User-Written Software for ATARI Home Computers
COSMATIC ATARI DEVELOPMENT PACKAGE

DISKETTE (APX-20051)
REQUIRES: 32K RAM
COSMATIC ATARI DEVELOPMENT PACKAGE

by

John R. Powers, III

Program and Manual Contents ©1982 John R. Powers, III

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******************************************************************
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PART I: THE COSMATIC ATARI

An 1802 Cross-Assembler
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INTRODUCTION

OVERVIEW

The COSMATIC ATARI is a cross-assembler for 1802 assembly language. The program takes your 1802 assembly language program and produces hex machine instructions and data. The 1802 microprocessor is used in many popular hobby computers and games because of its low cost and ease of implementation. Example systems include:

- RCA COSMAC Development System
- VIP Game Computer by RCA
- Studio II Programmable Game by RCA
- Hughes Development System
- ELF II Hobby Computer by Netronics
- The Anything Board by Netronics
- Super EIF by Quest Electronics
- CyberVision Home Computer
- Popular Electronics' COSMAC ELF Series

This cross-assembler will let you write 1802 programs in assembly language using all the power of symbolic references, mnemonics, and operand expression processing. You will have the same capabilities of systems costing over $5,000.
THE COSMATIC ATARI

FEATURES OF THE COSMATIC ATARI INCLUDE:

- Superset of both the RCA CRA Assembler and the Hughes HMDS Assembler
- The ability to add extensions
- Full operand expression evaluation with nesting to 10 levels
- Source File chaining option
- Sorted label table output
- Assembly at 20-to-30 source statements per minute
- Unique two-step methodology permitting the use of the intermediate file as backup
- Output fully compatible with UT4 and UT20 hex loading utilities
- Creation of source code file with or without line numbers for input to the assembler
- Sample 1802 source files to demonstrate and test features
THE COSMATIC ATARI

SYSTEM REQUIREMENTS

The COSMATIC ATARI requires the following:

- An ATARI Computer with 32K or more of memory
- ATARI BASIC Language Cartridge
- One or more ATARI 810 Disk Drives

An ATARI printer is optional.

THE SCOPE OF THIS MANUAL

This manual instructs you in the use of the COSMATIC ATARI program. It is not an instruction guide to 1802 programming.

Information is also provided on how the COSMATIC ATARI works as well as tips on how to add extensions to the implementation. The sample 1802 source files on the diskette are included to give you plenty of examples.

One note on terminology used in this manual - since the primary output of the COSMATIC ATARI is hex machine instructions and data, BASIC programmers may be confused by the use of byte-related terms. Here are some definitions:

**Character**
- A symbol representing a digit or letter. Examples are "0-9" and "A-F".

**Byte**
- An 8-bit quantity represented by two characters. Examples are "00,01,02,..., FF". The terms "byte" and "hex byte" are used interchangeably.

**Two Bytes**
- A 16-bit quantity represented by four characters. Used interchangeably with "a pair of bytes" or "Four-digit hex number".

All input to the COSMATIC ATARI is in the form of characters representing decimal and hexadecimal (hex) digits and alphabetic characters. All assembled output from the cosmatic ATARI is in the form of characters representing hexadecimal digits.
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USING THE COSMATIC ATARI

GET READY AND GO

Prepare your 1802 assembly language source program and store it on a diskette file. Source language preparation can be done with the ATARI Assembler-Editor cartridge, the ATARI Program-Text Editor™ (available through APX), or similar text editors. If your 1802 source file has line numbers, such as those produced by the Assembler-Editor cartridge, the COSMATIC ATARI will automatically skip over them. In every case, the last line in the source file must contain the "END" directive.

You may also enter source lines directly to the COSMATIC ATARI. In this case, your source file name is "E:" for the screen editor.

Insert the program diskette and RUN "D:ASM" to load and execute the COSMATIC ATARI. The first screen will show the copyright message and a message indicating that the program is preparing data. This will take a few seconds.

When the program is ready, you will be prompted for the source input file name. Include the device code (e.g., D: for disk drive). You will then be prompted for the hex output file name. Include the device code. Alternatives to disk file output include "S:" for the screen and "P:" for the printer.

Following the first step of reading through the source code, the label table will be displayed in alphabetical sequence. You will then be prompted to press RETURN so that step two can start. Following step two, you will be prompted to press RETURN to restart the program.

FILE USAGE

You will be defining the file names for input to and output from the COSMATIC ATARI. In addition, the program will create a temporary file defined as "D:COSMAC.TMP". Be sure your diskette in drive one does not have the write protect tab in place.

Your APX diskette contains many files for you to use. Only one file is essential, that is "ASM", the program in BASIC SAVEd format. The other files are 1802 source files intended to demonstrate the capabilities of the COSMATIC ATARI. They are:

<table>
<thead>
<tr>
<th>FILE NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPAR01.LST</td>
<td>Test of Parsing</td>
</tr>
<tr>
<td>TOND01.LST</td>
<td>Test of Operand Expressions</td>
</tr>
<tr>
<td>TDAT01.LST</td>
<td>Test of Data Statements and END</td>
</tr>
<tr>
<td>TDATE02.LST</td>
<td>Evoked by TDAT01.LST</td>
</tr>
<tr>
<td>TFWD01.LST</td>
<td>Test of Forward References</td>
</tr>
<tr>
<td>TOPC01.LST</td>
<td>Test of all op-codes</td>
</tr>
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<td>TMSG01.LST</td>
<td>Demonstration of program messages</td>
</tr>
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<td>CLICK.LST</td>
<td>Sample Feature mix</td>
</tr>
<tr>
<td>FECHR.LST</td>
<td>Simple macro routine</td>
</tr>
</tbody>
</table>
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All the 1802 source files have line numbers so that you can ENTER them into the Assembler-Editor Cartridge. Or you may simply COPY the file to your printer (P:) or screen (S:) using the DOS 2.0S copy option.

