EduCALC TECHNICAL NOTES

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HP-41 EPROMs
Am I Ready For This Form Of Memory Expansion?

EPROM is an advanced user product[1] that allows the HP-41 user to make his own 'custom ROM' at a reasonable cost. Because EPROM is reprogrammable with the right equipment it is possible to make periodic changes. The memory available for EPROM usage is 4 or 8K in each port or a maximum of 32K if you use all four ports. It is possible to double this memory if banked switching (see below) is used. There are two reasons to use EPROM for storing your programs or data. The first reason is obvious, more memory—at a price—up to 65,536 words compared to 2,237 words in mainframe memory. The second reason is reliability. System crashes or a loss of power won't affect programs or data stored in EPROM, which is often the next consideration after running out of extended memory. One of the big advantages in using EPROM is that mainframe memory is made available for data register use. EPROMs and EPROM burning are subjects that are not covered in any of HP's owner's manuals related to the HP-41.

HISTORY

EPROMS[2] have traditionally been associated with engineering prototypes of software for computer systems. In the early days of the HP-41, Hewlett-Packard provided an EPROM box that was loaned to the customer who wanted to develop a custom ROM. HP's EPROM box was large, heavy, and required a substantial battery to power it. Jim DeArras of Richmond, Virginia designed an interface that low duty cycle sampled the EPROM during the read cycle so the heavy power drain was greatly reduced. Jim's EPROM box was still larger than the HP-41 itself, but it could be powered by the machine and still stay within the limit of 5 Ma maximum per port specified by Hewlett-Packard. A company was formed to produce the EPROM box and even though their main product lines are no longer dedicated to HP handhelds, EduCALC still carries items supplied by Hand Held Products. Jim received a patent for his unique interface.

The EPROMs used in the early EPROM boxes[3] were NMOS 2716 or 2732 type devices. Because the EPROM is used in place of an HP-41 ROM,[4] each word must be 10 BITS long. Commercial EPROMs are organized and addressed as 8 BIT words. This presents a problem on how to efficiently use memory, whether two consecutive EPROM words be used for each HP-41 word with 6 BITS wasted, or should two EPROMs be used with one being dedicated to the lower eight BITS and another, smaller size, dedicated to the upper two BITS. Each EPROM word could store the upper two BITS of four HP-41 words. Three manufacturers were involved at the time; Hewlett-Packard, Dallas Development Systems, and Hand Held Products. After much discussion, all three companies agreed to use the same format that HP started with, and most EPROMs of that era will have L8 or U2 marked on their labels. These EPROMs are standard packaged ICs often called 'bugs' or erroneously called 'chips'—a chip, or die, is an unpackaged integrated circuit. They are completely different from what most users today know as EPROMs. Later, other companies such as CMT and W & W entered the marketplace. The CMT EPROM box was called the CMT-110 and EPROMs for this model are still available in the EduCALC catalog. The smallest size package that was available had a single pair of sockets in the standard HP card reader shell. Hand Held Products and W & W offered card reader EPROM boxes.

A benefit of using EPROMs is the ability to expose the EPROMs to ultraviolet light to erase them and make changees by re-burning. The power saving circuits, addressing two different EPROMs, and interfacing to the unique HP-41 ports, required considerable electronics. The EPROMs were low cost, three to eight dollars each, but the EPROM box with its expensive special sockets cost from 100 to several hundred dollars. Handling and storing the EPROMs also

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[1] See Technical Note 8, 'Advanced User Products.'
[2] See Technical Note 19, 'HP-41 Glossary Of Terms,' for additional information on terms used in this TN.
[3] See Technical Note 5, 'Adding More Memory To My HP-41.'
[4] See Technical Note 13, 'Programming 'Languages' On the HP-41.'

presented a problem for non-technical users who didn't understand that the leads most be kept straight and that electrostatic charges could damage or alter the memory contents. What was needed was a package for the EPROM that would protect it physically, yet still use garden-variety low-cost EPROMs. In terms of today's products the PSION Organizer design solves this problem. In HP-41 terms, it took CMT to make the tremendous investment to put all the electronics in into an integrated circuit which would reduce the size of the EPROM box to that of a normal plug-in module. The CMT-10 combines the EPROM 'box' and the EPROM itself into one package. CMT also used the latest technology CMOS EPROMs which kept the power requirements to acceptable levels. The combining of the EPROM box with the EPROM itself did two things. First, it confused the users who were familiar with EPROMs and EPROM boxes. One term was being used for both. Second, it increased the cost of an 'EPROM' from the $5 range to the $100 range. For every EPROM you had to buy a 'box.' Using the obsolete card reader W & W #41-526 as an example, a user who needed half a dozen EPROMs would pay $150 for the EPROM box and $60 for the EPROMs. This total cost of $210 is in contast to six CMT 10 EPROMS at $100 each for a total of $600. The advantges of the smaller second generation HP-41 EPROMs is convenience, reliability, and modules identical to regular plug-in ROMs. The internal organizatin of memory is no longer important to the user because there is only a module, not two devices to get mixed up when plugging them in.

