3.1"    PRG
1  "----------------"   USR   68 "S/S INST.V3.1"       PRG
3  "WORDPRO READER"     PRG   11 "S/S FILE CONV3.1"    PRG
1  "+--------------+"   USR   1  ">++++-----++++<"     USR
48 "1ST.DIAL.DOC1W/P"   PRG   67 "BACGAMMON V2.1"      PRG
33 "1ST.DIAL.DOC2W/P"   PRG   1  ">+++++----+++++<"    USR
1  ">--------------<"   USR   31 "WINTER SCENE.C"      PRG
8  "2ND.TERM.BOOT..."   PRG   18 "FIFTEEN PUZZLE"      PRG
4  "2ND.DIAL.DATA.01"   PRG   9  "C-64 JUKEBOX"        PRG
1  "2ND.TERM.DATA.02"   PRG   11 "CELESTIAL SWAMI"     PRG
73 "SECONDDATA"         PRG   11 "CELESTIAL DATA"      PRG
1  ">+------------+<"   USR   5  "CHESS BOOT"          PRG
3  "WORD PRO READER"    PRG   50 "CHESS-64"            PRG
1  ">++----------++<"   USR   1  "CHESS/CLK"           PRG
44 "2ND.DIAL.DOC1W/P"   PRG   9  "CHS/CHAR"            PRG
8  BLOCKS FREE.
```

```
"CCC LIBRARY DISK" Z1 2A
3  "MINUTE LOADER"      PRG   57 "THE VALLEY"          PRG
34 "MINUTE WALTZ.D"     PRG   52 "CASTLE ADVN"         PRG
2  "THOSE LOADER"       PRG   61 "HOLYHALTER 1"        PRG
21 "THOSE WERE THE.D"   PRG   61 "HOLYHALTER 3"        PRG
56 "THIRSTY NELLAN"     PRG   61 "HOLYHALTER 4"        PRG
18 "SWERVE"             PRG   61 "HOLYHALTER 5"        PRG
53 "ATLANTIS ADVN."     PRG   44 "CENTRIPOD"           PRG
28 "WESTWARD HO!"       PRG   22 "SLITHER ON"          PRG
23 "OTHELLO"            PRG
7  BLOCKS FREE.
```

```
"CCC LIBRARY DISK" Z2 2A
6  "BIKE QUIZ INST.C"   PRG   3  "PRINT SEQ FILE.C"    PRG
92 "BIKE QUIZ MON.C"    PRG   9  "2DRIVECOPY.C"        PRG
1  "SERIAL PRINTER.C"   PRG   9  "WILLIE'S WEDGE.C"    PRG
98 "BIKE QUIZ PRNT.C"   PRG   18 "WILLIE'S INST.C"     PRG
1  "----------------"   SEQ   1  "- ------------ -"    SEQ
1  "NEXT  12  FILES "   SEQ   21 "GUN RELOADCOST"      PRG
1  "ARE RELATED FILE"   SEQ   9  "BULLET DIST"         PRG
1  "   BY  WILLIE   "   SEQ   41 "SIMPLE SENT"         PRG
1  " -------------- "   SEQ   64 "COMPOUND SENT"       PRG
37 "INSTRUCTIONS.C"     PRG   15 "CINQUIAN"            PRG
2  "BASIC CAT LIST.C"   PRG   26 "DRILL ER/IR/UR"      PRG
16 "FILE DIRECTORY.C"   PRG   17 "DRILL IE/EI"         PRG
3  "LIST CATALOG.C"     PRG   18 "DRILL OU/OW"         PRG
4  "LIST CAT SORT.C"    PRG   3  "FILE/BOOT"           PRG
4  "LIST MEMORY.C"      PRG   48 "FILE/MASTER"         PRG
9  "1DISKFILECOPY.C"    PRG   24 "FILE/EXPLAIN"        PRG
3  "PRINT CATALOG.C"    PRG   19 "FILE/TITLES"         PRG
4  "PRINT CAT SORT.C"   PRG   3  "FILE/SORT"           PRG
5  "PRINT MEMORY.C"     PRG
27 BLOCKS FREE.
```

AND A NEW VIC TAPE . . .

