# Modified Roland PG1000

**John Talbert, 1994**

# The Roland PG1000

The PG-1000 is a dedicated programmer for the Roland D-50 keyboard synthesizer and the D-550 rack mounted version. It works with MIDI system exclusive, and requires an external 9V power supply. It has an impressive 56 faders used to set the four partials, two tones and one common parameter block for each D-50 patch. Programming was made easier by displaying parameter values on a backlit LCD screen along with dedicated partial/tone select buttons.

Its impressive number of faders and MIDI output immediately suggest a possible use as a generic MIDI controller device. When it came out in the late 1980's Midi Controller devices were rare. However, the MIDI output of the PG1000 is in System Exclusive form and each fader is tied to a specific D-50 function with a specific range of values; all of which does not easily translate to any use as a generic MIDI controller.

Upon opening up the PG1000, the internal circuitry turned out to be very simple and straightforward. It consists mainly of a NEC 78C10 Processor running code from a 32K PROM memory chip. The Processor includes eight 8-bit Analog to Digital Converters which are used to convert the 0 to 5 volt output from each slider. Each of the 8 ADCs handles 8 sliders routed through a 4051 CMOS Data Selector chip. Note that this scheme allows for a total of 64 sliders and the unit has only 56. One of the processor's ADC is not being used – a point that will turn out to be useful later.

The NEC 78C10 Processor, better described as a single chip microcomputer, has a number of other useful features put to good use in the PG1000: an internal serial I/O engine used for the MIDI I/O, internal clocks and counters used to set the MIDI and serial data rates, a small amount of RAM memory for storing setup data, and extra I/O lines dedicated to the LCD controller and several pushbuttons.

# The Task

Seeing how simple and traceable the internal circuitry was, the task of reprogramming the PROM memory to turn the PG1000 into a MIDI slide controller became a viable possibility. To avoid as much assembly language programming as possible, I chose to set up a Forth Language operating system on the memory chip. This route was made possible by the development of the eForth system by C. H. Ting. The eForth system is a complete Forth system, designed to be small enough to fit on a memory chip. It requires that only 31 simple code words be built from assembly code for any particular processor. The remaining higher level eForth code words are then built from these 31 base words. With eForth, after programming the base words, I then had a complete higher-level programming language to facilitate building the main code that will turn the PG1000 into a MIDI Controller.

The rest of this paper will document how this was done.  First, here is a description of the end product.

## Modified Roland PG1000

This Roland PG1000 has been reprogrammed to put out conventional Midi command instead of System Exclusive.

The unit has 56 sliders numbered from 0 to 55. (There is also the capability for 8 external, zero to five volt, control voltage inputs numbered as sliders 56 to 63.) It also has 10 pushbuttons, 8 of which have taken on new functions as Cursor Left, Cursor Right, Field increment, Field Decrement, Slide increment, Slide Decrement, ENTER, and MIDI.

The unit has four modes of operation:

## (1) Edit Mode.

Each Slider has an Edit Window on the LCD display with the following fields:  Slider number, slider on/off, Midi channel number, Midi operation, Midi operation data, and Slider value.

An LCD cursor can be moved to any of the above fields using the Left/Right buttons. The selected field can then be edited using the Field Increment/Decrement buttons. The edited Slider Window is only loaded into memory when the Enter button is pressed. The Slide Increment/Decrement buttons enable you to step through the Slider Windows without moving the cursor.

No Midi data is sent while in the Edit Mode. The Slider value field provides a running display of the slider value.

The unit supports the following Midi Operations:

**Key#**

Midi Key On is sent when a slider movement up from zero peaks out. The key value sent is programmed in the Midi data field and the key velocity sent is the peak value of the slider movement. A note off is sent when the slider returns to zero.

**Key# AT**

Midi Key On with After-touch. Midi Key On/Off values are sent as described above in Key#. In addition, a continuous Midi

After-touch value is sent with any slider movement until it is returned to zero.

**Control#**

Midi Controller. A continuous controller value is sent with any slider movement. The Controller number is set in the Midi data field.

**Program#**

Midi Program Change. When the slider goes above a certain threshold value, the program change number as set in the midi data field is sent once. The data is not sent again unless the slider is returned below the threshold value.

**Ch Press**

Midi Channel Pressure. A continuous channel pressure value is sent with any slider movement. The midi data field is not used.

**Ptch Whl**

Pitch Wheel. A continuous pitch wheel value is sent with any slider movement. The midi data field is not used so that only a 7 bit value is sent.

## (2) Midi Run Mode.

When the Midi button is pressed, the display will change to "Midi Running" and the enabled Sliders will start sending Midi data. To get back to Edit Mode press Enter, Increment, or Decrement.

## (3) Setup Mode.

One problem with the unit is that when powered off, all the slider setting you set  in the Edit Mode are lost.  To help alleviate this inconvenience, a “Setup Mode” was programmed to allow you to easily setup the sliders with a number of fixed settings stored away in some available EPROM space.

To enter the Setup Mode move the cursor under the Edit field labeled "Slider#" and then press Up or Down. The display will change to read "Setup# nn". There are a total of 64 possible slider setups stored in ROM memory. To load a particular setup use the Up/Down buttons to select the setup number and then press the Enter Button. The display will then go back to Edit Mode.

Setup# 00 disables all 64 sliders. Setup# 01 was designed for a class. Most of the remaining setups act like Setup#00 but are empty, available for future customizing.

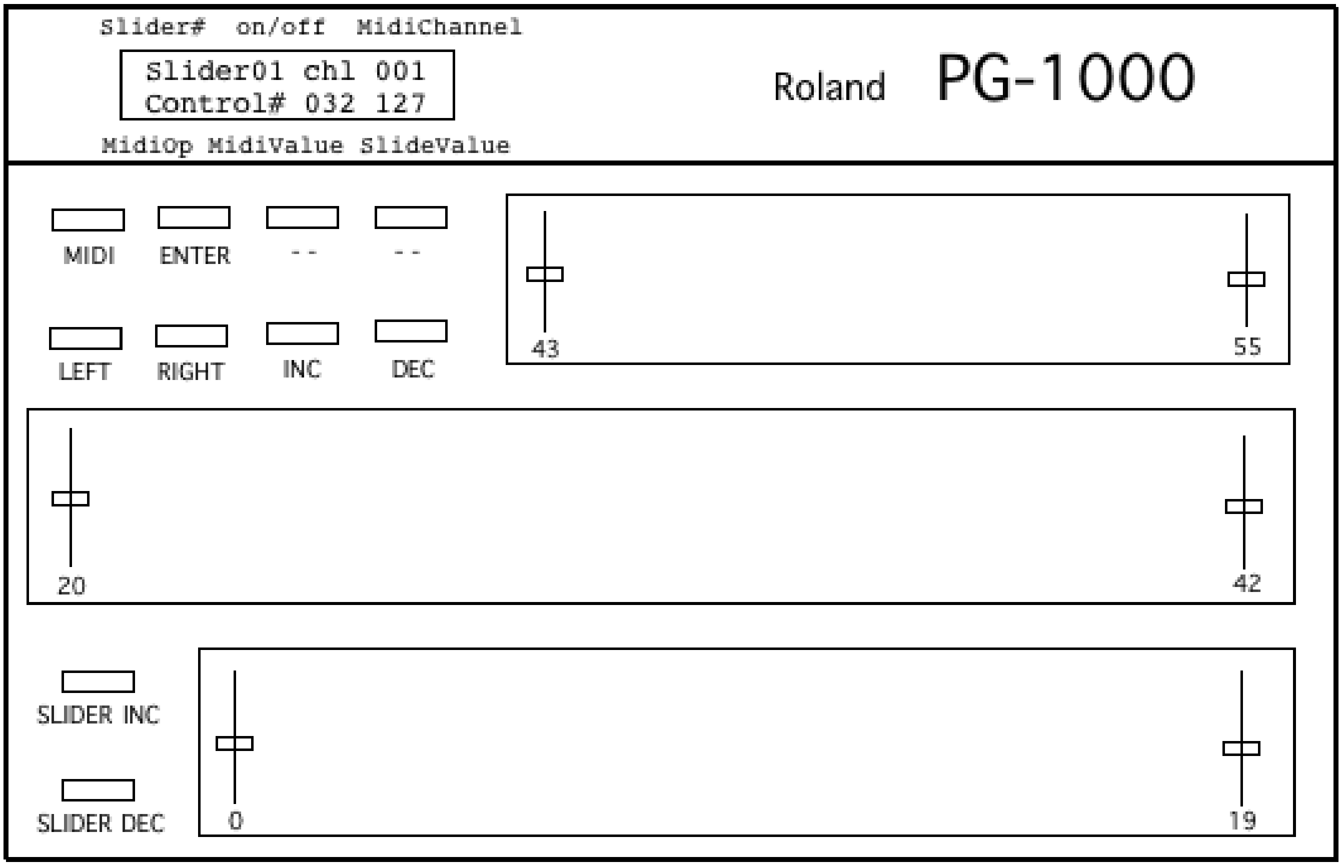
## (4) Forth Mode.

The unit can have a serial input/output port which connects to any computer's serial I/O. With a terminal emulation program set for 9600 baud, 8-bits, 1 stop bit, you can access the Forth language operating system used in the unit. There is a small amount of Ram memory available on the processor chip for implementing your own programs.

The unit will exit its Edit program loop and enter the "Forth Mode" with any key action on the computer terminal when the serial port is connected. To re-enter the Edit program just type EDIT and return.

## Availability

If you would like one of these units for your own, your first problem is finding an original Roland PG1000.  They are a pretty scarce item.  Once you manage to find one, you will then need to burn a 27C128 EPROM memory chip with the available code and then install it in place of the unit’s original PROM memory.