SECOND GENERATION

The second generation EPROMs that included the interfacing electronics also added another capability. Their memory organization is to use two consecutive EPROM words for each HP-41 ROM word. The extra six BITS are not wasted, but used to add features to the EPROM. One very important feature is the concept known as bank switching. Basically the idea is like making a special box that allows you to plug in four modules into each port. A selector switch is used to switch in the desired module. Banked switch EPROMs use the same idea except the switching is done automatically. This gives the user the ability to have 8 or 16K of programs (or data) in the same address space that previously only used 4K. HP was the first company to offer a banked switched product, a ROM. When the HP-41CX was introduced it added three 4K pages (2, 3) of ROM memory using only two pages of address space. Page five was banked switched. The user does not know that this is happening, and the idea of bank switching memory is used with the most successful computer systems that outgrow their designed range of memory addresing. Bank switching has its limitations, and it is important to be aware of them.

CMT introduced bank switching to commerical EPROMs. HP also offers a plug-in ROM module that is bank switched, the Advantage ROM. This ROM is a 12K ROM that uses the 8K addressing range of one port. The CMT 16K EPROM, for example, uses the same method of bank switching that HP uses except it is logically extended to add a second 4K page to the one HP added. One of the 4K pages is called the primary bank. The program pointer is placed in this page whenever the HP-41 is turned on. An 8K EPROM has two banks, bank 0 and bank 1. If it is to be a 12K banked switched EPROM, bank 1 becomes the primary bank. When the bank switch instruction is executed the program pointer is switched to the next address of bank 2. If the EPROM is a 16K version the switching may be between bank 1, 2, or 3. The problem with the CMT design is that when the microprocessor stops, or the machine is turned off, the switching logic returns the program pointer to the primary bank. This means that programs must not stop for input. This puts a severe contraint on how the EPROM may be programmed. Zengrange, of the UK, solves this problem with their ZEPROM, which does not switch when the processor stops. The ideal bank switching concept is to bank switch a 4K page with three additional 4K pages for a total of 16K in an addressing space of 4K. This advancement has been announced but is not yet available from VM Electronics in Denmark.

WHAT'S INVOLVED?

An EPROM may be used because you need more memory, or it may be the first step toward developing a commercial product. If it is the latter, the next step after a fully tested EPROM is burned is to order your 'ROMs' in quantity either in 10 or more as an OTP, or as a regular ROM if the quantity is in the 100 to 250 piece range.

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Putting your program or data into EPROM costs money. You either have an EPROM burned, or you burn it yourself. If you are thinking of offering your programs as a commericial product you probably should burn your own EPROMs. If you have frequent changes to your programs you should also make the investment to burn and erase your own EPROMs. You may want to consider having an EPROM burned even if you do not program very much yourself. You may just want to gather the programs you use frequently and put them all into one convenient module. These may be programs out of your favorite ROMs, or they may be programs obtained from any source. They may even be a mixture of user code and and MCODE[1], but the extraction of MCODE routines from ROMs requires considerable skill and testing. These routines should be evaluated by the EPROM burning service before having this done. Remember the copyright laws if you intend you sell copies of your EPROM.

To help organize your EPROM, request a copy of the worksheet stock number 41-617. Study the first three pages, then complete the form and send it in with your order to burn the EPROM. See EPROM Services in the EduCALC catalog. If you are going to burn your own EPROMs you will need three items: an EPROM burner, an EPROM eraser, and software to burn HP-41 formatted EPROMs. The various equipment is discussed below. The most straightforward item is the EPROM eraser. Any type will work although the short wavelength ultraviolet models will save time because they will erase an EPROM in 2-3 minutes. Some models have large drawers for multiple EPROMs while the lowest cost models will hold only one or two EPROMs. Some have timers that automatically turn off the lamp so as not to overexpose the EPROMs. Prices range from $50 to hundreds of dollars. EduCALC may offer a low cost general purpose EPROM eraser in the future.

WHAT DOES IT COST?

Having your EPROM burned by someone else saves the investment cost of an EPROM burner and eraser as well as the time required to get familiar with EPROM technology, programs, and equipment. The EduCALC catalog lists these. Remember that the CMT-110/HHP EPROMs are true EPROMs. As described above these are first generation EPROMs (true EPROMs) and they require an EPROM box. That is why they are lower in cost than the other EPROMs.