You are encouraged to look at the sample files to see all the things the COSMATIC ATARI can do for you. It is also an excellent way to see examples of source line syntax. The samples are deliberately ragged to demonstrate the flexibility of the cross-assembler.

An additional file on your diskette is "ASMP". That is the printer version of "ASM", in BASIC SAVED format. "ASMP" may be used in place of "ASM" if you have an 80-column printer.

MESSAGES

There are only a few messages generated by the COSMATIC ATARI. Extensive error checking would make the assembly uselessly slow. The program will attempt to assemble no matter what. You will need to inspect the hex output if you suspect the accuracy of your source code syntax.

The following messages are possible:

- **Function?** Expecting function code preceding a left parenthesis.
- **Re-defined Label** Permissive warning message. The label has been redefined, discarding the previous value.
- **Unknown Op-Code** The op-code mnemonic was not found in the op-code table.
- **Error opening file** Error occurred while attempting to open file.
- **n forward references** Informative message only.
- **Bad hex** A character other than 0-9 or A-F occurred in a hex number.
- **n unsatisfied references** References were made to undefined labels. A *; line will be generated in the hex load file for each unsatisfied reference.

A line such as the following may occur in the final, step two output:

```
XXXX ;* source line
```
Where XXXX is a hex address and the "source line" is a duplicate of a line of your source. This line occurs after the second step when a label in the source line was never defined in the program. This is an unsatisfied reference and the ";*" is the mark for that condition.

The above line may also occur in the intermediate file output of step one. That is okay as it is assumed to be a forward reference which will be satisfied in step two.
A TWO-STEP ASSEMBLER

Most assemblers read the source file twice, once to collect labels and addresses and then to generate the hex output. That is a two-pass approach.

This assembler uses a two-step approach. The first step generates an intermediate file which, in turn, is the input for the second step. Each file is read only once.

The first step collects labels and addresses and attempts to generate hex output. If there are references to labels which have not yet been defined, the generation of hex code for these cases is deferred until the second step. These are called forward references. If the source file contains no forward references then there are no source statements deferred until the second step. In these cases, the intermediate file is almost identical to the second-step output file.

The approach is basically recursive. The source line processor treats each step identically. This means that forward references unsatisfied in the second step are passed on to the output file for imaginary third-step processing. An error message is generated when this occurs.

The net effect is a very efficient assembly algorithm which helps to compensate for the natural slowness of BASIC interpretation.

Within each source line, the operational steps are as follows:

1. Parse line into
   a) label
   b) op-code
   c) operand
   d) comment
       using blanks as delimiters

2. Store label and address, if present

3. Lookup op-code or directive, if present

4. Evaluate operand, if present

5. Store generated hex

6. Go to (4) if comma present, else next source line
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The lookup of op-codes and labels uses a binary search in a sorted list. The insertion of newly-defined labels is done so as to maintain the sorted list. A binary search is much faster than a linear search, helping to compensate for the slowness of BASIC interpretation.

OPCODES

The assembly of op-code mnemonics into hex instructions is table-driven making changes and extensions easy. You may, for example, wish to add new op-codes to incorporate the expanded 1800-microprocessor family.

The op-code table is located in lines 30400 thru 30999. Each op-code field consists of seven characters as follows:

<table>
<thead>
<tr>
<th>Char 1-4</th>
<th>Op-code mnemonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-6</td>
<td>Machine-code hex</td>
</tr>
<tr>
<td>7</td>
<td>Type</td>
</tr>
</tbody>
</table>

How the machine-code hex is assembled depends on the type identified in character 7. The types are:

0  The machine-code hex is used exactly as shown with no additional hex bytes. Any operand data is ignored.

1  The machine-code hex is used exactly as shown followed by one additional hex byte. An operand is required. Only the lower-order 8-bit byte portion of the evaluated operand is used.

2  The machine-code hex is used exactly as shown followed by two additional hex bytes. An operand is required. The full, 16-bit two-byte evaluated operand is used.

3  Only the higher-order 4-bit nybble (half a byte) portion of the machine-code hex is used. An operand is required. The lower-order 4-bit nybble portion of the machine-code hex is formed from the lowest-order 4-bit nybble portion of the evaluated operand.

4  Directive or special case. The machine-code hex is optional and is entirely a function of the unique directive processing (see below).

All op-codes and directives must be in ascending alphabetic sequence in the table. They must be unique in name, but need not be unique in function. The end of the list must be marked with an asterisk terminator.
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The op-code and directive table will be stored in memory by the program, and operations will be automatically adjusted for its size.

DIRECTIVES

Directive mnemonics are located in the same table as the op-codes (see above). The "Type" portion of the directive table data determines processing. The op-code section describes how to add new mnemonics.

Directive processing is located in lines 18000 thru 19999. Specific directive lines are as follows:

<table>
<thead>
<tr>
<th>Directive</th>
<th>Type</th>
<th>Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>(not assigned)</td>
<td>4</td>
<td>18100 - 18199</td>
</tr>
<tr>
<td>ORG</td>
<td>5</td>
<td>18200 - 18299</td>
</tr>
<tr>
<td>PAGE</td>
<td>6</td>
<td>18300 - 18399</td>
</tr>
<tr>
<td>INP</td>
<td>7</td>
<td>18400 - 18499</td>
</tr>
<tr>
<td>(not assigned)</td>
<td>8</td>
<td>18500 - 18599</td>
</tr>
<tr>
<td>END</td>
<td>9</td>
<td>18600 - 18799</td>
</tr>
</tbody>
</table>

Types 4 and 8 are available for your use. The existing directives can serve as examples. The following variables may be useful:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>The decimal value of the evaluated operand.</td>
</tr>
<tr>
<td>PC</td>
<td>The decimal current program address counter, the value of the asterisk (*) symbol.</td>
</tr>
<tr>
<td>TLEN</td>
<td>The decimal count of the number of bytes assembled for this statement.</td>
</tr>
<tr>
<td>OPHX$</td>
<td>The op-code hex set by your routine. Length is zero upon entry, may be zero, one, or two characters upon exit. (Remember, it takes two characters to represent one hex byte)</td>
</tr>
<tr>
<td>OPHX$</td>
<td>The operand hex set by your routine. Length is zero upon entry, may be from zero to 80 characters upon exit.</td>
</tr>
</tbody>
</table>
The following subroutines may also be helpful:

GOSUB 28800
Converts decimal D to its 4-character, two-hex-byte string representations H$.