Slider#
on/off
MidiChannel
Slider01 chl 001
Control# 032 127
MidiOp MidiValue SlideValue
Roland
PG-1000
MIDI
ENTER
- -
- -
LEFT
RIGHT
INC
DEC
43
55
20
42
SLIDER INC
SLIDER DEC
0
19

# Setups

0 All off except slider 0 with pitch wheel,
and slider 1 with channel pressure.

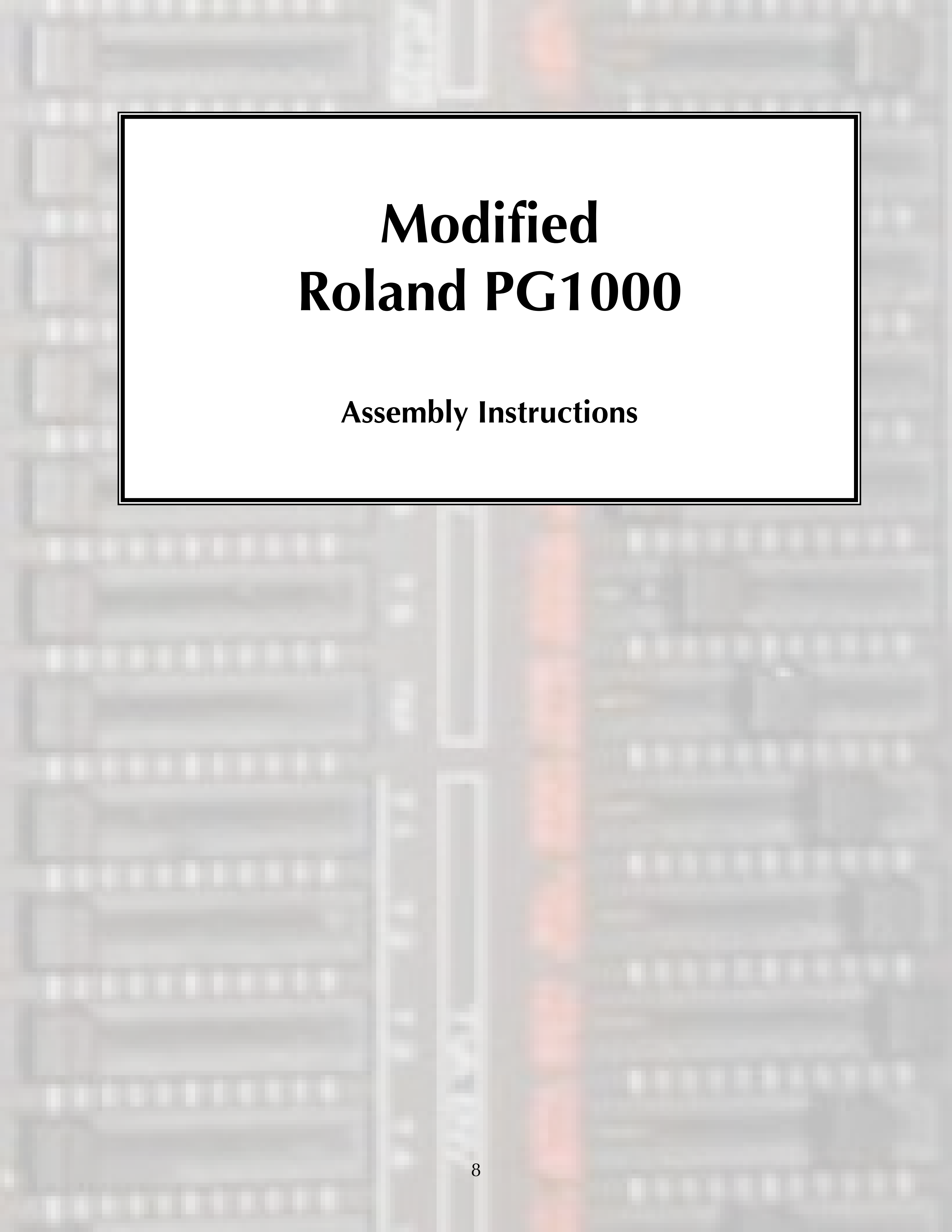
1 Combination of Note On with aftertouch, and midi control.

2 Midi Control 0 through 63, Midi channel 15.

3 Midi Program changes 0 through 63, Midi channel 0
4 Midi Program changes 64 through 127, Midi channel 0

5 Key On 0 through 63, Midi channel 15
6 Key On 64 through 127, Midi channel 15

7 Key On with Aftertouch 0 through 63, Midi channel 15
8 Key On with Aftertouch 64 through 127, Midi channel 15



# Modified Roland PG1000

## Assembly Instructions

# Modified PG1000 Disassembly

Once you have an EPROM chip burned with the new code, you will have to install it in place of the original PROM. The following instructions detail how this is done.

1. Remove power connector. Pull off all the slider knobs.

2. Remove 6 screws on the bottom.

3. Open up the back.

4. Remove all the screws holding the main circuit board, including the bar across the middle.

5. Gently lift up the circuit board and flip it over. Be careful not to pull any of the connections to the other smaller boards.

6. Look for the socketed PROM chip (28-pin chip). One end of the chip will have a small half-circle indentation. Make a note of how the indentation is oriented.

7. Using a small flat screw driver, work the chip out of its socket by prying up each end. Take your time, pry up a little at a time.

8. Replace the original PROM with the new one.

## IMPORTANT!

- The chips can be destroyed with static electricity. Touch something metal before handling.
- Make sure the chip orientation (indentation) is the same as the original.
- Make sure all the pins are set in the socket before pushing.
- After pushing, make sure all pins have gone in straight.

9. Reassemble. It may take some gentle jiggling around to get the main board back in place. Don't start screwing until it is in place. Remember that the bottom two screws to the circuit board go in from the back panel.

10. Plug in and power on.

# PG1000 Circuit Revisions

Beyond changing  the operation of the PG1000 by replacing its EPROM instructions, a couple circuit changes can also be made to the PG1000.

First of all, the new EPROM contains a complete FORTH language operating system which can be accessed through a standard RS232 serial connection (which was how the new code was built).  There is a small amount of RAM memory available on the processor chip to allow some additional programming.

Secondly, the 78C10 processor has available 8 Analog to Digital Converters.  One of them is not being used.  This unused ADC can be revived to provide an additional eight external control voltages.  These 0 to 5 volt control voltages can be generated by any number of devices, several of which will be shown here.

What follows are instructions for making these changes.

## General

These changes require a small circuit board mounted to the inside of the PG1000 with connections to the main computer chip on the large circuit board and to the smaller MIDI/Power board.  You will need the following:

- MAX 232  chip by Dallas Semiconductors  (RS232 Serial Interface)
- 4051 CMOS chip (8 in to 1 out multiplexer)
- a small circuit board and two 16-pin chip sockets
- 9 pin D plug ( male and female)
- 47K Resistor
- 4 Capacitors - 10 µF

A circuit diagram is shown on the following page.  I have mounted the board onto the back  end of the PG1000 using a 9-pin D plug.  Solder 2-inch lengths of solid wire (heavy gauge, about 20) to the 9 pins on the plug.  Insert the other wire ends into the edge holes of the board and then solder to the 4051 chip socket.  Bend the 9 wires until the D-plug is at a right angle to the board.  Drill holes for the D-plug on the back of the PG1000 where the Roland name appears.  The board will sit under the LCD panel.

Ribbon cable makes the connections to the main board a little easier.  Most of the connections are to the Main processor chip.  This chip has 64 pins.  A figure shows its orientation and pin numbering scheme.

Too much heat to any chip's pins can destroy the internal connection; therefore, use a low wattage soldering iron, clean the tip on a wet sponge till it is shiny, and don't contact the pin for more than 2 or 3 seconds. In most cases you won't need to solder directly to the processor's pins. I suggest that whenever possible, you trace the connection to another pad and solder it there.

## Serial Input/Output

This RS232 Serial I/O will allow you to explore the Forth Language operating system on the new EPROM memory chip. A small amount of RAM memory is available for creating your own programs. I used this interface to reprogram the box.

The serial interface requires only three lines - send, receive and ground). They connect to another computer running a terminal emulation program. I have used the 5-pin DIN plug labeled "parameter in" on the PG1000 to get these three lines plus a Reset line out of the box. You will then need to make a cable to go from the 5-pin DIN to your own computer’s RS232 connector.

See the "Modified PG1000" description sheet for more information on this "Forth Mode" of operation. If you are not interested in this mode, ignore the MAX232 part of the circuit diagram.

## External Control Voltages

The internal processor has 8 Analog to Digital Converters each of which takes care of 8 sliders. The PG1000 uses only 7 of these ADC's for a total of 56 sliders. The eighth one (AN7) is grounded. So by disconnecting the ground to AN7 and adding another 4051 chip you can get 8 more zero to 5 volt control inputs numbered 55 through 63.

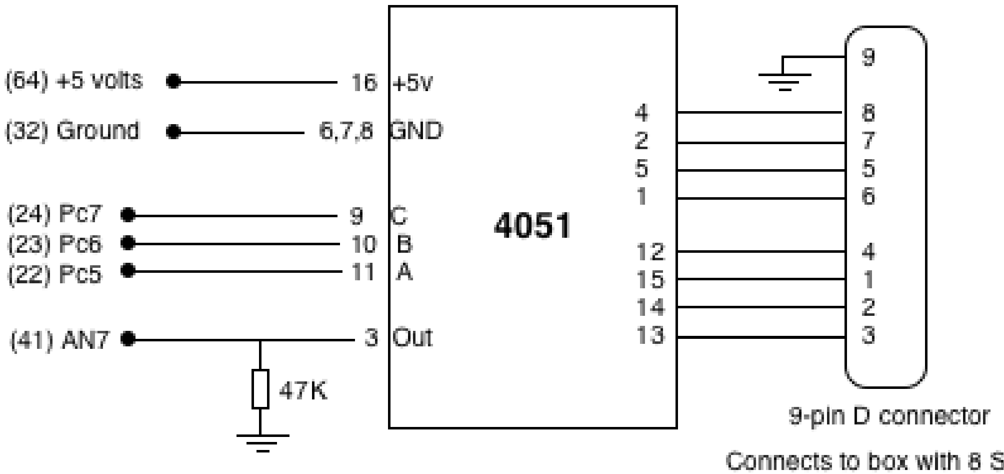
The 8 control voltage inputs and circuit ground are brought out of the box using a 9-pin D plug. Each of the 8 inputs can then be connected to any 0 to 5 volt source. Zero volts will read as a 0, and 5 volts will read as 127. Be careful to limit the voltage on these inputs to the range 0 to +5 volts.

# Simple Controllers

The external inputs can come from a wide variety of devices - switches, pedals, pots, light sensors, motion sensors, pressure sensors. A few simple devices are shown in the accompanying sheets.