```
"CCC VIC TAPE 25 " 25 2A
13 "DIRECTORY       U" PRG   5  "TURBOTAPE        U" PRG
7  "PRG CLASS VIC   U" PRG   2  "VIC 40 LOADER    U" PRG
24 "SPEEDSCRPT3 8K  B" PRG   29 "VIC 40"             PRG
13 "NIMBOTS 8K      G" PRG   17 "DEMO"               PRG
25 "DOCTOR 8K       G" PRG   18 "VICTERM OLDPROTO"   PRG
8  "ASSEMBLER       A" PRG   7  "VIC OLD PROTO ML"   PRG
14 "GUMBALL         G" PRG   15 "VICTERM NEWPROTO"   PRG
3  "SINE            P" PRG   7  "VIC NEW PROTO ML"   PRG
3  "DONA NOBIS PACEM"  PRG   1  "PLUS/TERM-VIC   C"  PRG
16 "WORD GUESS 8K   E" PRG   23 "P/T.VIC.BASIC"      PRG
6  "TIME CLOCK      P" PRG   10 "P/T.ML/VIC"         PRG
9  "LETTER ATTACK   E" PRG   10 "VIC DT"             PRG
11 "WHEEL OF GOLD   G" PRG   1  "DDDDDDDDDDDDDDDD"   PRG
8  "DUMPER          G" PRG   4  "DIRECTORY        "  PRG
355BLOCKS FREE.
```

A COMPLEAT GUIDE TO MACHINE LANGUAGE PROGRAMMING ON THE PET

(Editor's Note: This marks the last section of Harold Brochmann's book on ML for the PET which we have been running since our first issue in the Summer of 1983. Although this is supposed to be the tenth section of the book, it looks to me like it is actually the last part of the third, which was covered quite some time ago! In any case, if you have missed parts of this book, the whole thing is available on CCC Library disk P2. Thanks to Harold for his permission to use this material.)

By HAROLD BROCHMANN

(3-6) ASSEMBLER LANGUAGE

At the end of the last section we left you with the suggestion that you should write a BASIC program that would enter and call the ML code necessary to write your name at the top of the screen.

If your name is BILL, the ML coding looks like this:

```
.M,033A,033B
.:  033A A9 02 8D 00 80 A9 09 8D
              A9 0C 8D 02 80 8D
              60 .............
```

ASSEMBLER LANGUAGE is the MNEMONIC equivalent for machine code. The above coding would look like this in assembler:

```
033A A9 02    LDA #$02
              TA $8000
              DA #$09
              TA $8001
              DA #$0C
              TA $8002
              TA $8003
              TS
```

As you can see, the screen code for each letter is placed in the accumulator and then moved from the accumulator to some destination address.

In the above example, the accumulator is first loaded with the number 02, and then deposited in the address $8000. The # symbol in front of #$02 tells us that here we are talking about a NUMBER as opposed to an ADDRESS. We call this sort of thing IMMEDIATE ADDRESSING!.

The STA instruction makes reference to the specific address $8000. This is called ABSOLUTE ADDRESSING.

LDA may also be used with absolute addressing. In this program the accumulator is loaded with the contents of an address referred to rather than the number which follows.

```
033A AD 00 80 LDA $8000
              TA $8028
              DA $8001
              TA $8029
              DA $8002
              TA $802A
              TS
```

Use MLM to enter this program as follows:

```
.:  033A AD 00    80 8D 28 80 AD 01
                  29 80 AD 02 80 8D
                  60 ..............
```

Exit MLM, place three symbols in the top left corner of the screen and SYS 826. This should reproduce the three symbols on the second row of the screen.

SUMMARY OF CHAPTER

- Machine code instructions, although they are actually NUMBERS, may be talked about using ASSEMBLER MNEMONICS. This makes things a lot easier.
- We have encountered RTS, BRK, STA and LDA. LDA may use ABSOLUTE or IMMEDIATE addressing. STA uses absolute addressing.
- RTS and BRK don't seem to use addresses. We call this IMPLIED addressing.
- Machine code may be entered directly into the PET's memory using the Machine Language Monitor.
- Machine code is sequentially accessed by the microprocessor. The program counter keeps track of which instruction is next.
- The accumulator can be loaded with a number and placed somewhere in memory.

APPENDIX A -- THE STACK

The stack, among other things, keeps track of return addresses for the RTS instruction.