The service vs invest-your-own-time equipment decision can be made based on the importance of turn-around time and the number of times you will need to burn an EPROM. EPROMs are typically burned three times before they are in final form. This does not include the types that will change because the programs change. The many unexpected re-burns occur because you will experience differences when all your programs are available at one time compared to testing them individually. Name conflicts, data form or location changes for chaining programs, etc., all become more apparent when they are together in one 4, 8 or 16K EPROM.

The lowest cost do-it-yourself approach is to buy a ZEPROM (only one 16K size is available), a One at a Time programmer, and some extra alkaline batteries. The investment will be $126 + 60 + 4 for a total of $190. Because the programs you will use to burn the ZEPROM are in one of its four pages, you will have only 12K of space—16K of addressing—for your own programs. You can put the burn programs in some other form such as a 4K EPROM or RAM box, erase the ZEPROM first, and bank-switch program it so you have 16K or your own programs in 8K of addressing space. This will require additional equipment and skill. The next step up the ladder is to buy a ZEPROM programmer from Firmware ($600) to burn your own ZEPROMs. This programmer is very easy to use and it provides an 8K RAM box to allow you to fully test everything before actually burning the ZEPROM.

If you study the catalog you will notice that the CMT EPROMs are lower in cost than ZEPROMs. These will be attractive if you are going to have them burned for you or if you need only one 4K module. If you are going to burn them youself, however, you will have to factor in the cost of the EPROM burner. You will need the HP-IL stock number IL-615 and the CMT-10

[1] See Technical Notes 19 and 13 for additional information on these terms.

fixture for a total investment of $1,445. Compared to the $600 ZEPROM investment the difference in EPROM prices will require a large number of EPROMs to be burned to justify the IL programmer. Usually individuals buy the ZEPROM programmer whereas businesses invest in the more general IL programmer. Two examples taken from catalog 39 will illustrate.

27 4K EPROMs are to be burned; which is the lowest cost system?

27 × $90 ea = $2,430 + $1,445 for burner = $3,875 using CMT EPROMs
27 × $126 ea = $3,402 + $ 445 for burner = $3,847 using ZEPROMs

Using the Firmware programmer and ZEPROMs is the lowest cost approach.

If 28 or more 4K EPROMs are to be burned, CMT EPROMs are lowest in cost.

If, however, the 16K size were compared, the cross over point where the CMT EPROMs would be lower in cost would be 53 or more EPROMs.

A similar analysis could be made for burning EPROMs yourself vs having them burned at $50 each. Because of the many possiblilites, you will have to do your own analysis. Keep in mind the non-cost considerations. You may, for example, not have the funds to invest in a programmer. The IL programmer is a general tool and it will probably have the ability to burn ZEPROMs in the future. It is more of a professional tool that will burn many different kinds of EPROMs whereas the other programmers are dedicated to the HP-41 EPROMs. Also keep in mind that there will always be pressure to expand memory and the ZEPROM bank switching works best. The ZEPROM is more flexible in that it may be configured when burned. One good approach would be to have the ZEPROM program ROM burned in a CMT 4K ROM and use it with the ONE-OFF programmer. This added $140 investment makes the burning process easier, gives more ports, and allows the full power of the ZEPROM system to be used.

The above cost analysis only considered the EPROM and programmer costs. There are other considerations such as additional hardware and software. The latter, like the choice of professional (IL) vs amateur (ONE-OFF) programmer involves the value of time. Programs that assemble, move, and store ROM images are very important time savers. Also it should be pointed out that when you use EPROM memory capacities of 4K files, you will eventually realize the importance of having some form of mass storage to back up your files. Taking this into consideration you may opt for having the EPROM service burn your EPROMs simply because you don't have the funds available for investment. If you are planning on a commercial product you had better be prepared to make the hardware investment. Time is important because the HP-41 is in the twilight of its life.

CONCLUSION

HP41 EPROMs are advanced user products that greatly expand the memory of the HP-41 by using ROM addressing. Burning your own programs into EPROM requires knowledge that is not provided by Hewlett-Packard in its owner's manuals. Burning a CMT 4K EPROM a reasonable cost option (about $140) to putting your programs into 'ROM' form and making mainframe memory available for data registers. Beyond this simple memory expansion example, the best approach requires considerable knowledge about EPROMs that is only briefly covered by this Technical Note. VM Electronics will probably offer its EPROM technology in the future. Their bank switching allows a full 16K using 4K addressing space. This could ultimately allow a double module in each port for a total of 128K of your own programs. Compared to the 2K in mainframe RAM this is spectacular.