For a light sensor use Cadmium Cells ( source - Radio Shack), also known as Photoresistors. A simple pressure sensitive resistance is skin resistance accomplished by bridging across two metal poles with your finger. The harder you press the smaller the skin resistance. Another simple pressure sensitive substance is the black foam that distributors sometime use to protect chips from static electricity. This foam changes its resistance when pressed. Just sandwich it between two metal plates for a variable resistance when pressed. Piezoelectric disks can be directly connected to the inputs with some success. You can get better response, though, by electrically buffering them. Piezo's, often used in drum pads, put out a voltage which varies with changing pressure applied to it.

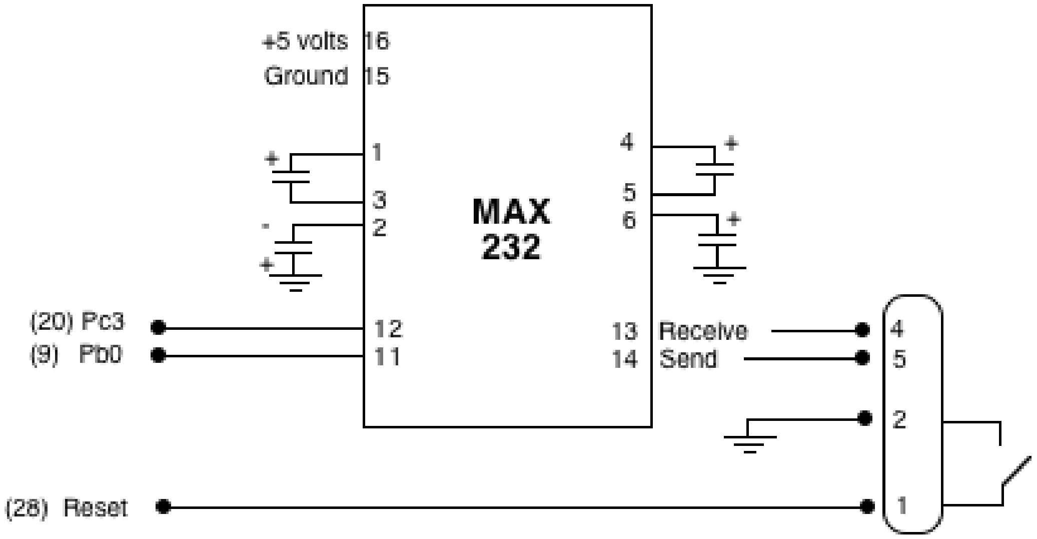
One useful way of distributing your 8 voltage inputs is by connecting the 9-pin D connector to a small box with 8 stereo phone jacks. Also inside the box is a simple 5 volt power supply using a 9 volt DC power wart and a 5 volt regulator, shown on an accompanying sheet. The 5 volt power source is connected to the ring of each stereo jack which is a convenient way to send power to each of your eight controller devices. I prefer this method to taking 5 volts from inside the PG1000. Each of the simple circuits shown on the sheets assumes you are using stereo plugs for the connections with a 5 volt power source on the ring.



9-pin D connector

Cut trace from (41) to Gnd

Connects to box with 8 Stereo Phone Jacks. Signal on tips, separate 5 volt power supply on rings, Ground on sleeves.



Numbers in parenthesis are NEC 78C10 pin numbers

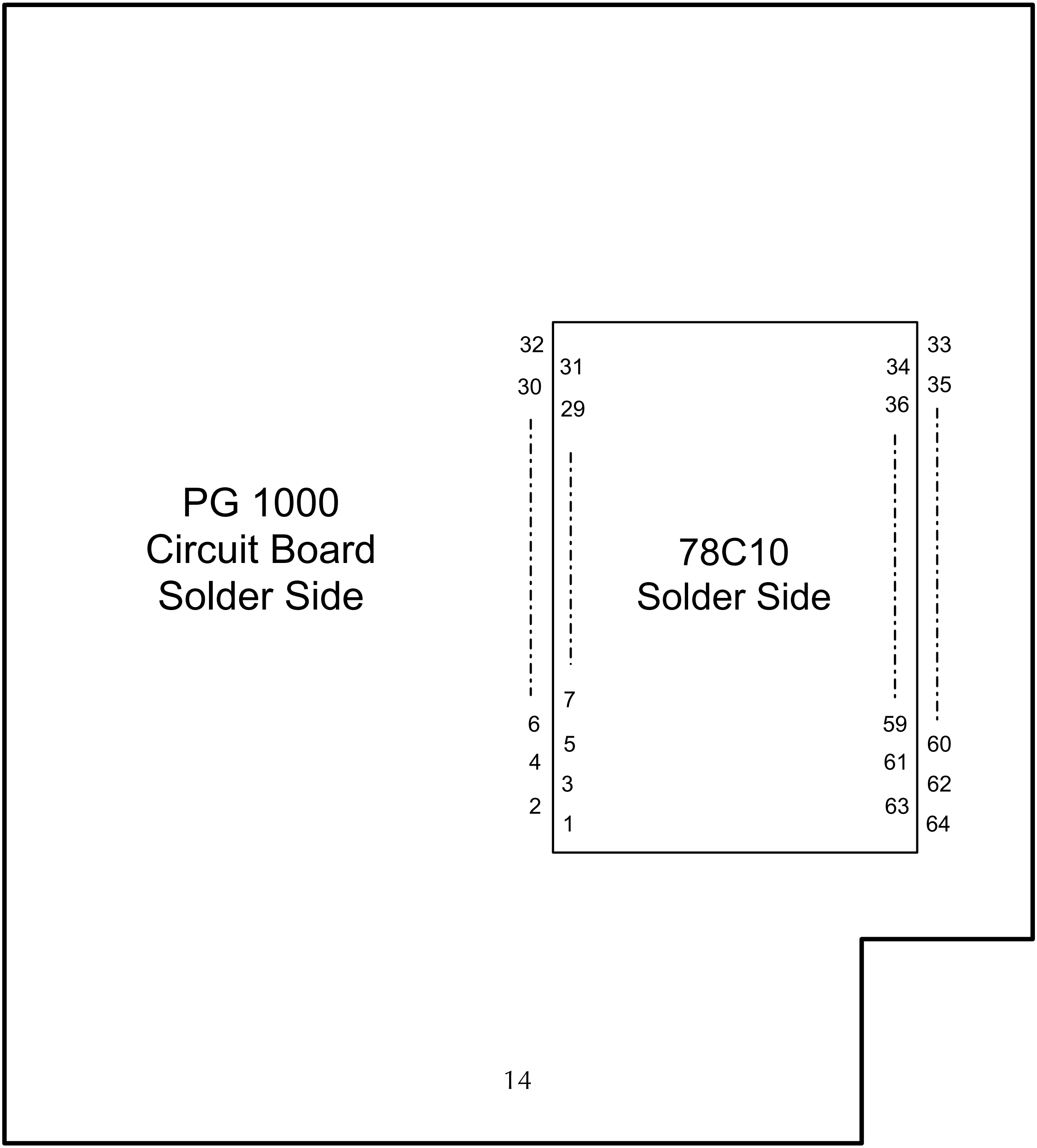
5 pin DIN jack

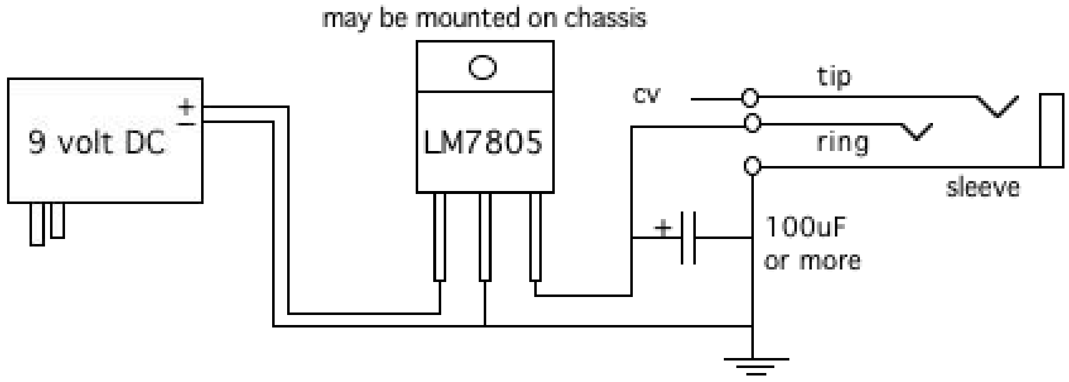
"Parameter IN"
on the PG1000

cut traces to pins 4, 5
connect 2 to Ground

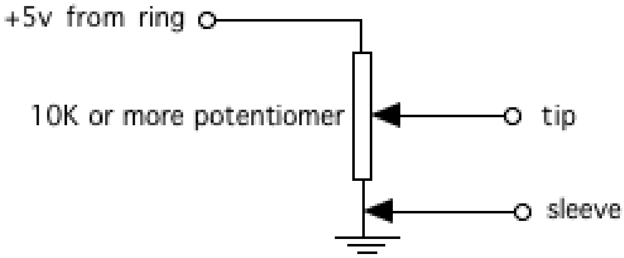
# PG1000 Revisions

## Serial I/O and 8 External 0-5v Control Inputs

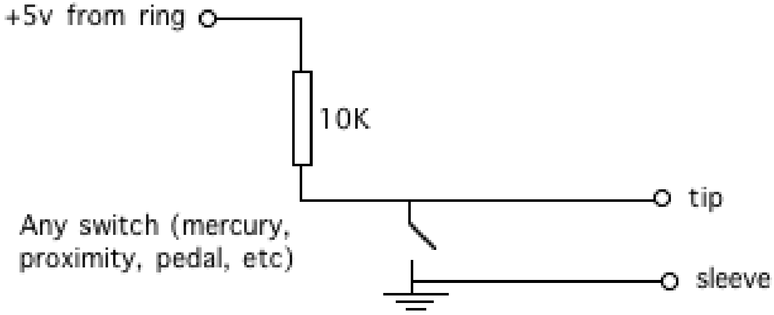

PG 1000
Circuit Board
Solder Side
78C10
Solder Side
32
31
30
29
7
6
5
4
3
2
1
33
34
35
36
59
60
61
62
63
64



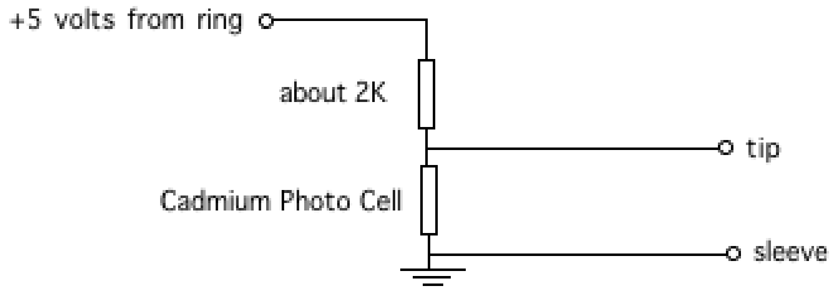
5 volt power supply for 8 external control voltages



