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Implementing the Forth Inner Interpreter in High Level Forth

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Threaded Code
- Number literals
- Printing string literals
- Control structures
- Limitations

Implementation
- Inner Interpreter
- Return stack operations
- Inline number literals
- Printing inline string literals
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- Compiler to threaded code
- Interpreter in threaded code

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- development of hard real time system
- desire to have an interactive command shell while still meeting the real time requirements
- idea: have a controllable Forth interpreter (inner & outer) stepwise execution

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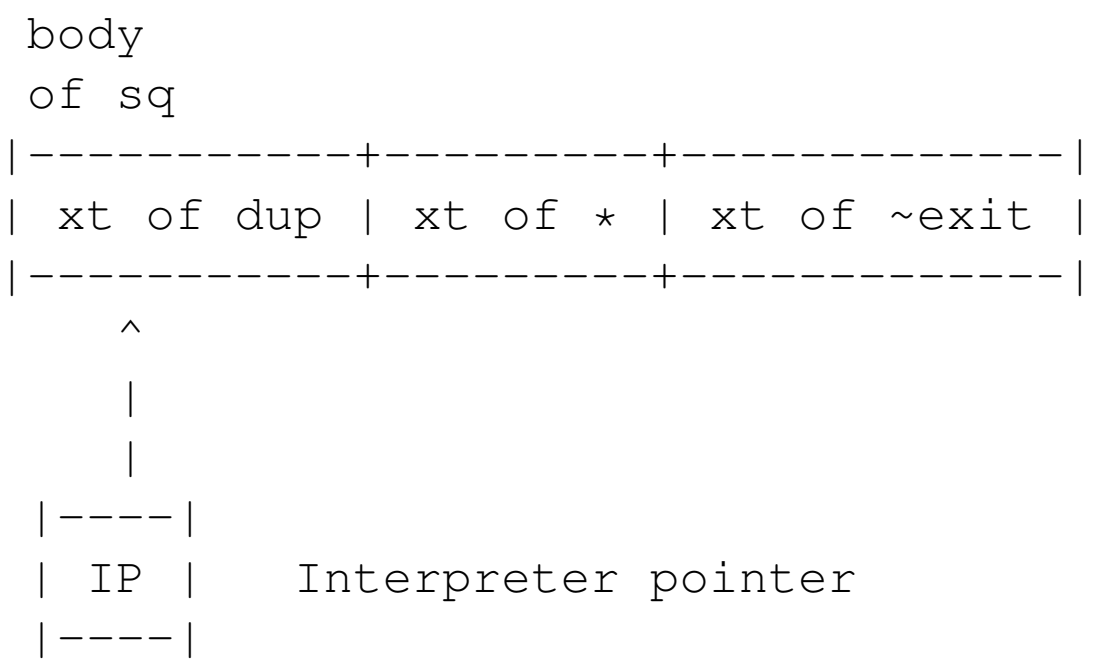
Threaded Code

- words of underlying system become primitives
- only threaded code no structure of header/dictionary

```
~: sq ( x – x ) dup * ~;
```



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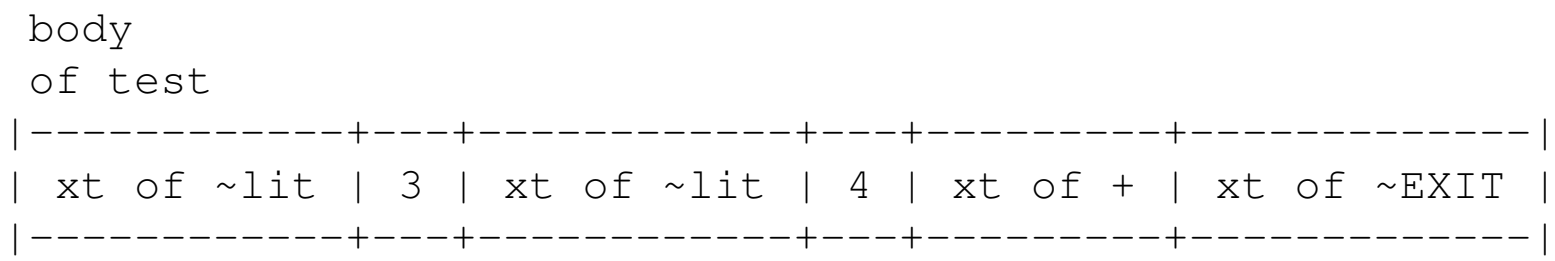
Number literals

```
~: test ( - u ) 3 4 + ~;
```