GOSUB 28900
Converts the 4-character, two-hex-byte string representation, H$, to its decimal representation, D.

**EXPRESSION OPERATORS**

You may define your own operand expression operators if you wish. The allocated operators are as follows:

<table>
<thead>
<tr>
<th>Char.</th>
<th>ASC (char)</th>
<th>WOP</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>37</td>
<td>1</td>
<td>not defined</td>
</tr>
<tr>
<td>&amp;</td>
<td>38</td>
<td>2</td>
<td>not defined</td>
</tr>
<tr>
<td>'</td>
<td>39</td>
<td>3</td>
<td>not defined</td>
</tr>
<tr>
<td>(</td>
<td>40</td>
<td>4</td>
<td>reserved</td>
</tr>
<tr>
<td>)</td>
<td>41</td>
<td>5</td>
<td>reserved</td>
</tr>
<tr>
<td>*</td>
<td>42</td>
<td>6</td>
<td>reserved</td>
</tr>
<tr>
<td>+</td>
<td>43</td>
<td>7</td>
<td>add</td>
</tr>
<tr>
<td>,</td>
<td>44</td>
<td>8</td>
<td>reserved</td>
</tr>
<tr>
<td>-</td>
<td>45</td>
<td>9</td>
<td>subtract</td>
</tr>
</tbody>
</table>

Operator execution is localized in lines 14220 thru 14240. For example:

14230 If WOP = 7 THEN WAC = WAC + D
14232 If WOP = 9 THEN WAC = WAC - D

The variable "WAC" is the expression accumulator and "D" is the value of the previously-evaluated portion of the expression. To review, expressions are evaluated from inner-to-outer parentheses levels and from left-to-right at the same level.

It is very easy to add multiplication and division to your program. You simply decide which symbols you want to assign out of those available. The operator table above shows three possibilities: %, &, and ,. The program operator codes are 1, 2, and 3 respectively. If you were to use the first two, simply add the following two lines:

14234 If WOP = 1 THEN WAC = WAC / D
14236 If WOP = 2 THEN WAC = WAC * D
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The nesting and evaluation of constants and variables within the expression is handled for you. All you have to do is write your source line expressions using the two new operators as desired.

LABEL TABLE

All labels are dynamically sorted and stored in array LAB$ as they are encountered and evaluated. The dimensioned length of this array determines the maximum number of labels. There is no overflow checking.

The array LAB$ also holds all the op-codes and directives. The partitioning of the array is handled automatically by the program. In the released version of the program, 588 characters are used for op-codes and directives. This leaves 1012 characters for labels. Since the 4-character hex representation of the label's value is stored along with the 6-character label, 10 characters must be allowed for each label. The result is room for 101 labels. Increase the dimension of LAB$ in line 29110 by 10 for each additional label. The dimension can be expanded to about 5000 characters ((5000-588)/10= 441 labels) and still run on a 32K system. There is no performance penalty for dimensioned but unused label storage.

INTERMEDIATE FILE

The file "COSMAC.TMP" is used by the program to store the results of step one. This file may be discarded after step two. However, it may be considered a backup file since its contents are stored in hex load format. The hex load format and file usage are described in other sections.

To change the temporary file name, only line 27080 need be altered. This line also defines the device upon which the temporary file is resident (default is "D:"). The released version contains:

```
27080 FD2$ = "D:COSMAC.TMP"
```

HEX LOAD FILE

The output of the assembler is a hex load file. This is a character file with one record of hex digits per record of source. Source lines which do not generate hex digits (e.g., comments and various directives) have no corresponding output.

The hex load file format is as follows:

<table>
<thead>
<tr>
<th>Char</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>hex load address</td>
</tr>
<tr>
<td>5</td>
<td>blank</td>
</tr>
<tr>
<td>6-end</td>
<td>hex literals to load terminated by a semicolon (;)</td>
</tr>
</tbody>
</table>
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Comments may follow the semicolon up to the end-of-line.

The intermediate file (COSMAC.TMP) is also in hex load format. Source lines deferred for step two are made to look like comments in the intermediate file output.
TYPES OF SOURCE STATEMENTS

instructions
directives
comments

INSTRUCTIONS AND DIRECTIVE FORMAT

LABEL OP-CODE OPERAND ..COMMENT

Fields are separated by one or more blanks. The label field must start in
column one or two or, if not present, at least two blanks must precede the
op-code field. The comment, if present, must be preceded by two consecutive
periods (..). A RETURN terminates the source line.

-Options: (1) The label field may take the form "LABEL:". In this case the
label may start in any column and need not be separated from
the op-code field by any blanks.

(2) The comment, if present, may be preceded by a semicolon (;)
rather than consecutive periods (..).

LABEL
1-6 alphanumeric characters; first character must be uppercase alphabetic.

OP-CODE
An 1802 instructions mnemonic or directive

OPERAND
Register data

R0, R1, R2, ..., RF
0, 1, 2, ..., 9, 10, ..., 15
#00, #01, ..., #0F

Single-byte data

For immediate instructions and short branches
range 0 to 255, #00 to #FF

Address Data

For long branches
range 0 to 65535, #0000 to #FFFF
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I/O device code

Integer from 1 to 7

COMMENTS

Must be preceded by semicolon (;)
or consecutive periods (..).
May begin in any column.

DECIMAL DATA

No prefix

HEX DATA

Must be preceded by pound sign (#).
Must be from one to four hex digits.
Assumed to be right-justified in a four-hex-digit field.
Option: may be preceded by a dollar sign ($) rather than a pound sign.