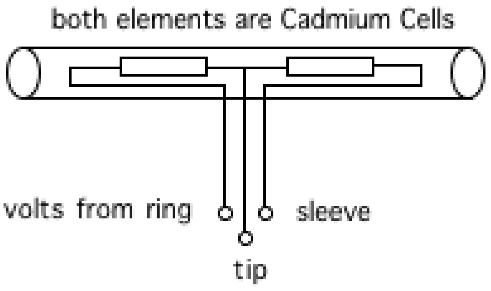
Continuous controller / Pedal



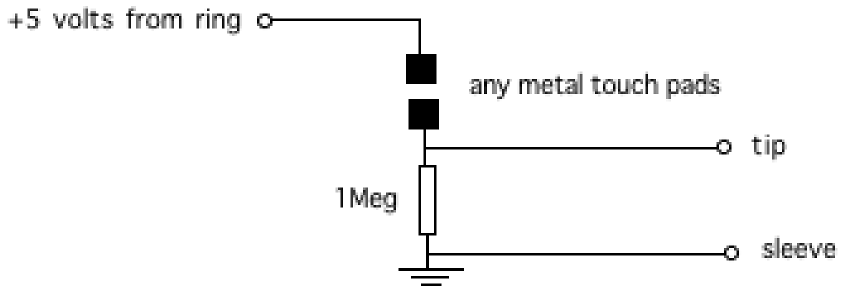
Switching (0, 5v) Controller



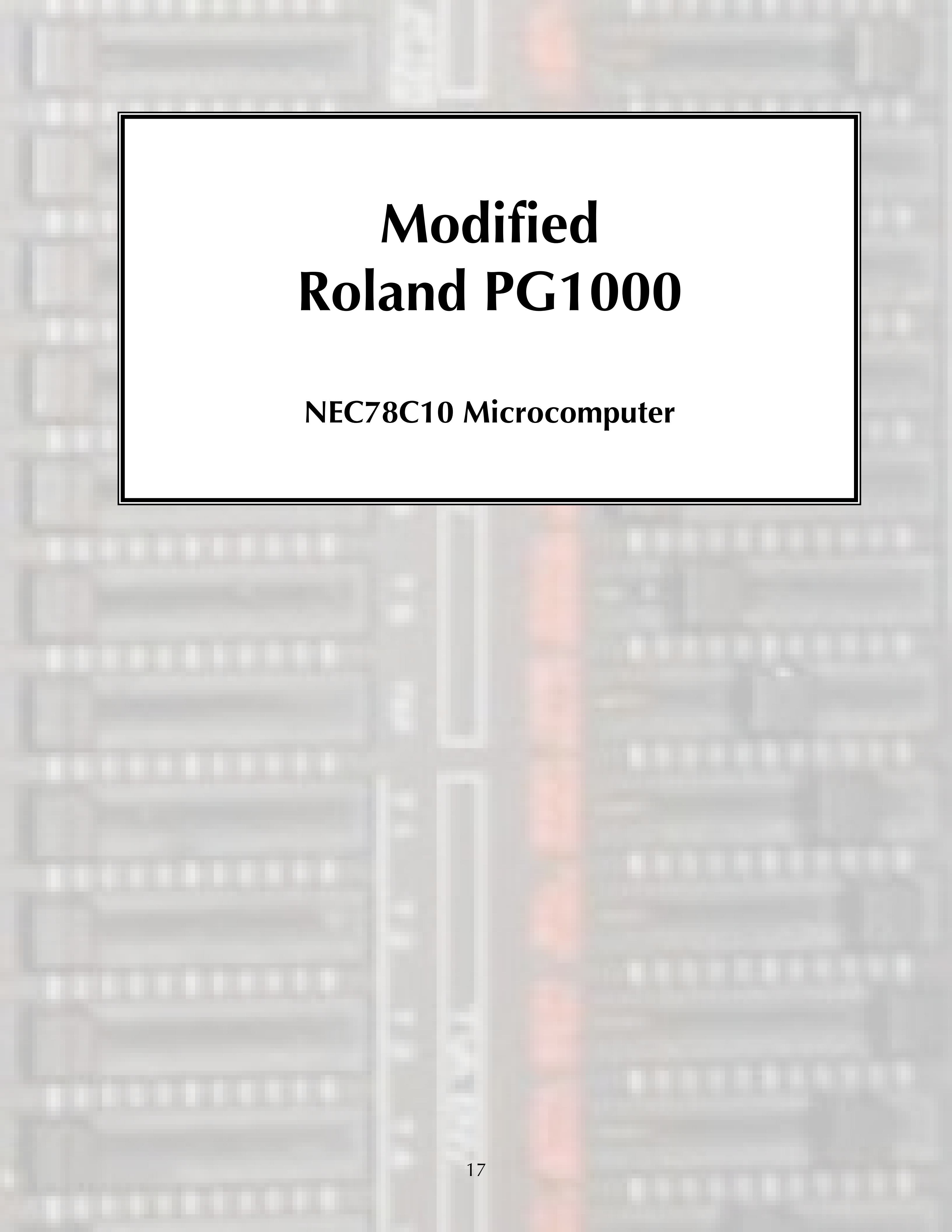
Light Sensor Control Voltage



Light Wand



Pressure Sensor Controller



# Modified Roland PG1000

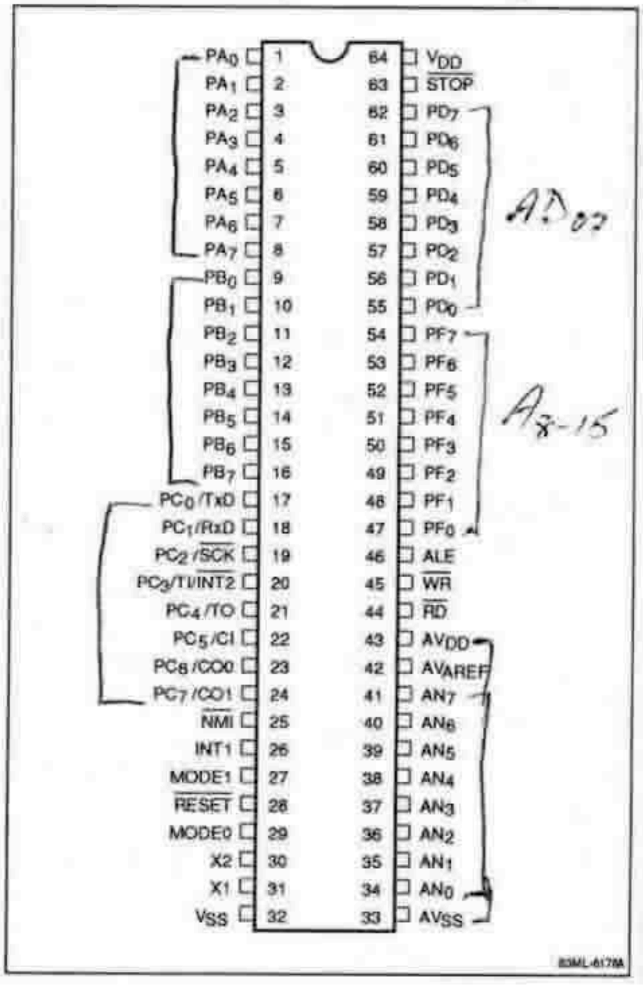
## NEC78C10 Microcomputer

# NEC 78C10 Microcomputer

At the heart of the Roland PG1000 is a NEC 78C10 single-chip microcomputer. It integrates on-chip functions that are normally provided by external components. These functions include a 16-bit ALU, a 256-byte RAM memory (used for program variables), an eight channel Analog to Digital converter (used to convert 56 slider voltages), a 16-bit timer/event counter, two 8-bit timers, a USART serial interface (used to send MIDI) and a total 44 input/output lines (used for the LCD screen, pushbuttons, LEDs, serial I/O, and other uses).

What follows is the pin configuration for the 64-pin chip, and a table of its instruction set. More detailed info can be found in the NEC Single-Chip Microcontroller Data Book (1990, NEC Electronics Inc).

***64-Pin QUIP or SDIP (Plastic or Ceramic)***



| | | | |
|---|---|---|---|
| 00 | NOP | 1 | No operation |
| 01 | LDAW wa | 2 | A < ( V / offset ) |
| 04 | LXI rp2,word | 3 | SP < word |
| 05 | ANIW wa,byte | 3 | (V / offset) < (V / offset) AND byte |
| 07 | ANI A,byte | 2 | A < A AND byte |
| 08 | MOV A, r1 | 1 | A < EAH |
| 09 | MOV A, r1 | 1 | A < EAL |
| 0A | MOV A, r1 | 1 | A < B |
| 0B | MOV A, r1 | 1 | A < C |
| 0C | MOV A, r1 | 1 | A < D |
| 0D | MOV A, r1 | 1 | A < E |
| 0E | MOV A, r1 | 1 | A < H |
| 0F | MOV A, r1 | 1 | A < L |
| 10 | EXA | 1 | Alternate V, A, EA register sets |
| 11 | EXX | 1 | Alternate B, C, D, E, H, L register sets |
| 12 | INX rp | 1 | BC < BC +1 |
| 13 | DCX rp | 1 | BC < BC - 1 |
| 14 | LXI rp2,word | 3 | BC < word |
| 15 | ORIW wa,byte | 3 | (V / offset) < (V / offset) OR byte |
| 16 | XRI A,byte | 2 | A < A EX-OR byte |
| 17 | ORI A,byte | 2 | A < A OR byte |
| 18 | MOV r1,A | 1 | EAH < A |
| 19 | MOV r1,A | 1 | EAL < A |
| 1A | MOV r1,A | 1 | B < A |
| 1B | MOV r1,A | 1 | C < A |
| 1C | MOV r1,A | 1 | D < A |
| 1D | MOV r1,A | 1 | E < A |
| 1E | MOV r1,A | 1 | H < A |
| 1F | MOV r1,A | 1 | L < A |
| 20 | INRW wa | 2 | (V / offset) < (V / offset) + 1, Skip if carry |
| 21 | JB | 1 | PC(hi) < B, PC(lo) < C |
| 22 | INX rp | 1 | DE < DE +1 |
| 23 | DCX rp | 1 | DE < DE - 1 |
| 24 | LXI rp2,word | 3 | DE < word |
| 25 | GTIW wa,byte | 3 | (V / offset) < (V / offset) - byte - 1, Skip if no borrow |
| 26 | ADINC A,byte | 2 | A < A + byte, Skip if no carry |
| 27 | GTI A,byte | 2 | A < A - byte - 1, Skip if no borrow |
| 29 | LDAX rpa2 | 1 | A < (BC) |
| 2A | LDAX rpa2 | 1 | A < (DE) |
| 2B | LDAX rpa2 | 1 | A < (HL) |
| 2C | LDAX rpa2 | 1 | A < (DE)+ |
| 2D | LDAX rpa2 | 1 | A < (HL)+ |
| 2E | LDAX rpa2 | 1 | A < (DE)- |
| 2F | LDAX rpa2 | 1 | A < (HL)- |
| 30 | DCRW wa | 2 | (V / offset) < (V / offset) - 1, Skip if borrow |
| 31 | BLOCK | 1 | Block transfer (HL)+ to (DE)+ for C counts |
| 32 | INX rp | 1 | HL < HL + 1 |
| 33 | DCX rp | 1 | HL < HL - 1 |
| 34 | LXI rp2,word | 3 | HL < word |
| 35 | LTIW wa,byte | 3 | (V / offset) - byte, Skip if borrow |
| 36 | SUINB A,byte | 2 | A < A - byte, Skip if no borrow |
| 37 | LTI A,byte | 2 | A - byte, Skip if borrow |
| 39 | STAX rpa2 | 1 | (BC) < A |