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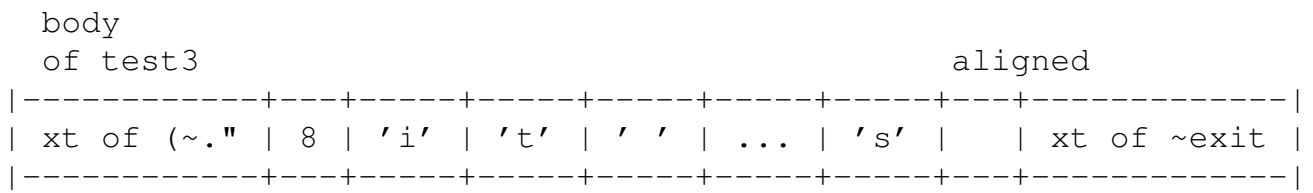
Printing string literals

```
~: test3 ( – ) ~." it works" ~;
```



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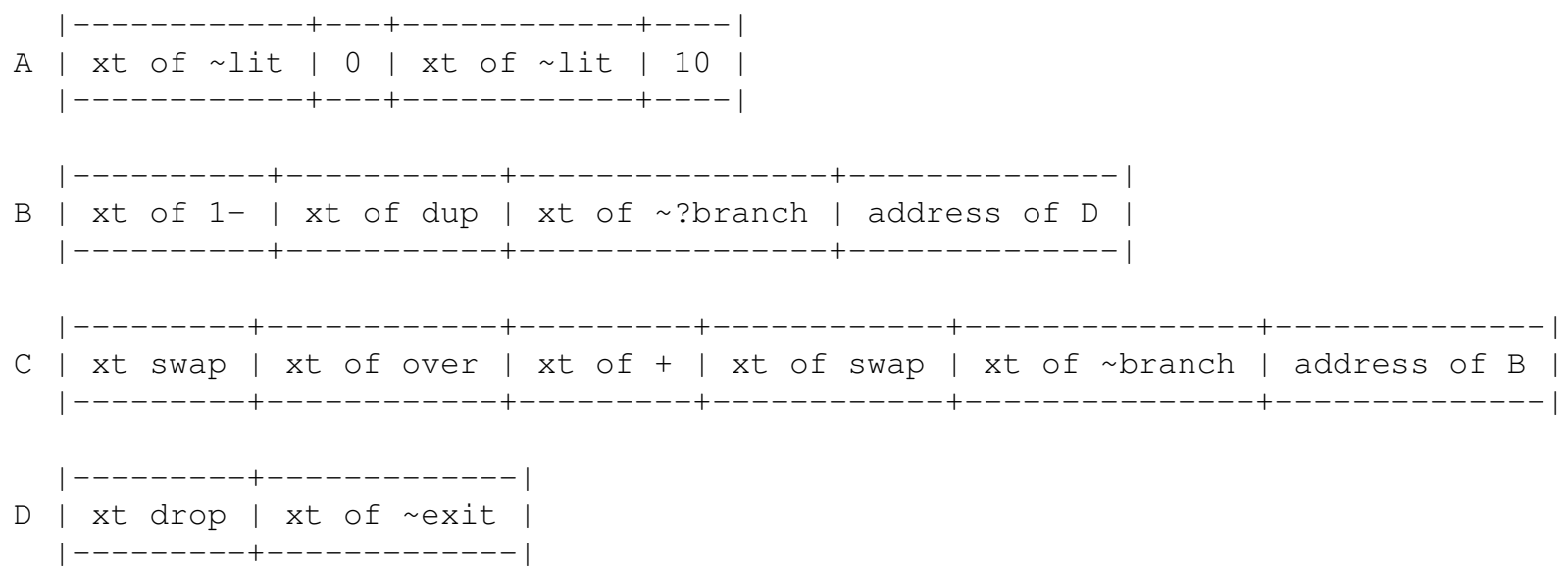
Control structures

```
: looptest ( -- )
   0 10
   ~BEGIN
     1-  dup
   ~WHILE
     swap over + swap
   ~REPEAT drop  ~;
```