CURRENT PROGRAM ADDRESS COUNTER

Asterisk (*) is the symbol.
The address of the first byte of the
instruction or data statement in
which it occurs.
Used in operand field only.

LABEL VALUES (EQUATES)

LABEL=OPERAND

Creates the label and stores the value of the operand.
Any valid operand expression may be used.
Evaluated to a two-byte, 16-bit value.
Label may start in any column.
There must be no embedded blanks.

OPERAND EXPRESSIONS

May be used for any operand.
Operators:
   + addition
   - subtraction

Functions:

H(expr)  High byte (8-bits)
L(expr)  Low byte (8-bits)
A(expr)  Two bytes (16-bits)
B(expr)  Two bytes, reversed (16-bits)
Rules:

Multiple operators may be used in any sequence.
Parentheses may be nested to ten levels.
Expressions are evaluated first from the innermost parentheses,
then from left-to-right within a parentheses pair.
The asterisk (*) current program counter may be mixed in the
expression.
Decimal and hex values may be mixed.
Labels and constants may be mixed.

Options (1) A.0(expr) may be used for L(expr).
(2) A.1(expr) may be used for H(expr).

DIRECTIVES

ORG OPERAND

Sets the current program address counter to the value of the operand.
Forward references not supported.
Any valid operand expression may be used.
Evaluated as a 16-bit address.

PAGE

Increments the current program address counter to the beginning of the
next memory page.
Equivalent to H(L(B(*))+1)
or H(*+#0100).

LABEL DC OPERAND, OPERAND, ...

Defines memory-resident constants.
Label, if used, references first byte.
Each operator is evaluated to one byte unless the outermost function
is A(exp) or B(exp), which is evaluated to two, 16-bit bytes.
Each one- or two-byte element in an operand list must be separated
by a comma.
Any valid operand expression may be used.
END chain-file-name

Must terminate a source module.
The chain-file-name, if present,
defines the next source file to be assembled without operator
intervention. All labels remain valid for the chain-file. The
current address program counter remains current.
The device id should not be included in the chain-file-name. The
COSMATIC ATARI will use the same device that the previous source
file was on.

DATA STATEMENTS

Occasionally it is convenient to assemble hex data along with the hex
machine instructions. Examples include data tables, table indices,
display pixels, parameter passing, and macros. There are two ways to
assemble hex data:

1. The DC op-code
2. the comma (,) delimiter

The DC op-code takes the form:

LABEL DC OPERAND

The label is optional. The operand is a standard operand expression and is
evaluated to a 2-byte 16-bit quantity. The length of the stored hex depends
on the outermost expression function. The possibilities are:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC #12</td>
<td>12</td>
</tr>
<tr>
<td>DC #ABCD</td>
<td>CD</td>
</tr>
<tr>
<td>DC A(#12)</td>
<td>0012</td>
</tr>
<tr>
<td>DC A(#ABCD)</td>
<td>ABCD</td>
</tr>
<tr>
<td>DC L(#1234)</td>
<td>34</td>
</tr>
<tr>
<td>DC H(#ABCD)</td>
<td>AB</td>
</tr>
<tr>
<td>DC B(#1234)</td>
<td>3412</td>
</tr>
</tbody>
</table>

Another method is to use the comma (,) delimiter. Any operand that follows a
comma (note, no blanks!) will be assembled as a hex data constant. More than
one comma may be used in a single source line. Examples are:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME ,4</td>
<td>04</td>
</tr>
<tr>
<td>,#12,A(#ABCD)</td>
<td>12ABCD</td>
</tr>
<tr>
<td>SEP CALL,A(SUBR)</td>
<td>D41001</td>
</tr>
</tbody>
</table>

(-16-)
<table>
<thead>
<tr>
<th>Statement</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDI #33,#44, L(#1234)</td>
<td>3344</td>
</tr>
<tr>
<td>A(#1234),A(#5678), #1234,#5678</td>
<td>12345678, 3478</td>
</tr>
</tbody>
</table>

Only one or two bytes (8 or 16 bits) may be assembled for each comma. Examples of the uses for data statements are as follows:

```plaintext
.. TABLE INDEX
DIGS:  DC A.0(DIG0)
      DC A.0(DIG1)
      DC A.0(DIG2)

.. DISPLAY PIXELS
DIGF:  DC #F0,#80
DIGF:  DC #F0,#80,#80,#80

.. PARAMETER PASSING
SEP   R4,A(SUBR1),#F4
LDI   A.0(SUBR2)
PLO   R1
SEP   R1,#20,#00

.. MACROS
FECH=#D7
,FECH,#01
```
THE COSMATIC ATARI

USER NOTES

To assign values to symbolic names use

```
LABEL=OPERAND
```

To set aside memory storage use

```
ORG *n
```
Where n = number of storage bytes