|  |  |  |  |
|---|---|---|---|
| 3A | STAX  rpa2 | 1 | (DE) < A |
| 3B | STAX  rpa2 | 1 | (HL) < A |
| 3C | STAX  rpa2 | 1 | (DE)+ < A |
| 3D | STAX  rpa2 | 1 | (HL)+ < A |
| 3E | STAX  rpa2 | 1 | (DE)- < A |
| 3F | STAX  rpa2 | 1 | (HL)- < A |
| 40 | CALL  word | 3 | Subroutine call, PC < word |
| 41 | INR  r2 | 1 | A < A + 1, Skip if carry |
| 42 | INR  r2 | 1 | B < B + 1, Skip if carry |
| 43 | INR  r2 | 1 | C < C + 1, Skip if carry |
| 44 | LXI  rp2,word | 3 | EA < word |
| 45 | ONIW  wa,byte | 3 | (V / offset) AND byte,  Skip if no zero |
| 46 | ADI  A,byte | 2 | A < A + byte |
| 47 | ONI  A,byte | 2 | A AND byte,  Skip if no zero |
| 48 01 | SLRC  r2 | 2 | A shift logical right,  Skip if carry |
| 48 02 | SLRC  r2 | 2 | B shift logical right,  Skip if carry |
| 48 03 | SLRC  r2 | 2 | C shift logical right,  Skip if carry |
| 48 05 | SLLC  r2 | 2 | A shift logical left,  Skip if carry |
| 48 06 | SLLC  r2 | 2 | B shift logical left,  Skip if carry |
| 48 07 | SLLC  r2 | 2 | C shift logical left,  Skip if carry |
| 48 0A | SK  f | 2 | Skip if CY = 1, |
| 48 0B | SK  f | 2 | Skip if HC = 1, |
| 48 0C | SK  f | 2 | Skip if Z = 1, |
| 48 0A | SK  f | 2 | Skip if CY = 1, |
| 48 0B | SK  f | 2 | Skip if HC = 1, |
| 48 0C | SK  f | 2 | Skip if Z = 1, |
| 48 21 | SLR  r2 | 2 | A shift logical right |
| 48 22 | SLR  r2 | 2 | B shift logical right |
| 48 23 | SLR  r2 | 2 | C shift logical right |
| 48 25 | SLL  r2 | 2 | A shift logical left |
| 48 26 | SLL  r2 | 2 | B shift logical left |
| 48 27 | SLL  r2 | 2 | C shift logical left |
| 48 28 | JEA | 2 | PC < EA |
| 48 29 | CALB | 2 | Subroutine call, PC < BC |
| 48 2A | CLC | 2 | CY < 0 |
| 48 2B | STC | 2 | CY < 1 |
| 48 2D | MUL  r2 | 2 | EA < EA x A, |
| 48 2E | MUL  r2 | 2 | EA < EA x B, |
| 48 2F | MUL  r2 | 2 | EA < EA x C, |
| 48 31 | RLR  r2 | 2 | A rotate logical right |
| 48 32 | RLR  r2 | 2 | B rotate logical right |
| 48 33 | RLR  r2 | 2 | C rotate logical right |
| 48 35 | RLL  r2 | 2 | A rotate logical left |
| 48 36 | RLL  r2 | 2 | B rotate logical left |
| 48 37 | RLL  r2 | 2 | C rotate logical left |
| 48 38 | RLD | 2 | A, (HL) rotate left digit |
| 48 39 | RRD | 2 | A, (HL) rotate right digit |
| 48 3A | NEGA | 2 | Negate A, add 1   (two's complement) |
| 48 3B | HLT | 1 | Set Halt mode |
| 48 3D | DIV  r2 | 2 | EA < EA div A,  A < remainder |
| 48 3E | DIV  r2 | 2 | EA < EA div B,  B < remainder |
| 48 3F | DIV  r2 | 2 | EA < EA div C,  C < remainder |
| 48 40 | SKIT  irf | 2 | Skip if NMI = 1, |

| | | | |
|---|---|---|---|
| 48 41 | SKIT  irf | 2 | Skip if FT0 = 1, |
| 48 42 | SKIT  irf | 2 | Skip if FT1 = 1, |
| 48 43 | SKIT  irf | 2 | Skip if F1 = 1, |
| 48 44 | SKIT  irf | 2 | Skip if F2 = 1, |
| 48 45 | SKIT  irf | 2 | Skip if FE0 = 1, |
| 48 46 | SKIT  irf | 2 | Skip if FE1 = 1, |
| 48 47 | SKIT  irf | 2 | Skip if FEIN = 1, |
| 48 48 | SKIT  irf | 2 | Skip if FAD = 1, |
| 48 49 | SKIT  irf | 2 | Skip if FSR = 1, |
| 48 4A | SKIT  irf | 2 | Skip if FST = 1, |
| 48 4B | SKIT  irf | 2 | Skip if ER = 1, |
| 48 4C | SKIT  irf | 2 | Skip if OV = 1, |
| 48 50 | SKIT  irf | 2 | Skip if AN4 = 1, |
| 48 51 | SKIT  irf | 2 | Skip if AN5 = 1, |
| 48 52 | SKIT  irf | 2 | Skip if AN6 = 1, |
| 48 53 | SKIT  irf | 2 | Skip if AN7 = 1, |
| 48 54 | SKIT  irf | 2 | Skip if SB = 1, |
| 48 60 | SKNIT  irf | 2 | Skip if NMI  = 0, |
| 48 61 | SKNIT  irf | 2 | Skip if  FT0 = 0, |
| 48 62 | SKNIT  irf | 2 | Skip if FT1  = 0, |
| 48 63 | SKNIT  irf | 2 | Skip if  F1 = 0, |
| 48 64 | SKNIT  irf | 2 | Skip if  F2 = 0, |
| 48 65 | SKNIT  irf | 2 | Skip if  FE0 = 0, |
| 48 66 | SKNIT  irf | 2 | Skip if  FE1 = 0, |
| 48 67 | SKNIT  irf | 2 | Skip if  FEIN = 0, |
| 48 68 | SKNIT  irf | 2 | Skip if FAD  = 0, |
| 48 69 | SKNIT  irf | 2 | Skip if FSR  = 0, |
| 48 6A | SKNIT  irf | 2 | Skip if  FST = 0, |
| 48 6B | SKNIT  irf | 2 | Skip if ER  = 0, |
| 48 6C | SKNIT  irf | 2 | Skip if  OV = 0, |
| 48 70 | SKNIT  irf | 2 | Skip if AN4  = 0, |
| 48 71 | SKNIT  irf | 2 | Skip if AN5  = 0, |
| 48 72 | SKNIT  irf | 2 | Skip if AN6 = 0, |
| 48 73 | SKNIT  irf | 2 | Skip if AN7 = 0, |
| 48 74 | SKNIT  irf | 2 | Skip if  SB  = 0, |
| 48 82 | LDEAX  rpa3 | 2 | EAL<(DE), EAH<(DE+1) |
| 48 83 | LDEAX  rpa3 | 2 | EAL<(HL), EAH<(HL+1) |
| 48 84 | LDEAX  rpa3 | 2 | EAL<(DE++), EAH<(DE++ +1) |
| 48 85 | LDEAX  rpa3 | 2 | EAL<(HL++), EAH<(HL++ +1) |
| 48 8B | LDEAX  rpa3 | 3 | EAL<(DE+byte), EAH<(DE+byte+1) |
| 48 8C | LDEAX  rpa3 | 2 | EAL<(HL+A), EAH<(HL+A+1) |
| 48 8D | LDEAX  rpa3 | 2 | EAL<(HL+B), EAH<(HL+B+1) |
| 48 8E | LDEAX  rpa3 | 2 | EAL<(HL+EA), EAH<(HL+EA+1) |
| 48 8F | LDEAX  rpa3 | 3 | EAL<(HL+byte), EAH<(HL+byte+1) |
| 48 92 | STEAX  rpa3 | 2 | (DE)<EAL, (DE+1)<EAH |
| 48 93 | STEAX  rpa3 | 2 | (HL)<EAL, (HL+1)<EAH |
| 48 94 | STEAX  rpa3 | 2 | (DE++)<EAL, (DE++ +1)<EAH |
| 48 95 | STEAX  rpa3 | 2 | (HL++)<EAL, (HL++ +1)<EAH |
| 48 9B | STEAX  rpa3 | 3 | (DE+byte)<EAL, (DE+byte+1)<EAH |
| 48 9C | STEAX  rpa3 | 2 | (HL+A)<EAL, (HL+A+1)<EAH |
| 48 9D | STEAX  rpa3 | 2 | (HL+B)<EAL, (HL+B+1)<EAH |
| 48 9E | STEAX  rpa3 | 2 | (HL+EA)<EAL, (HL+EA+1)<EAH |
| 48 9F | STEAX  rpa3 | 3 | (HL+byte)<EAL, (HL+byte+1)<EAH |