Limitations

- (user) variables or constants.
- `DO LOOP`s.
- Neither defining words nor `DOES>`
- a primitive for pushing address and length of string literals on the stack (like `S"`).

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Implementation

- Inner Interpreter
- Return Stack
- Compiler *to* Threaded Code
- Outer Interpreter *in* Threaded Code

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Inner Interpreter

```
Variable IP  0 IP !

\ Perform a single interpretation step
: step ( i*x -- j*x )
   IP @ dup cell+ IP !
   @ catch
   ?dup IF cr ." Error " . reset THEN ;

\ Loop steps
: run ( i*x -- j*x )
   BEGIN IP @ WHILE  step  REPEAT ;
```


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Interpreter State

- Interpreter Pointer `IP`:

```
Variable IP  0 IP !
```

- `~R0` with corresponding return stack pointer `RP`.

```
Create ~R0  20 cells allot
Variable RP  ~R0 RP !
```

- a data stack shared with the underlying system
- memory (code and data) also shared with the underlying system.

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Return stack operations

```
Create ~R0  20 cells allot
Variable RP  ~R0 RP !
```

```
: ~>r ( x -- )
  \ push a cell to the return stack
  RP @ !   1 cells RP +! ;

: ~r> ( -- x )
  \ pop a cell from the return stack
  -1 cells RP +!   RP @ @ ;
```