To mask the lower 8-bits of a 16-bit address use

```
L(#abcd) yields #00cd
```

To mask the higher 8-bits of a 16-bit address use

```
H(#abcd) yields #ab00 if not outermost function

H(#abcd) yields #ab if outermost function and used for a single-byte op-code
```
<table>
<thead>
<tr>
<th>Syntax</th>
<th>Machine System</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC</td>
<td>74</td>
<td>0</td>
<td>Add with carry</td>
</tr>
<tr>
<td>ADCI expr</td>
<td>7C</td>
<td>1</td>
<td>Add with carry immediate</td>
</tr>
<tr>
<td>ADD</td>
<td>F4</td>
<td>0</td>
<td>Add</td>
</tr>
<tr>
<td>ADI expr</td>
<td>FC</td>
<td>1</td>
<td>ADD immediate</td>
</tr>
<tr>
<td>AND</td>
<td>F2</td>
<td>0</td>
<td>And</td>
</tr>
<tr>
<td>ANI expr</td>
<td>FA</td>
<td>1</td>
<td>And immediate</td>
</tr>
<tr>
<td>B1 expr</td>
<td>34</td>
<td>1</td>
<td>Short branch if EF1=1</td>
</tr>
<tr>
<td>B2 expr</td>
<td>35</td>
<td>1</td>
<td>Short branch if EF2=1</td>
</tr>
<tr>
<td>B3 expr</td>
<td>36</td>
<td>1</td>
<td>Short branch if EF3=1</td>
</tr>
<tr>
<td>B4 expr</td>
<td>37</td>
<td>1</td>
<td>Short branch if EF4=1</td>
</tr>
<tr>
<td>BDF expr</td>
<td>33</td>
<td>1</td>
<td>Short branch if DF=1</td>
</tr>
<tr>
<td>BN1 expr</td>
<td>3C</td>
<td>1</td>
<td>Short branch if EF1=0</td>
</tr>
<tr>
<td>BN2 expr</td>
<td>3D</td>
<td>1</td>
<td>Short branch if EF2=0</td>
</tr>
<tr>
<td>BN3 expr</td>
<td>3E</td>
<td>1</td>
<td>Short branch if EF3=0</td>
</tr>
<tr>
<td>BN4 expr</td>
<td>3F</td>
<td>1</td>
<td>Short branch if EF4=0</td>
</tr>
<tr>
<td>BNF expr</td>
<td>3B</td>
<td>1</td>
<td>Short branch if DF=0</td>
</tr>
<tr>
<td>BNQ expr</td>
<td>39</td>
<td>1</td>
<td>Short branch if Q=0</td>
</tr>
<tr>
<td>BNZ expr</td>
<td>3A</td>
<td>1</td>
<td>Short branch if D not 0</td>
</tr>
<tr>
<td>BQ expr</td>
<td>31</td>
<td>1</td>
<td>Short branch if Q=1</td>
</tr>
<tr>
<td>BR expr</td>
<td>30</td>
<td>1</td>
<td>Short branch</td>
</tr>
<tr>
<td>BZ expr</td>
<td>32</td>
<td>1</td>
<td>Short branch if D=0</td>
</tr>
<tr>
<td>DEC reg</td>
<td>20</td>
<td>3</td>
<td>Decrement register</td>
</tr>
<tr>
<td>DIS</td>
<td>71</td>
<td>0</td>
<td>Disable</td>
</tr>
<tr>
<td>END</td>
<td>n/a</td>
<td>9</td>
<td>Directive, End Source</td>
</tr>
<tr>
<td>GHI reg</td>
<td>90</td>
<td>3</td>
<td>Get high register</td>
</tr>
<tr>
<td>GLD reg</td>
<td>80</td>
<td>3</td>
<td>Get low register</td>
</tr>
<tr>
<td>IDL</td>
<td>00</td>
<td>0</td>
<td>Idle</td>
</tr>
<tr>
<td>INC reg</td>
<td>10</td>
<td>3</td>
<td>Increment register</td>
</tr>
<tr>
<td>INP expr</td>
<td>60</td>
<td>7</td>
<td>Input</td>
</tr>
<tr>
<td>IRX</td>
<td>60</td>
<td>0</td>
<td>Increment register X</td>
</tr>
<tr>
<td>KBDF expr</td>
<td>C3</td>
<td>2</td>
<td>Long branch if DF=1</td>
</tr>
<tr>
<td>LBNF expr</td>
<td>CB</td>
<td>2</td>
<td>Long branch if DF=0</td>
</tr>
<tr>
<td>LBNQ expr</td>
<td>C9</td>
<td>2</td>
<td>Long branch if Q=0</td>
</tr>
<tr>
<td>LBNZ expr</td>
<td>CA</td>
<td>2</td>
<td>Long branch if D not 0</td>
</tr>
<tr>
<td>LBQ expr</td>
<td>C1</td>
<td>2</td>
<td>Long branch if Q=1</td>
</tr>
<tr>
<td>LBR expr</td>
<td>C0</td>
<td>2</td>
<td>Long branch</td>
</tr>
<tr>
<td>LBZ expr</td>
<td>C2</td>
<td>2</td>
<td>Long branch if D=0</td>
</tr>
<tr>
<td>LDA reg</td>
<td>40</td>
<td>3</td>
<td>Load advance via register</td>
</tr>
<tr>
<td>LDI expr</td>
<td>F8</td>
<td>1</td>
<td>Load immediate</td>
</tr>
<tr>
<td>LDN reg</td>
<td>00</td>
<td>3</td>
<td>Load via register</td>
</tr>
<tr>
<td>LDX</td>
<td>F0</td>
<td>0</td>
<td>Load via X</td>
</tr>
<tr>
<td>LDXA</td>
<td>72</td>
<td>0</td>
<td>Load advance via X</td>
</tr>
<tr>
<td>LSDF</td>
<td>CF</td>
<td>0</td>
<td>Long skip if DF=1</td>
</tr>
<tr>
<td>LSIE</td>
<td>CC</td>
<td>0</td>
<td>Long skip if IE=1</td>
</tr>
<tr>
<td>LSKP (expr)</td>
<td>C8</td>
<td>2</td>
<td>Long skip</td>
</tr>
</tbody>
</table>
## Syntax