|  |  |  |  |
|---|---|---|---|
| 48 A0 | DSLR  EA | 2 | EA shift logical right |
| 48 A4 | DSLL  EA | 2 | EA shift logical left |
| 48 A8 | TABLE | 2 | C < (PC+3+A),     B < (PC+3+A+1) |
| 48 B0 | DRLR  EA | 2 | EA rotate logical right |
| 48 B4 | DRLL  EA | 2 | EA rotate logical left |
| 48 BB | STOP | 1 | Set software Stop mode |
| 48 C0 | DMOV  EA,sr4 | 2 | EA < ECNT |
| 48 C1 | DMOV  EA,sr4 | 2 | EA < ECPT |
| 48 D2 | DMOV  sr3,EA | 2 | ETM0 < EA |
| 48 D3 | DMOV  sr3,EA | 2 | ETM1 < EA |
| 49 | MVIX  rpa1, byte | 2 | (BC) < byte |
| 4A | MVIX  rpa1, byte | 2 | (DE) < byte |
| 4B | MVIX  rpa1, byte | 2 | (HL) < byte |
| 4C | MOV  A,sr1 | 2 | A < sr1          (1 1 s5 s4 s3 s2 s1) |
| 4D | MOV  sr,A | 2 | sr < A          (1 1 s5 s4 s3 s2 s1) |
| 4E | JRE | 2 | PC < PC + 2 + disp forward |
| 4F | JRE | 2 | PC < PC + 2 -  disp backward |
| 50 | EXH | 1 | Alternate  H, L  register sets |
| 51 | DCR  r2 | 1 | A < A - 1,   Skip if borrow |
| 52 | DCR  r2 | 1 | B < B - 1,   Skip if borrow |
| 53 | DCR  r2 | 1 | C < C - 1,   Skip if borrow |
| 54 | JMP  word | 3 | PC < word |
| 55 | OFFIW  wa,byte | 3 | (V / offset) AND byte, Skip if zero |
| 56 | ACI  A,byte | 2 | A < A + byte + CY |
| 57 | OFFI  A,byte | 2 | A AND byte,  Skip if zero |
| 5H | BIT  bit,wa | 2 | Skip if (V / offset) bit (b2,b1,b0)  is 1 |
| 60 0H | ANA  r,A | 2 | r < r AND A      (r = V, A, B, C, D, E, H, L) |
| 60 1L | XRA  r,A | 2 | r < r EX-OR A      (r = V, A, B, C, D, E, H, L) |
| 60 1H | ORA  r,A | 2 | r < r OR A      (r = V, A, B, C, D, E, H, L) |
| 60 2L | ADDNC  r,A | 2 | r < r + A, Skip if no carry |
| 60 2H | GTA  r,A | 2 | r - A - 1, Skip if no borrow |
| 60 3L | SUBNB  r,A | 2 | r < r - A, Skip if no carry |
| 60 3H | LTA  r,A | 2 | r - A, Skip if borrow |
| 60 4L | ADD  r,A | 2 | r < r + A      (r = V, A, B, C, D, E, H, L) |
| 60 5L | ADC  r,A | 2 | r < r + A + CY      (r = V, A, B, C, D, E, H, L) |
| 60 6L | SUB  r,A | 2 | r < r - A      (r = V, A, B, C, D, E, H, L) |
| 60 6H | NEA  r,A | 2 | r - A,  Skip if no zero |
| 60 7L | SBB  r,A | 2 | r < r - A - CY      (r = V, A, B, C, D, E, H, L) |
| 60 7H | EQA  r,A | 2 | r - A,  Skip if zero |
| 60 8H | ANA  A,r | 2 | A < A AND r      (r = V, A, B, C, D, E, H, L) |
| 60 9L | XRA  A,r | 2 | A < A EX-OR r      (r = V, A, B, C, D, E, H, L) |
| 60 9H | ORA  A,r | 2 | A < A OR r      (r = V, A, B, C, D, E, H, L) |
| 60 AL | ADDNC  A,r | 2 | A < A + r, Skip if no carry |
| 60 AH | GTA  A,r | 2 | A - r - 1,  Skip if no borrow |
| 60 BL | SUBNB  A,r | 2 | A < A - r, Skip if no carry |
| 60 BH | LTA  A,r | 2 | A - r,  Skip if borrow |
| 60 CL | ADD  A,r | 2 | A < A + r      (r = V, A, B, C, D, E, H, L) |
| 60 CH | ONA  A,r | 2 | A AND r, Skip if no zero |
| 60 DL | ADC  A,r | 2 | A < A + r + CY      (r = V, A, B, C, D, E, H, L) |
| 60 DH | OFFA  A,r | 2 | A AND r, Skip if zero |
| 60 EL | SUB  A,r | 2 | A < A - r      (r = V, A, B, C, D, E, H, L) |
| 60 EH | NEA  A,r | 2 | A - r, Skip if no zero |
| 60 FL | SBB  A,r | 2 | A < a - r - CY      (r = V, A, B, C, D, E, H, L) |

| | | | |
|---|---|---|---|
| 60 FH | EQA A,r | 2 | A - r, Skip if zero |
| 61 | DAA | 1 | Decimal adjust A |
| 62 | RETI | 1 | Return from Interrupt |
| 63 | STAW wa | 2 | (V / offset ) < A |
| 64 0L | MVI sr2,byte | 3 | sr2 < byte (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 8L | MVI sr2,byte | 3 | sr2 < byte (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 0H | ANI sr2,byte | 3 | sr2 < sr2 AND byte, (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 8H | ANI sr2,byte | 3 | sr2 < sr2 AND byte, (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 1L | XRI sr2,byte | 3 | sr2 < sr2 EX-OR byte (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 9L | XRI sr2,byte | 3 | sr2 < sr2 EX-OR byte (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 1H | ORI sr2,byte | 3 | sr2 < sr2 OR byte, (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 9H | ORI sr2,byte | 3 | sr2 < sr2 OR byte, (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 2L | ADINC sr2,byte | 3 | sr2 < sr2 + byte, Skip if no carry (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 AL | ADINC sr2,byte | 3 | sr2 < sr2 + byte, Skip if no carry (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 2H | GTI sr2,byte | 3 | sr2 - byte-1, Skip if no borrow (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 AH | GTI sr2,byte | 3 | sr2 - byte-1, Skip if no borrow (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 3L | SUINB sr2,byte | 3 | sr2 < sr2 - byte, Skip if no borrow (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 BL | SUINB sr2,byte | 3 | sr2 < sr2 - byte, Skip if no borrow (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 3H | LTI sr2,byte | 3 | sr2 - byte, Skip if borrow (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 BH | LTI sr2,byte | 3 | sr2 - byte, Skip if borrow (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 4L | ADI sr2,byte | 3 | sr2 < sr2 + byte (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 CL | ADI sr2,byte | 3 | sr2 < sr2 + byte (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 4H | ONI sr2,byte | 3 | sr2 AND byte, Skip if no zero (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 CH | ONI sr2,byte | 3 | sr2 AND byte, Skip if no zero (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 5L | ACI sr2,byte | 3 | sr2 < sr2 + byte + CY (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 DL | ACI sr2,byte | 3 | sr2 < sr2 + byte + CY (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 5H | OFFI sr2,byte | 3 | sr2 AND byte, Skip if zero (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 DH | OFFI sr2,byte | 3 | sr2 AND byte, Skip if zero (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 6L | SUI sr2,byte | 3 | sr2 < sr2 - byte (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 EL | SUI sr2,byte | 3 | sr2 < sr2 - byte (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 6H | NEI sr2,byte | 3 | sr2 - byte, Skip if no zero (PA,PB,PC,PD, -,PF,MKH,MKL) |

| | | | |
|---|---|---|---|
| 64 EH | NEI sr2,byte | 3 | sr2 - byte, Skip if no zero (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 7L | SBI sr2,byte | 3 | sr2 < sr2 - byte - CY, (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 FL | SBI sr2,byte | 3 | sr2 < sr2 - byte - CY, (ANM,SMH,-,EOM, -,TMM,-,-) |
| 64 7H | EQI sr2,byte | 3 | sr2 - byte, Skip if zero (PA,PB,PC,PD, -,PF,MKH,MKL) |
| 64 FH | EQI sr2,byte | 3 | sr2 - byte, Skip if zero (ANM,SMH,-,EOM, -,TMM,-,-) |
| 65 | NEIW wa,byte | 3 | (V / offset) - byte, Skip if no zero |
| 66 | SUI A,byte | 2 | A < A - byte |
| 67 | NEI A,byte | 2 | A - byte, Skip if no zero |
| 68 | MVI r,byte | 2 | V < byte |
| 69 | MVI r,byte | 2 | A < byte |
| 6A | MVI r,byte | 2 | B < byte |
| 6B | MVI r,byte | 2 | C < byte |
| 6C | MVI r,byte | 2 | D < byte |
| 6D | MVI r,byte | 2 | E < byte |
| 6E | MVI r,byte | 2 | H < byte |
| 6F | MVI r,byte | 2 | L < byte |
| 70 0E | SSPD word | 4 | (word) < SP(low), (word + 1) < SP(hi) |
| 70 0F | LSPD word | 4 | SP(lo) < (word), SP(hi) < (word + 1) |
| 70 1E | SBCD word | 4 | (word) < C, (word + 1) < B |
| 70 1F | LBCD word | 4 | C < (word), B < (word + 1) |
| 70 2E | SDED word | 4 | (word) < E, (word + 1) < D |
| 70 2F | LDED word | 4 | E < (word), D < (word + 1) |
| 70 3E | SHLD word | 4 | (word) < L, (word + 1) < H |
| 70 3F | LHLD word | 4 | L < (word), H < (word + 1) |
| 70 41 | EADD EA,r2 | 2 | EA < EA + A |
| 70 42 | EADD EA,r2 | 2 | EA < EA + B |
| 70 43 | EADD EA,r2 | 2 | EA < EA + C |
| 70 61 | ESUB EA,rp3 | 2 | EA < EA - A |
| 70 62 | ESUB EA,rp3 | 2 | EA < EA - B |
| 70 63 | ESUB EA,rp3 | 2 | EA < EA - C |
| 70 6H | MOV r,word | 4 | r < (word) (r = V, A, B, C, D, E, H, L) |
| 70 7H | MOV word,r | 4 | (word) < r (r = V, A, B, C, D, E, H, L) |
| 70 8H | ANAX rpa | 2 | A<A AND (rpa),<br>(-,BC,DE,HL, DE+,HL+,DE-,HL-) |
| 70 9L | XRAX rpa | 2 | A<A EX-OR (rpa),<br>(-,BC,DE,HL, DE+,HL+,DE-,HL-) |
| 70 9H | ORAX rpa | 2 | A<A OR (rpa),<br>(-,BC,DE,HL, DE+,HL+,DE-,HL-) |
| 70 AL | ADDNCX rpa | 2 | A < A + (rpa), Skip if no carry |
| 70 AH | GTAX rpa | 2 | A - (rpa) - 1, Skip if no borrow |
| 70 BL | SUBNBX rpa | 2 | A < A - (rpa) - CY, Skip if no borrow |
| 70 BH | LTAX rpa | 2 | A _ (rpa), Skip if borrow |
| 70 CL | ADDX rpa | 2 | A<A+(rpa),<br>(-,BC,DE,HL, DE+,HL+,DE-,HL-) |
| 70 CH | ONAX rpa | 2 | A AND (rpa), Skip if no zero |
| 70 DL | ADCX rpa | 2 | A<A+(rpa)+CY,<br>(-,BC,DE,HL, DE+,HL+,DE-,HL-) |
| 70 DH | OFFAX rpa | 2 | A AND (rpa), Skip if zero |
| 70 EL | SUBX rpa | 2 | A<A-(rpa), (-,BC,DE,HL, DE+,HL+,DE-,HL-) |