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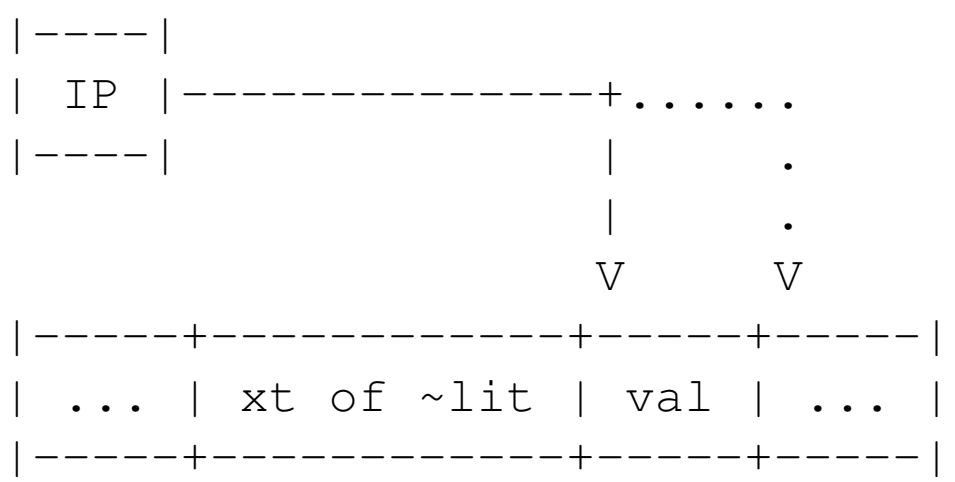
Inline number literals




```
: ~lit ( -- n )
  \ extract inline number literal
  IP @ @  1 cells IP +! ;
```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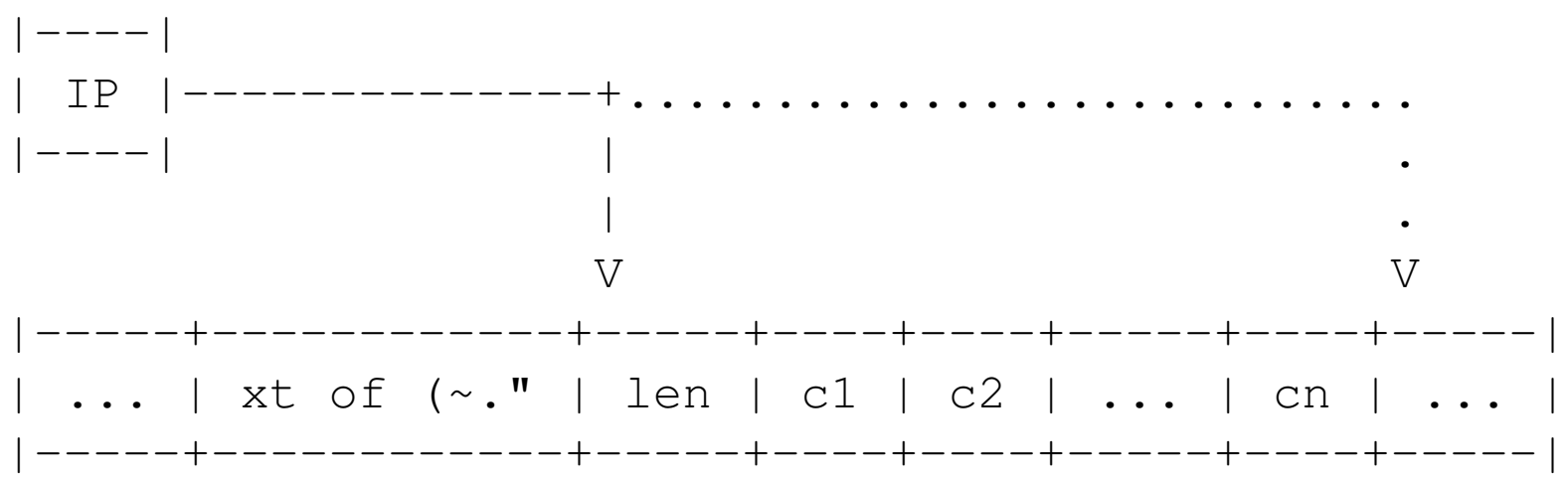
Printing inline string literals




```
: ~." ( <ccc>" -- )
  \ Compile inline string to be
  \ printed later when executed.
  \ Like ." but for threaded code
  ['] (~." ,
  [char] " word count
  here over 1+ chars allot place align
; immediate
```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Control structures

```
: ~branch ( -- )
   \ absolute unconditional jump
   IP @ @ IP ! ;

: ~?branch ( f -- )
   \ absolute conditional jump
   IF  1 cells IP +!
   ELSE ~branch THEN ;
```

```
: ~IF ( -- x )  ['] ~?branch , here 0 , ; immediate
: ~AHEAD ( -- x )  ['] ~branch here 0 , ; immediate
: ~ELSE ( x -- x' )  ['] ~branch , here 0 , swap here swap ! ; immediate
: ~THEN ( x -- )  here swap ! ; immediate

: ~BEGIN ( -- x ) here ; immediate
: ~WHILE ( x1 -- x2 x1 )  ['] ~?branch ,  here 0 , swap ; immediate
: ~AGAIN ( x -- )  ['] ~branch , , ; immediate
: ~UNTIL ( x -- )  ['] ~?branch , , ; immediate
: ~REPEAT ( x2 x1 -- )  postpone ~AGAIN  postpone ~THEN ; immediate
```