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Machine System</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSNF</td>
<td>C7</td>
<td>0</td>
<td>Long skip if DF=0</td>
</tr>
<tr>
<td>LSNQ</td>
<td>C5</td>
<td>0</td>
<td>Long skip if Q=0</td>
</tr>
<tr>
<td>LSNZ</td>
<td>C6</td>
<td>0</td>
<td>Long skip if D not 0</td>
</tr>
<tr>
<td>LSQ</td>
<td>CD</td>
<td>0</td>
<td>Long skip if D=0</td>
</tr>
<tr>
<td>MARK</td>
<td>79</td>
<td>0</td>
<td>Push X,P to stack</td>
</tr>
<tr>
<td>NBR (expr)</td>
<td>38</td>
<td>1</td>
<td>No short branch</td>
</tr>
<tr>
<td>NLBR expr</td>
<td>C8</td>
<td>2</td>
<td>No long branch</td>
</tr>
<tr>
<td>NOP</td>
<td>C4</td>
<td>0</td>
<td>No operation</td>
</tr>
<tr>
<td>OR</td>
<td>F1</td>
<td>0</td>
<td>Or</td>
</tr>
<tr>
<td>ORG</td>
<td>n/a</td>
<td>5</td>
<td>Directive, Define origin</td>
</tr>
<tr>
<td>ORI expr</td>
<td>F9</td>
<td>1</td>
<td>Or immediate</td>
</tr>
<tr>
<td>OUT expr</td>
<td>60</td>
<td>3</td>
<td>Output</td>
</tr>
<tr>
<td>PAGE</td>
<td>n/a</td>
<td>6</td>
<td>Directive, Next memory page</td>
</tr>
<tr>
<td>PHI reg</td>
<td>B0</td>
<td>3</td>
<td>Put high register</td>
</tr>
<tr>
<td>PLO reg</td>
<td>A0</td>
<td>3</td>
<td>Put low register</td>
</tr>
<tr>
<td>REQ</td>
<td>7A</td>
<td>0</td>
<td>Reset Q</td>
</tr>
<tr>
<td>RET</td>
<td>70</td>
<td>0</td>
<td>Return</td>
</tr>
<tr>
<td>SAV</td>
<td>78</td>
<td>0</td>
<td>Save</td>
</tr>
<tr>
<td>SD</td>
<td>F5</td>
<td>0</td>
<td>Subtract D</td>
</tr>
<tr>
<td>SDB</td>
<td>75</td>
<td>0</td>
<td>Subtract D with borrow</td>
</tr>
<tr>
<td>SDBI expr</td>
<td>7D</td>
<td>1</td>
<td>Subtract D with borrow immediate</td>
</tr>
<tr>
<td>SDI expr</td>
<td>FD</td>
<td>1</td>
<td>Subtract D immediate</td>
</tr>
<tr>
<td>SEP reg</td>
<td>D0</td>
<td>3</td>
<td>Set P</td>
</tr>
<tr>
<td>SEQ</td>
<td>7B</td>
<td>0</td>
<td>Set Q</td>
</tr>
<tr>
<td>SEX reg</td>
<td>E0</td>
<td>3</td>
<td>Set X to register</td>
</tr>
<tr>
<td>SHL</td>
<td>FE</td>
<td>0</td>
<td>Shift left</td>
</tr>
<tr>
<td>SHLC</td>
<td>7E</td>
<td>0</td>
<td>Shift left with carry</td>
</tr>
<tr>
<td>SHR</td>
<td>F6</td>
<td>0</td>
<td>Shift right</td>
</tr>
<tr>
<td>SHRC</td>
<td>76</td>
<td>0</td>
<td>Shift right with carry</td>
</tr>
<tr>
<td>SKP (expr)</td>
<td>38</td>
<td>1</td>
<td>Short skip</td>
</tr>
<tr>
<td>SM</td>
<td>F7</td>
<td>0</td>
<td>Subtract memory</td>
</tr>
<tr>
<td>SMB</td>
<td>77</td>
<td>0</td>
<td>Subtract memory with borrow</td>
</tr>
<tr>
<td>SMBI expr</td>
<td>7F</td>
<td>1</td>
<td>Subtract memory immed with borrow</td>
</tr>
<tr>
<td>SMI expr</td>
<td>FF</td>
<td>1</td>
<td>Subtract memory immed</td>
</tr>
<tr>
<td>STR reg</td>
<td>50</td>
<td>3</td>
<td>Store via register</td>
</tr>
<tr>
<td>STXD</td>
<td>73</td>
<td>0</td>
<td>Store via X and decrement</td>
</tr>
<tr>
<td>XOR</td>
<td>F3</td>
<td>0</td>
<td>Exclusive or</td>
</tr>
<tr>
<td>XRI</td>
<td>FB</td>
<td>1</td>
<td>Exclusive or immediate</td>
</tr>
</tbody>
</table>

### LEGEND

- **expr**: expression evaluated to a 16-bit, 2-byte quantity; assembled into 1 or 2 bytes depending on type
- **req**: register expression evaluated to a 16-bit, 2-byte quantity; lowest (least significant) 4-bits masked onto op-code machine stem.

---

-20-
Legend (Continued)

Type 0  -  Machine code stem used as is; no operand expression.
Type 1  -  Additional hex byte assembled from 8-bits of operand expression.
Type 2  -  Two additional hex bytes assembled from operand expression.
Type 3  -  Machine code stem merged with lowest 4-bit nybble of operand expression.
Type 4-9  -  Exception or Directive

Note - The op-code "DC" is treated as a special case. The program translates "DC" to a comma (,) and then evaluates the source line as a data statement.
PART II: THE COSMATIC DEVELOPER

An 1802 Development System
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<td>8</td>
</tr>
<tr>
<td>RS-232 Interface Circuit</td>
<td>8</td>
</tr>
</tbody>
</table>
THE COSMATIC DEVELOPER

INTRODUCTION

OVERVIEW

The COSMATIC DEVELOPER is a pair of programs which turn your ATARI Home Computer into an 1802 Development System. The system lets you do the following with your ATARI Home Computer:

- Inspect 1802 Memory
- Change 1802 Memory
- Start 1802 Execution at any Address
- Transfer ATARI Diskette Files to the 1802
- Transfer 1802 Memory to the ATARI Diskette
- Print 1802 Memory Contents
- Have an Intelligent Terminal for the 1802

The 1802 microprocessor is used in many popular hobby computers and games because of its low cost and ease of implementation. Example systems include:

- RCA COSMAC Development System
- VIP Game Computer by RCA
- Studio II Programmable Game by RCA
- Hughes Development System
- ELF II Hobby Computer by Netronics
- The Anything Board by Netronics
- Super ELF by Quest Electronics
- CyberVision Home Computer
- Popular Electronics' COSMAC ELF Series

The COSMATIC DEVELOPER will let you extend the capabilities of your ATARI Home Computer to the low cost 1802 system.
THE COSMATIC DEVELOPER

SYSTEM REQUIREMENTS

The COSMATIC DEVELOPER requires:

- ATARI BASIC Language Cartridge
- 16K of memory
- ATARI 850 Interface Module
- ATARI 810 Disk Drive
- Printer (optional)

Your 1802 should have an RS-232 electrical interface and the UT4 program in ROM or RAM. An RS-232 interface circuit description and UT4 ROM replacement program are included with the COSMATIC DEVELOPER.