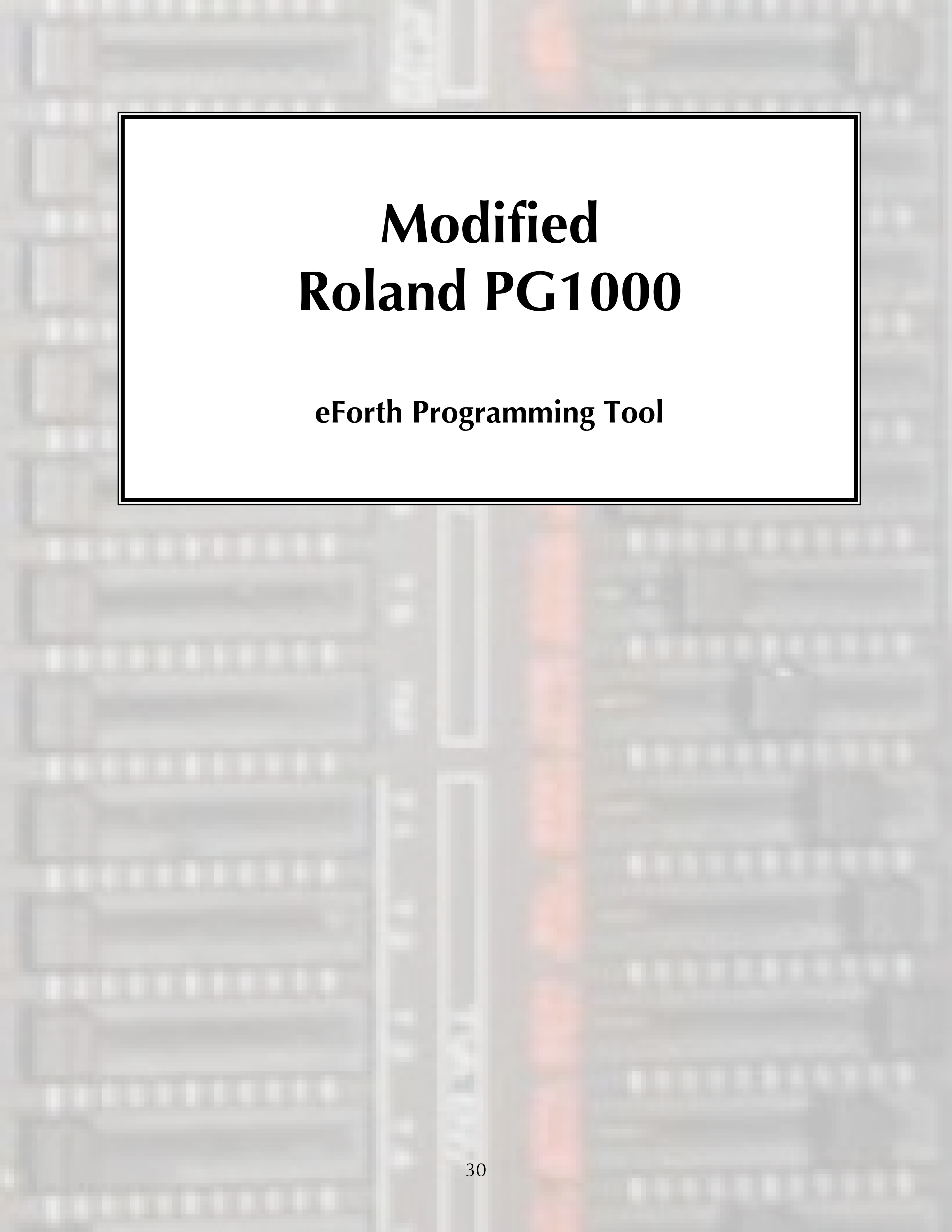
|  |  |  |  |
|---|---|---|---|
| 70 EH | NEAX rpa | 2 | A - (rpa), Skip if no zero |
| 70 FL | SBBX rpa | 2 | A<A-(rpa)-CY,<br>(-,BC,DE,HL, DE+,HL+,DE-,HL-) |
| 70 FH | EQAX rpa | 2 | A - (rpa), Skip if zero |
| 71 | MVIW wa,byte | 3 | ( V / offset ) < byte |
| 72 | SOFTI | 1 | Software Interrupt |
| 74 0L | ANI r,byte | 3 | r < r AND byte, (r = V,A,B,C, D,E,H,L) |
| 74 1L | XRI r,byte | 3 | r < r EX-OR byte, (r = V,A,B,C, D,E,H,L) |
| 74 1H | ORI r,byte | 3 | r < r OR byte, (r = V,A,B,C, D,E,H,L) |
| 74 2L | ADINC r,byte | 3 | r < r + byte, Skip if no carry |
| 74 2H | GTI r,byte | 3 | r - byte - 1, Skip if no borrow |
| 74 3L | SUINB r,byte | 3 | r < r - byte, Skip if no borrow |
| 74 3H | LTI r,byte | 3 | r - byte, Skip if borrow |
| 74 4L | ADI r,byte | 3 | r < r + byte, (r = V,A,B,C, D,E,H,L) |
| 74 4H | ONI r,byte | 3 | r AND byte, Skip if no zero |
| 74 5L | ACI r,byte | 3 | r < r + byte + CY, (r = V,A,B,C, D,E,H,L) |
| 74 5H | OFFI r,byte | 3 | r AND byte, Skip if zero |
| 74 6L | SUI r,byte | 3 | r < r - byte, (r = V,A,B,C, D,E,H,L) |
| 74 6H | NEI r,byte | 3 | r - byte, Skip if no zero |
| 74 7L | SBI r,byte | 3 | r < r - byte - CY, (r = V,A,B,C, D,E,H,L) |
| 74 7H | EQI r,byte | 3 | r - byte, Skip if zero |
| 74 88 | ANAW wa | 3 | A < A AND ( V / offset ) |
| 74 8D | DAN EA,rp3 | 2 | EA < EA AND BC, |
| 74 8E | DAN EA,rp3 | 2 | EA < EA AND DE |
| 74 8F | DAN EA,rp3 | 2 | EA < EA AND HL, |
| 74 90 | XRAW wa | 3 | A < A EX-OR ( V / offset ) |
| 74 95 | DXR EA,rp3 | 2 | EA , EA EX-OR BC, |
| 74 96 | DXR EA,rp3 | 2 | EA , EA EX-OR DE, |
| 74 97 | DXR EA,rp3 | 2 | EA , EA EX-OR HL, |
| 74 98 | ORAW wa | 3 | A < A OR ( V / offset ) |
| 74 9D | DOR EA,rp3 | 2 | EA < EA OR BC, (BC, DE, HL) |
| 74 9E | DOR EA,rp3 | 2 | EA < EA OR DE, (BC, DE, HL) |
| 74 9F | DOR EA,rp3 | 2 | EA < EA OR HL, (BC, DE, HL) |
| 74 A0 | ADDNCW wa | 3 | A < A + ( V / offset ), Skip if no carry |
| 74 A5 | DADDNC EA,rp3 | 2 | EA < EA + BC, Skip if no carry, |
| 74 A6 | DADDNC EA,rp3 | 2 | EA < EA + DE, Skip if no carry, |
| 74 A7 | DADDNC EA,rp3 | 2 | EA < EA + HL, Skip if no carry, |
| 74 A8 | GTAW wa | 3 | A - ( V / offset ) - 1, Skip if no borrow |
| 74 AD | DGT EA,rp3 | 2 | EA-BC-1, Skip if no borrow, |
| 74 AE | DGT EA,rp3 | 2 | EA-DE-1, Skip if no borrow, |
| 74 AF | DGT EA,rp3 | 2 | EA-HL-1, Skip if no borrow, |
| 74 B0 | SUBNBW wa | 3 | A < A - ( V / offset ), Skip if no borrow |
| 74 B5 | DSUBNB EA,rp3 | 2 | EA < EA - BC, Skip if no borrow, |
| 74 B6 | DSUBNB EA,rp3 | 2 | EA < EA - DE, Skip if no borrow, |
| 74 B7 | DSUBNB EA,rp3 | 2 | EA < EA - HL, Skip if no borrow, |
| 74 B8 | LTAW wa | 3 | A - ( V / offset ), Skip if borrow |
| 74 BD | DLT EA,rp3 | 2 | EA - BC Skip if borrow, |
| 74 BE | DLT EA,rp3 | 2 | EA - DE, Skip if borrow, |
| 74 BF | DLT EA,rp3 | 2 | EA - HL, Skip if borrow, |
| 74 C0 | ADDW wa | 3 | A < A + ( V / offset ) |
| 74 C5 | DADD EA,rp3 | 2 | EA < EA + BC, |
| 74 C6 | DADD EA,rp3 | 2 | EA < EA + DE, |
| 74 C7 | DADD EA,rp3 | 2 | EA < EA +HL, |
| 74 C8 | ONAW wa | 3 | A AND ( V / offset ), Skip if no Zero |

