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THE PDP-8 ROUTE

Fred Sias likes the Digital Equipment Corporation's PDP-8/S computer enough to borrow a lot of ideas from it. He writes:

"It is a little difficult for me to see a computer sitting around doing nothing. There are plenty of chances to use a machine to teach highschoolers. A number of PDP-8/S are in use for this purpose already. I think there is opportunity to develop low-cost inventory systems for small businesses. These ideas are in the line of income-producing sidelines, but computer time is valuable and anyone with a machine should be able to produce income with it. A particularly fruitful area should be in software development. At the present state of technology, practically any company with an engineer or two can market a computer. Software support is the costly and time-consuming requirement for success in the computer business, however. This suggests that amateur-built machines could provide support to the vast software needs of the computer industry. To do this, an amateur machine would only need the same order structure as some commonly used commercial machine. There are over 2,000 machines in use of the PDP-5, 8, 8/S and 8/I series. These machines vary considerably, but share a common order structure.

The software problem is a two-way street, also. DECUS is a users' society for DEC machines that provides a medium for the exchange of programs and ideas. Probably an amateur computer builder could become a non-voting member of the society. Interested persons might approach their local DEC sales representative. User-developed assemblers, statistical packages, arithmetic subroutines, and special software for peripheral devices is available to any member. For instance, I just recently obtained a software symbol generator for displaying text on an oscilloscope. Text output by this route is very inexpensive. Keyboard input and scope output is probably the most inexpensive I/O system for an amateur computer.

I'd like to present some of the features of the PDP-8 series of computers that make them worth looking at for ideas for amateur construction. Should I eventually construct a machine, it will start out looking like a PDP-8/S and may eventually be changed to a PDP-8. The difference is that the 8/S is a serial machine. That is, all transfer between registers is done through the adder, bit by bit. A serial adder has much less logic than a full parallel adder. Consequently the complete PDP-8/S has the following complement of logic:

- 92 flip-flops
- 2 clock multivibrators
- 2 one-shot delays
- 52 pulse amplifiers
- 161 inverters
- 160 NAND gates
- 62 diode gates
- 70 drivers for displays
- 1 Schmitt trigger
- 1 4K, 12-bit memory, and decoding and driving logic.

The commercial unit uses a 6-microsecond parallel core memory even though the rest of the machine is serial. Data is transferred into the memory buffer register serially and then into the memory in parallel. Consequently, two separate clocks are needed, and run independently, depending on the phase of the word timing. Incidentally, I understand the original design of the PDP-8/S was to use a drum or disc, but the cost of core memories dropped so radically that the machine was marketed with a core memory. That core is available from DEC for $2000. Application notes and driving logic are available, too.

If I were starting to build a machine from surplus parts, I think I would choose the PDP-8 instruction set, construct the serial logic with a disc memory first, later convert to a parallel core memory, and finally convert to full parallel logic. Even using serial logic, the slow version has a respectable 28 to 54-microsecond operation time.

Some other features of the PDP-8 are worth mentioning. The machine has a 12-bit word size. Where analog devices are to be attached to the machine, 12 bits is a natural precision. A-to-D converters are usually 12 or less bits in precision (for a number of reasons) and a resolution of 1 part in 4096 is more than adequate for devices like scope displays. Multi-precision arithmetic software, both fixed-point and floating-point, is readily available, so a longer word length is unnecessary for anyone except a professional computer person who has a requiement demanding higher-speed, multiprecision arithmetic. In support of this statement, one might note that the IBM 360 series equipment has turned to the small basic word size with multiple-byte memory accessing to gain speed. Early machines required large word size due to the slowness of memory access.

The PDP-8 has only eight basic instructions, but the set can be expanded to a hundred or more by micro-programming the operate and input/output instructions. This permits one to use a simple octal decoder for decoding instructions.

Basic input/output transfer on the PDP-8 is via the accumulator. Transfer is in parallel, both for the standard and serial machines. A party-line bus system is used, with each peripheral device recognizing its own microprogrammed device-select code. The logic to do this is simple, with the commercial device-select logic costing only about $50. This is one of the simplest input/output systems that I have seen, and it is thoroughly described in the DEC "Small Computer Handbook," available free from any DEC salesman. I endorse this handbook as a liberal education in computer design.

Do you think there would be any interest in approaching DEC about supplying a basic kit for amateur construction of a version of the 8/S computer?

The parallel-to-serial conversion device mentioned in your last newsletter is available from DEC for $150. I recommend the free DEC "Logic Handbook" as a second liberal education.

Incidentally, one does not need a separate device for parallel-to-serial conversion. One merely needs to shift the data word out of the accumulator, testing the link bit each shift, and outputting a pulse if a one is present in the link bit. ("The link is a 1-bit flip-flop register attached to the accumulator, and is used primarily in calculations in which 12 bits are not enough to represent the numbers involved," according to the Small Computer Handbook.) See an article by Park and Ohkuma in the Fall 1967 DECUS Proceedings. The article, by the way, describes a magnetic-tape system using an ordinary unaltered audio-tape transport for recording digital data. Cost of the interface is about $200, using commercial logic modules. This is one of the cleverest designs that I have seen for a digital magnetic-tape system at minimum cost.