The designation "UT4" refers to a part number in RCA development systems. This part is a 512-byte ROM containing the software for terminal communication with the development system. This is the communication "standard" used in the COSMATIC DEVELOPER. If you already have an RCA development system with a UT4 or equivalent ROM, then the COSMATIC DEVELOPER is fully compatible. If not, a new but compatible UT4 program is included with the COSMATIC DEVELOPER for your use.
DISK CONTENTS

The following files are included on your COSMATIC DEVELOPER diskette:

**DOS.SYS**
- Disk operating system and utility package. The DOS has been modified to work with only a single drive to reduce memory requirements. Refer to Appendix G in your DOS II reference manual to see how it was done. You must use this modified DOS if you have a 16K system. Larger systems can use an unmodified DOS.

**DUP.SYS**
- This the the standard AUTORUN.SYS File provided with DOS II and required for use with the disk and 850 interface module.

**AUTORUN.SYS**
- A text file containing 1802 hex machine code. This file was cross-assembled from UT4E.SRC and may be read by the COSMATIC DEVELOPER. This format is in the form created by the COSMATIC ATARI.

**UT4E.OBJ**
- A text file containing the same 1802 hex machine code that is in UT4E.OBJ. The format, however, is in the form created by the COSMATIC DEVELOPER when it transfers data from the 1802 to ATARI disk.

**UT4E.DMP**
- UT4E.OBJ and UT4E.DMP are functionally identical and both conform to the UT4 standard.

**UT4E.SRC**
- A text file containing the 1802 assembly language source which generated UT4E.OBJ. This source file may be copied to the screen or printer, entered into an assembler-editor cartridge for inspection, or cross-assembled by the COSMATIC ATARI.

**DEV**
- The COSMATIC DEVELOPER in BASIC "LOAD" format.
THE COSMATIC DEVELOPER

USING THE COSMATIC DEVELOPER

STARTUP

The following steps should be used in sequence:

1. Turn on the disk drive.
2. Turn on the interface module.
3. Insert the COSMATIC DEVELOPER diskette.
4. Insert the BASIC cartridge in the cartridge slot of your computer.
5. Turn on your computer.
6. When you get the "READY" prompt, enter:

   RUN "D:DEV"

The following screen should appear:

   THE COSMATIC DEVELOPER
   AN 1802 DEVELOPMENT SYSTEM

   RESET 1802 SYSTEM
   THEN PRESS START
THE COSMATIC DEVELOPER

Before you press START be sure you have done the following:

1. Connect the 1802 RS-232 interface to port #1 of the ATARI Interface Module.

2. Startup the UT4 program in the 1802.

Pressing START will cause the ATARI Home Computer to send a synchronizing character to the 1802. This character is used by the UT4 program in the 1802 to determine data rate (600 baud) and duplex (full). An acknowledgement is sent back to the ATARI Home Computer. When this occurs, the following screen will appear:

THE COSMATIC DEVELOPER
AN 1802 DEVELOPMENT SYSTEM

RESET 1802 SYSTEM
THEN PRESS START
SYNC CHAR SENT AND ACKNOWLEDGED
SELECT MODE:

1. KEYBOARD
2. 1802 --> FILE
3. FILE --> 1802
4. RESTART

At this point you may select one of three operating modes or restart. The restart will prompt you again for resetting the 1802 system and pressing START. Restart is helpful if a problem occurs either with the ATARI Home Computer or the 1802.

If you do not get the acknowledgement and "SELECT MODE" menu, then the 1802 system is not running or not connected. The COSMATIC DEVELOPER will not work without an 1802 executing a UT4 program.
KEYBOARD MODE

Entering "1" to the "SELECT MODE" choice will place you in keyboard mode. Here your ATARI Home Computer acts as a keyboard and display terminal to the 1802 system. The following screen will appear:

THE COSMATIC DEVELOPER
AN 1802 DEVELOPMENT SYSTEM

KEYBOARD MODE

If you press RETURN at this point without any other entries, you will be returned to the "SELECT MODE" prompt. No data will be sent to the 1802.

Any other keys will be sent directly to the 1802. In fact, characters entered after the question mark are displayed as they are echoed back from the 1802. This is the full-duplex nature of the system's operation.

You may inspect, change, and execute the 1802 memory from your ATARI Home Computer as follows:

?Maaaa bb           To inspect bb bytes starting at location aaaa
!Maaaa b...b        To enter b...b bytes starting at location aaaa
$Paaaaa              To start 1802 execution at location aaaa (PC=R0)

All numeric entries must be in hexadecimal. The COSMATIC DEVELOPER will right-justify and zero-fill hex addresses less than four digits in length.
The following is an example of the inspect command and its output:

```
THE COSMATIC DEVELOPER

AN 1802 DEVELOPMENT SYSTEM

KEYBOARD MODE

```

Note the two question marks. The first is displayed by the program, the second was entered from the keyboard. Both are required.

The following is an example of the change command:

```
THE COSMATIC DEVELOPER

AN 1802 DEVELOPMENT SYSTEM

KEYBOARD MODE

```

Spaces can be inserted in the data as entered if desired.
The following is an example of the change command for longer strings of hex data:

```
>??M00 10
0000 0F0E 0D0C 0B0A 0908
0706 0504 0302 0100
>??M00 0081020304050607,
>??00902060C0D0E0F
>??M00 10
0000 0001 0203 0405 0607
0809 0A0B 0C0D 0E0F
```

Note the comma at the end of the data to be entered. This signals the UT4 software in the 1802 system that the next line is to follow in memory. The new address need not be entered (nor the "!M"). The continuation can be marked with the concluding comma for as many lines as necessary.