```
033A 20 3D 03 JSR $033D
PLA
TAX
PLA
TAY
BRK
```

The subroutine at $033D pulls the low address of the departure address off the stack PLA and places it in the X register. Similarly the high adress is deposited in the Y register.

When the routine is run an examination of the registers will demonstrate this.

In a similar way it is possible to LDA and PHA (push on to the stack) an adress in two stages. The RTS instruction will now cause a jump to this address.

The actual stack contents are located in zero page. The stack pointer keeps track of the various entries.

APPENDIX B -- THE STATUS REGISTER

The status register contains a number of flags which are used by such instructions as BEQ, BNE, BPL etc. This section will explain how to decipher the contents of this register.

```
Enter MICROMON
PC  IRQ  SR AC XR YR SP
         32 00 6B 00 F8
Enter $0032
$0032 @ 2 0000 0000 0011 0010
```

This tells us that the tatus register contents ($32) in this case) is equivalent to 00110010 binary.

The right-most bit (bit 0) is the carry bit. It is set to 1 if an arithmetic operation on two bytes exceeds $FF.

Bit 1 indicates whether or not the last result was zero.

Bit 2 is the interrupt bit. It is set by SEI and cleared by CLI. These instructions were discussed earlier.

Bit 3 is the decimal bit. The 6502 can do some decimal arithmetic operations.

Bit 4 indicates the BREAK status.

Bit 5 is unused.

Bit 6 is the overflow bit.

Bit 7 is set when the result of an arithmetic operation is negative.

The reader is encouraged to experiment with various ML instructions followed by BRK. Examining the SR with the help of MICROMON as illustrated will lead to a clearer understanding of the meaning of these various status register flags.

– BATTERIES INCLUDED –

(Continued from Page 3)

and a printer interface, which is necessary to transmit text from a computer to a printer. Hardware accounts for about 15% of Batteries' sales.

Paperclip's fame soon spread to the U.S., where Batteries hired an agent to sell its products. In 1983, it hired a full-time sales representative, although it still shipped the software from Canada. Today, 75% of Batteries' volume goes to the U.S. It has an incorporated U.S. subsidiary and a 2,000 sq.-ft. office in Orange County, Calif., where it employs 5 people and stores its products, which are still manufactured in Canada. The company also has marketing agreements with companies in Europe, South Africa, Australia, Britain and France.

This year, Batteries is spending $50,000 a month on advertising. That includes the cost of participating in 2 major computer shows, which chew up about $100,000 each. The rest goes to advertising in computer magazines, about 90% in the U.S.

Now, with 2,000 sq. ft. of office space and 8,000 sq. ft. for manufacturing, the company has launched a product acquisition program, publishing software developed by people outside the company. The first product developed this way entered the market this year. Royalties are 7%-15%, comparable to the book publishing industry. Meanwhile, when employees develop programs they get a royalty as an incentive, although it's considerably less than the royalties paid to independent developers.

Educational sales are no longer in the Batteries plan. And the retail store posed a problem, since it competed against stores that sell Batteries' software, so the company closed it in March of this year. But with or without the store, Krofchick says the firm has no intention of changing its unforgettable name.

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Club meetings are normally held: *Workshop*: first Tuesday of the month, 7:00 p.m., Thompson Secondary School cafeteria, 1755 E. 55th Ave. (near Victoria Drive); *Lecture*: third Wednesday of the month, 7:00 p.m., Emily Carr College of Art and Design, 1399 Johnston, Granville Island. For up-to-date information on any changes, please call the club BBS at 271-1082 or the club's 24-hour answering machine:

PET-3311 (738-3311)