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Compiler to threaded code

```
variable ~state   ~state off  \ threaded code outer interpreter state

-13 Constant #notfound

: ~] ( -- )  ~state on
   BEGIN ( )
      BEGIN ( )
        bl word dup c@   \ scan next token
      WHILE ( c-addr )   \ another token found
        find  ?dup       \ look up in dictionary
        IF   -1 = IF ,  ELSE execute  THEN  ~state @ 0= IF EXIT THEN  \ found
        ELSE   0 0 rot count
          over c@ [CHAR] - = dup >r IF  1- swap char+ swap THEN \ word not found
          >number IF  #notfound throw THEN
          drop drop r> IF negate THEN
          ['] ~lit , ,  \ compile threaded code literal
        THEN
      REPEAT ( c-addr )  \ no more tokens in input stream
      DROP
      SOURCE-ID 0= IF CR ." ] " THEN
      REFILL 0=    \ read more from input stream
   UNTIL ;  \ input stream exhausted
```


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Compiler to threaded code

```
: ~[ ( -- )  ~state off ; immediate   \ stop threaded code compiler

: ~: ( <name> -- )
   \ push IP to return stack and set IP to start of threaded code.
   Create ~]  Does> IP @ ~>r  IP ! ;

: ~EXIT ( -- )
   \ Pop IP from return stack
   ~r> IP ! ;

: ~; ( -- )
   \ Compile end of definition and leave threaded code outer compiler
   ['] ~EXIT ,   ~state off   ; immediate
```


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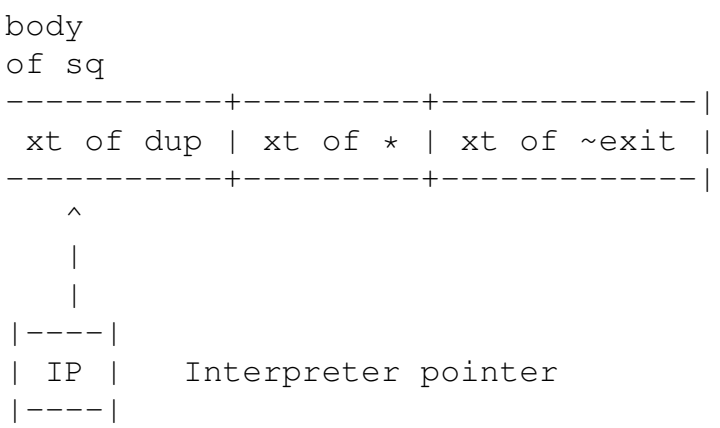
Compiler to threaded code

```
~: name ....    ~;

 name run
```

```
~: sq ( x – x ) dup * ~;
```



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Interpreter in threaded code

```
~: ~interpret ( -- )
    ~BEGIN ( )
      bl word dup c@    \ scan next token
    ~WHILE ( c-addr )   \ another token found
      find              \ lookup in dictionary
      dup  1 = ~IF drop execute  ~ELSE   \ immediate
      dup -1 = ~IF drop state @ ~IF  compile,  ~ELSE  execute ~THEN ~ELSE
      \ word not found, number?
      drop   0 0 rot count   over c@ 45 = dup ~>r ~IF  1- swap char+ swap ~THEN
           >number ~IF  #notfound throw ~THEN drop drop    \ maybe number
           ~r> ~IF  negate ~THEN
           state @ ~IF  postpone LITERAL  ~THEN  \ compile literal
      ~THEN ~THEN
    ~REPEAT ( c-addr )
   drop ~;

   ~: ~quit ( -- ) clear-stack   ~R0 RP ! ~state off  interpret-mode
     ~BEGIN cr state @ ~IF ~." ] " ~THEN  ~query ~interpret ~." ~ok"  ~AGAIN ~;



~quit run
```


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- threaded code structure for Forth colon definitions
- inner interpreter, `step`, in high level Forth.
- a compiler to generate this threaded code
- an interactive outer interpreter *in* threaded code controllable by `step`.
- interactive command interpreter in hard real time system

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