The following is an example of the start execution command:
Starting execution in the 1802 system really means transferring control from the UT4 program in the 1802 to another program in the 1802. This new program can also use subroutines in the UT4 program to display text on your ATARI Home Computer and accept text from your keyboard. Instructions in the UT4E.SRC file describe how to use the UT4 subroutines available to you. Knowledge of 1802 assembly language is assumed.

1802-to-file

Entering "2" to the "SELECT MODE" choices will place you in 1802-to-file mode. This mode transfers 1802 memory contents to a file of your choice. The following is an example:

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1802 --> FILE
FD (#=DIRECTORY) ?D:TEST.DMP
MAKE ENTRIES IN HEX
STARTING ADDR. ?0000
NUMBER OF BYTES ?20
0800 F800 B0B5 F808 A5D5
0808 F801 B1F8 08A3 D3F8
0810 8Ea3 D30D D32A D32A
0818 F800 4DBD F83E A3D3

STARTING ADDR. ?
First, the file description ("FD") is entered. This can be a disk file, the screen ("S:") or the printer ("P:").

Next, enter the 1802 starting address in hex. A null entry ("RETURN" only) will return you to the "SELECT MODE" menu.

Finally, enter the number of bytes desired in hex ("FFFF" maximum). Entering zero will return you to the "SELECT MODE" menu.

The program will then transfer the 1802 memory contents to the file you designate. You will then be prompted for a new starting address. A null entry ("RETURN" only) closes the file and returns you to the "SELECT MODE" menu. The following is an example of a continued transfer:

```
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1802 -> FILE
FD (==DIRECTORY) ?D:TEST.DMP
MAKE ENTRIES IN HEX
STARTING ADDR. ?9000
NUMBER OF BYTES ?20
0000 F800 B0B5 F800 A5D5
0008 F801 B3F8 00A3 D3F8
0010 8EAD D30D D30A D32A
0018 F900 ADBD F63E 83D3
STARTING ADDR. ?9100
NUMBER OF BYTES ?18
0100 F800 AEF F800 BCF8
0108 C4AC 37B4 3FD0 F303
0110 FF80 3A10 8F3A 1A37
STARTING ADDR. ?■
```

This process can be repeated until you have transferred all the memory contents you wish and in the sequence you desire. This is an excellent way to build an 1802 load file.

The file format always starts with a four-hex-character address followed by eight hex-characters of 1802 memory contents.
Entering "3" to the "SELECT MODE" choice will place you in file-to-1802 mode. This mode transfers the contents of an ATARI Home Computer file to 1802 memory. The following is an example using the UT4E.OBJ file:

The following is an example using the UT4E.DMP file:

The program prefixes the file with the "!M" characters and transfers it to the 1802 until an end of file is read.
All you have to enter is the file description ("FD"). The memory addresses and data are stored in the file.

Both file transfer modes permit you to get a disk directory. Entering an asterisk ("*") for the file description will give you a disk directory. The following is an example:

```
FILE --> 1802
FD (^=DIRECTORY) ?*
^ DOS SYS 039
^ DUP SYS 042
^ AUTORUN SYS 001
^ UT4E OBJ 024
^ UT4E DMP 012
^ UT4E SRC 030
^ DEU 047
452 FREE SECTORS
FD (^=DIRECTORY) ?*
```

To escape from this mode without a file transfer, press the "RETURN" key without any other entry.
THE COSMATIC DEVELOPER

THE 1802 INTERFACE

UT4 Program

The UT4 program runs in the 1802 to provide communication with the COSMATIC DEVELOPER. It takes less than 512 bytes and will also support RS-232 communication to the ATARI Home Computer by an 1802-host program.

RCA development systems include a UT4 ROM for terminal communication. If you do not have this ROM, use the UT4E files included with the COSMATIC DEVELOPER to burn your own EPROM.

Relocating UT4E is easy. The files provided have an origin of 0 (zero). You can either (1) reassemble UT4E.SRC with a new origin or (2) change two bytes in UT4E.OBJ or UT4E.DMP. The byte changes are:

<table>
<thead>
<tr>
<th>contents</th>
<th>address</th>
<th>current</th>
<th>new</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0001</td>
<td>00</td>
<td>origin page</td>
</tr>
<tr>
<td></td>
<td>0009</td>
<td>01</td>
<td>origin page + 1</td>
</tr>
</tbody>
</table>

You are encouraged to inspect the UT4E.SRC assembly language source file if you want to see how the program works.
RS-232 INTERFACE CIRCUIT

A number of circuits have been published to permit RS-232 communications with the 1802. The UT4 protocol uses the "Q" line for output from the 1802 and the "EF4" line for input to the 1802. Serial to parallel conversion is all done in software by the UT4; no UART is required. One possible interface circuit is as follows:

The circuit was designed by Jim McConnell (Chief Engineer, Astrovision, Inc.).

RCA has a number of excellent publications describing UT4 operation and RS-232 interfaces. One such reference is "Evaluation Kit Manual for the RCA CDP1802 COSMAC Microprocessor", part number MPM-203 from RCA.
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1. Name and AFX number of program ____________________________________________

2. If you have problems using the program, please describe them here.

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

3. What do you especially like about this program?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

4. What do you think the program's weaknesses are?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

5. How can the catalog description be more accurate and/or comprehensive?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

6. On a scale of 1 to 10, 1 being "poor" and 10 being "excellent", please rate the following aspects of this program?

   Easy to use
   User-oriented (e.g., menus, prompts, clear language)
   Enjoyable
   Self-instructive
   Useful (non-game software)
   Imaginative graphics and sound

7. Describe any technical errors you found in the user instructions (please give page numbers).
8. What did you especially like about the user instructions?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

9. What revisions or additions would improve these instructions?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

10. On a scale of 1 to 10, 1 representing “poor” and 10 representing “excellent”, how would you rate the user instructions and why?

__________________________________________________________________________

__________________________________________________________________________

11. Other comments about the software or user instructions:

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

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