Perhaps I have over-sold the virtues of the PDP-8 series of machines, but I think they have a number of minimum-cost design features that would benefit an amateur who does not have special reasons for using other, possibly more complicated, approaches.

Here are a few hardware ideas. For a control panel: Drill holes for all register indicator bits. Cover the whole panel with solid translucent plastic, with decals for labels. Insert lamps in holes in back of panel with only wires for connections to a backup mother board. Take a look at the PDP-8/S to see result.

We use strands from telephone cables in our wirewrap tool. The $50-or-so hand wirewrap tool from Gardner-Denver (Part. No. 14H-1C with No. 26263 bit and No. 18840 sleeve) is well worth the expense. Wire wrapping is a fantastic improvement over soldering connections. An unwrapping tool for $10 makes changing connections very simple. I would suggest that these are essential investments to ease much future pain.

The ACS member with the TTY code-conversion problem undoubtedly has a five-level Baudot code instead of ASCII. The simplest procedure for input would be to re-label T, CR, O. SP, H, N, M to represent the octal numbers 0 through 7. Larger binary numbers can then be assembled by shifting in the accumulator in the standard way. A hardware Baudot-to-octal conversion matrix could be constructed fairly easily, but once his computer can execute a few simple instructions, a table look-up program is simple to write and won't use up much memory. Output to the TTY would be via table look-up also. Only the 8 numbers in the octal number system need be converted, since text would be stored as is, and an assembler could be constructed by merely changing the symbol table definitions to Baudot, if his instruction set matches some commercial computer sold by a helpful salesman.

Several months ago I noticed IBM 1620 core stacks and drivers available for around $200. It happens that the 1620 accesses 12 bits per memory cycle, even though it is a decimal machine. That is, the memory is a 10K, 12-bit word size, and two BCD characters are accessed each memory cycle. Perfect core for a 12-bit machine. The PDP-8/S uses a 13-bit core, but the parity bit is really unnecessary since the machine comes to a screeching halt if a sense amplifier goes out and the machine starts getting incorrect parity. The 13th bit is probably a carry-over from its serial-memory ancestry. The 1620 memory has a 20-microsecond cycle time, which resulted in a relatively slow decimal machine, but would provide respectable speed in a binary configuration. Converting the decoding and core-driving logic might require some ingenuity.

Where one has some money to spend, I highly recommend the new Tektronix storage scope display Type 601 at $1050. I have just constructed an inexpensive interface, and find it a joy to get text output on the scope instead of waiting for the slow TTY to pound out results. Analog displays with a 35-mm camera for permanent records make this a very general-purpose interface.

Have thought about getting cheap logic cards. Of course, IBM SMS cards are readily available, but the connector is usually cut off. (Does anyone know where to get intact SMS cards?) Anyway, cut SMS cards probably could be most easily used by cementing on a short extension with an etched male PC connector. [For a cheaper way, see page 1 of the November 1967 ACS Newsletter.] A silk-screen outfit from your local art store is cheaper than the kit from Allied. Silk-screened and etched connectors for dozens of SMS cards could be made in a few hours.

This has been a rather rambling letter, but perhaps there are some ideas that will be of use to ACS members. I will be pleased to communicate with anyone who has chosen to use the PDP-8 instruction set and has programming or interfacing problems."

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Fred also sent along a short piece of paper tape to show why he chose those particular keys to be relabeled:

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DEC recently announced the PDP-8/L, a stripped-down model of the PDP-8. The interfacing circuits have been removed, and only a TTY can be used for I/O. The memory is 4K, with a maximum of 8K. Price is $8500, or $1500 less than the PDP-8.

As to a PDP-8/S kit, DEC says that there is the question of their responsability to the kit buyer. What happens if he can't make the kit work? Does he ship it back to the manufacturer, like a Heathkit, and get it fixed up for a price? Also, if the back panel is furnished pre-wired, how can the kit cost much below the assembled and tested price, because there isn't much to the assembly. And if the back-panel weren't pre-wired, how long would it take a man to go crazy trying to wire it all himself? DEC says the only practical place for a kit is the power supply, which is handwired.

HEATH MODULAR DIGITAL SYSTEMS

Speaking of Heath, if anybody has been patiently waiting for Heath to come out with a reasonably priced computer kit — forget it.

Recent Heath Company ads show the new 805 Universal Digital Instrument, which can be used as a frequency meter, events counter, digital voltmeter, time interval meter, etc. The same ads show the 801 Digital Analog System Modules, which include a power module, binary information module (10 neon lamps, 8 SPDT switches, 2 SPDT spring-return switches), timing module (0.1 cps to 10 Kc), and plug-in circuit cards (NANDs, dual JK flip-flops, dual one-shot, relay card, etc).

The 805 sells for $940 without the digital voltmeter function; $1250 with it, assembled. The 801 sells for $435 with a fixed set of 13 circuit cards. Other cards may be bought, at $10 to $40 each. Note that this is not a kit.

The 801 is for breadboarding circuits, using patch-wires that plug into the special connector boards on top of each card, which uses TTL integrated circuits.

At these prices, whatever more sophisticated digital circuits Heath may offer in the future will be quite expensive.

MOUNTING DIL ICS

Don Tarbell writes:

"I noticed some members are having trouble mounting dual in-line packages. A friend and I have gone together to form a small company which, among other things, manufactures a board for mounting the DIP's. You push the IC into the board from one side and solder to pads on the other side. There are two extra pads (also with holes) for interconnection to each pin. I use small telephone wire for interconnection, and find that a wire may easily be soldered and unsoldered many times without lifting a pad. A whole IC may be unsoldered by wicking the pads and prying it out, although I have found this not often necessary."

For a spec sheet on these IC breadboards, write:

Advanced Digital Design
P.O. Box 4409
Huntsville, Alabama 35802

The boards hold 32 of the 14-pin DIL ICs, cost $8 each.

Don continues: "In reference to Newsletter Number 7 (November 1967), page 5, SHIFT REGISTERS (by National Semiconductor), I wish to warn members that these shift registers are of the dynamic type, which require a continuous two-phase clock at a minimum of 10 Kc. This means that if the register is used to store data for future use, one must keep track of where it is in the continuous loop by an associated counter. I have done this, and have found that it loses no data if the power supply is adequately filtered. National also makes a dual 100-bit (200-bit) dynamic shift register which sells for $36 in single quantities; part number MM506."

Incidentally, Ungar now has an IC desoldering tip, No. 859, designed to "remove ICs rapidly without causing delamination." The desolderer melts all 16 solder pads at the terminals simultaneously. The device is designed for use with the Ungar 47½-watt heat unit, No. 4045, which fits the 777 or 776 handle. The Lafayette Radio price for the desoldering tip is $1.65; for the heat unit, $2.97.

WIRE-WRAP AND TERMI-POINT

For more information on tool-applied terminations, such as the wire-wrap discussed by Fred Sias earlier in this issue, see the February 1968 IEEE article, "Packaging/Interconnections, Part 1: Tool-Applied Terminations," pages 66 through 74.

BOOKS AND ARTICLES

"How to Build a Working Digital Computer," by Alcosser, Phillips and Wolk, Hayden Book Co., N.Y., 175 pages, $3.75.

The blurb on the back cover notes that the book "shows the reader how to construct a working model of a digital computer, using simple, inexpensive components." The six basic units are "encoder,

The Amateur Computer Society is open to all who are interested in building and operating a digital computer that can at least perform automatic multiplication and division, or is of a comparable complexity.

For membership in the ACS, and a subscription of at least eight issues of the Newsletter, send $3 (or a check) to:

Stephen B. Gray
Amateur Computer Society
260 Noroton Avenue
Darien, Conn. 06820

The Newsletter will appear about every eight weeks or so.

arithmetic unit, control panel, drum memory, core memory, and decoder."

The blurb is misleading, but the computer, although manually operated, is quite ingenious. The core memory is really a read-only memory made of paper clips, bent to form switches. The drum is also read-only, made of a large juice can and 29 paper clips that make contact with the drum through holes cut in graph paper wrapped around the can. The drum contains the program steps, using 26-bit instruction words.

The arithmetic unit consists of 39 DPDT switches and 5 SPST ones; the Appendix shows how you can build your own switches with paper clips and dowels.

This book may be of interest if you're working with a grade-school group or perhaps even a high-school bunch that's low on funds.

SQUARE ROOT

IC's Generate Instant Square Root, (EDN, March 1968, pp 26, 27), by Graham of Fairchild, gives a nice circuit for square root: To the 10's complement of the number is added 1, 3, 5, 7 ......, until the most significant bit changes to 0, at which point the total number of additions to the complement is the square root.

UNUSED LEADS

Q&A from the "Test Your IC IQ" page in Electronic Design (page 198, March 14, 1968):

Is there a rule of thumb to help us decide what to do with "extra" leads on digital ICs?

What is done with unused leads often depends on the particular circuit application. In general, it is safe to leave unused output leads open. Unused input leads, on the other hand, should be tied to ground or some other potential point to prevent parasitic transistor action or leakage under any possible signal combination. The best potential point to use will depend upon the circuit geometry, and in most cases will be apparent from the circuit schematic, which can be obtained from the manufacturer.

IC SOCKETS

An EEE survey on "Sockets for Integrated Circuits" appears in the July 1968 issue (pp 56, 58, 60, 61), and discusses packaging sockets, test sockets, contact problems and dielectric materials.

APPLICATION NOTES

The latest Application Note Catalog from Motorola, dated April 1968, lists 43 on digital circuits. Some are of little amateur interest, such as on IC reliability, but most give worthwhile design info, such as "Designing Integrated Serial Counters," or are about particular Motorola digital ICs.