|  |  |  |  |
|---|---|---|---|
| 74 CD | DON  EA,rp3 | 2 | EA AND BC,  Skip if no zero, |
| 74 CE | DON  EA,rp3 | 2 | EA AND DE,  Skip if no zero, |
| 74 CF | DON  EA,rp3 | 2 | EA AND HL,  Skip if no zero, |
| 74 D0 | ADCW  wa | 3 | A < A + ( V / offset ) + CY |
| 74 D5 | DADC  EA,rp3 | 2 | EA < EA + BC + CY, |
| 74 D6 | DADC  EA,rp3 | 2 | EA < EA + DE + CY, |
| 74 D7 | DADC  EA,rp3 | 2 | EA < EA + HL + CY, |
| 74 D8 | OFFAW  wa | 3 | A AND ( V / offset ),  Skip if zero |
| 74 DD | DOFF  EA,rp3 | 2 | EA AND BC,  Skip if zero, |
| 74 DE | DOFF  EA,rp3 | 2 | EA AND DE,  Skip if zero, |
| 74 DF | DOFF  EA,rp3 | 2 | EA AND HL,  Skip if zero, |
| 74 E0 | SUBW  wa | 3 | A < A - ( V / offset ) |
| 74 E5 | DSUB  EA,rp3 | 2 | EA < EA -BC, |
| 74 E6 | DSUB  EA,rp3 | 2 | EA < EA - DE, |
| 74 E7 | DSUB  EA,rp3 | 2 | EA < EA - HL, |
| 74 E8 | NEAW  wa | 3 | A - ( V / offset ),  Skip if no zero |
| 74 ED | DNE  EA,rp3 | 2 | EA - BC,  Skip if no zero, |
| 74 EE | DNE  EA,rp3 | 2 | EA - DE,  Skip if no zero, |
| 74 EF | DNE  EA,rp3 | 2 | EA - HL,  Skip if no zero, |
| 74 F0 | SBBW  wa | 3 | A < A - ( V / offset ) - CY |
| 74 F5 | DSBB  EA,rp3 | 2 | EA < EA - BC - CY, |
| 74 F6 | DSBB  EA,rp3 | 2 | EA < EA - DE - CY, |
| 74 F7 | DSBB  EA,rp3 | 2 | EA < EA - HL - CY, |
| 74 F8 | EQAW  wa | 3 | A - ( V / offset ),  Skip if zero |
| 74 FD | DEQ  EA,rp3 | 2 | EA - BC,  Skip if zero, |
| 74 FE | DEQ  EA,rp3 | 2 | EA - DE,  Skip if zero, |
| 74 FF | DEQ  EA,rp3 | 2 | EA - HL,  Skip if zero, |
| 75 | EQIW  wa,byte | 3 | (V / offset) - byte, Skip if zero |
| 76 | SBI  A,byte | 2 | A < A - byte - CY |
| 77 | EQI  A,byte | 2 | A - byte,  Skip if zero |
| 78 | CALF  word | 2 | Subroutine call to 8xx |
| 79 | CALF  word | 2 | Subroutine call to 9xx |
| 7A | CALF  word | 2 | Subroutine call to Axx |
| 7B | CALF  word | 2 | Subroutine call to Bxx |
| 7C | CALF  word | 2 | Subroutine call to Cxx |
| 7D | CALF  word | 2 | Subroutine call to Dxx |
| 7E | CALF  word | 2 | Subroutine call to Exx |
| 7F | CALF  word | 2 | Subroutine call to Fxx |
| 80 | CALT | 1 | Subroutine call to Jump Table 80 |
| 81 | CALT | 1 | Subroutine call to Jump Table 82 |
| 82 | CALT | 1 | Subroutine call to Jump Table 84 |
| 83 | CALT | 1 | Subroutine call to Jump Table 86 |
| 84 | CALT | 1 | Subroutine call to Jump Table 88 |
| 85 | CALT | 1 | Subroutine call to Jump Table 8A |
| 86 | CALT | 1 | Subroutine call to Jump Table 8C |
| 87 | CALT | 1 | Subroutine call to Jump Table 8E |
| 88 | CALT | 1 | Subroutine call to Jump Table 90 |
| 89 | CALT | 1 | Subroutine call to Jump Table 92 |
| 8A | CALT | 1 | Subroutine call to Jump Table 94 |
| 8B | CALT | 1 | Subroutine call to Jump Table 96 |
| 8C | CALT | 1 | Subroutine call to Jump Table 98 |
| 8D | CALT | 1 | Subroutine call to Jump Table 9A |
| 8E | CALT | 1 | Subroutine call to Jump Table 9C |

| | | | |
|---|---|---|---|
| 8F | CALT | 1 | Subroutine call to Jump Table 9E |
| 90 | CALT | 1 | Subroutine call to Jump Table A0 |
| 91 | CALT | 1 | Subroutine call to Jump Table A2 |
| 92 | CALT | 1 | Subroutine call to Jump Table A4 |
| 93 | CALT | 1 | Subroutine call to Jump Table A6 |
| 94 | CALT | 1 | Subroutine call to Jump Table A8 |
| 95 | CALT | 1 | Subroutine call to Jump Table AA |
| 96 | CALT | 1 | Subroutine call to Jump Table AC |
| 97 | CALT | 1 | Subroutine call to Jump Table AE |
| 98 | CALT | 1 | Subroutine call to Jump Table B0 |
| 99 | CALT | 1 | Subroutine call to Jump Table B2 |
| 9A | CALT | 1 | Subroutine call to Jump Table B4 |
| 9B | CALT | 1 | Subroutine call to Jump Table B6 |
| 9C | CALT | 1 | Subroutine call to Jump Table B8 |
| 9D | CALT | 1 | Subroutine call to Jump Table BA |
| 9E | CALT | 1 | Subroutine call to Jump Table BC |
| 9F | CALT | 1 | Subroutine call to Jump Table BE |
| A0 | POP rp1 | 1 | A<(SP), V<(SP+1), SP<SP+2 |
| A1 | POP rp1 | 1 | C<(SP), B<(SP+1), SP<SP+2 |
| A2 | POP rp1 | 1 | E<(SP), D<(SP+1), SP<SP+2 |
| A3 | POP rp1 | 1 | L<(SP), H<(SP+1), SP<SP+2 |
| A4 | POP rp1 | 1 | EA(lo)<(SP), EA(hi)<(SP+1), SP<SP+2 |
| A5 | DMOV EA,rp3 | 1 | EA < BC |
| A6 | DMOV EA,rp3 | 1 | EA < DE |
| A7 | DMOV EA,rp3 | 1 | EA < HL |
| A8 | INX EA | 1 | EA < EA + 1 |
| A9 | DCX EA | 1 | EA < EA - 1 |
| AA | EI | 1 | Enable Interrupt |
| AB | LDAX rpa2 | 2 | A < (DE + byte) |
| AC | LDAX rpa2 | 1 | A < (HL + A) |
| AD | LDAX rpa2 | 1 | A < (HL + B) |
| AE | LDAX rpa2 | 1 | A < (HL + EA) |
| AF | LDAX rpa2 | 2 | A < (HL + byte) |
| B0 | PUSH rp1 | 1 | (SP-1)<V, (SP-2)<A, SP<SP-2 |
| B1 | PUSH rp1 | 1 | (SP-1)<B, (SP-2)<C, SP<SP-2 |
| B2 | PUSH rp1 | 1 | (SP-1)<D, (SP-2)<E, SP<SP-2 |
| B3 | PUSH rp1 | 1 | (SP-1)<H, (SP-2)<L, SP<SP-2 |
| B4 | PUSH rp1 | 1 | (SP-1)<EA(hi), (SP-2)<EA(lo), SP<SP-2 |
| B5 | DMOV rp3,EA | 1 | BC < EA |
| B6 | DMOV rp3,EA | 1 | DE < EA |
| B7 | DMOV rp3,EA | 1 | HL < EA |
| B8 | RET | 1 | Return from subroutine |
| B9 | RETS | 1 | Return from subroutine then Skip |
| BA | DI | 1 | Disable Interrupt |
| BB | STAX rpa2 | 2 | (DE + byte) < A |
| BC | STAX rpa2 | 1 | (HL + A) < A |
| BD | STAX rpa2 | 1 | (HL + B) < A |
| BE | STAX rpa2 | 1 | (HL + EA) < A |
| BF | STAX rpa2 | 2 | (HL + byte) < A |
| C0 | JR | 1 | Jump 1 |
| C1 | JR | 1 | Jump 2 |
| C2 | JR | 1 | Jump 3 |
| C3 | JR | 1 | Jump 4 |

|  |  |  |  |
|---|---|---|---|
| C4 | JR | 1 | Jump 5 |
| C5 | JR | 1 | Jump 6 |
| C6 | JR | 1 | Jump 7 |
| C7 | JR | 1 | Jump 8 |
| C8 | JR | 1 | Jump 9 |
| C9 | JR | 1 | Jump 10 |
| CA | JR | 1 | Jump 11 |
| CB | JR | 1 | Jump 12 |
| CC | JR | 1 | Jump 13 |
| CD | JR | 1 | Jump 14 |
| CE | JR | 1 | Jump 15 |
| CF | JR | 1 | Jump 16 |
| D0 | JR | 1 | Jump 17 |
| D1 | JR | 1 | Jump 18 |
| D2 | JR | 1 | Jump 19 |
| D3 | JR | 1 | Jump 20 |
| D4 | JR | 1 | Jump 21 |
| D5 | JR | 1 | Jump 22 |
| D6 | JR | 1 | Jump 23 |
| D7 | JR | 1 | Jump 24 |
| D8 | JR | 1 | Jump 25 |
| D9 | JR | 1 | Jump 26 |
| DA | JR | 1 | Jump 27 |
| DB | JR | 1 | Jump 28 |
| DC | JR | 1 | Jump 29 |
| DD | JR | 1 | Jump 30 |
| DE | JR | 1 | Jump 31 |
| DF | JR | 1 | Jump 32 |
| E0 | JR | 1 | Jump -31 |
| E1 | JR | 1 | Jump -30 |
| E2 | JR | 1 | Jump -29 |
| E3 | JR | 1 | Jump -28 |
| E4 | JR | 1 | Jump -27 |
| E5 | JR | 1 | Jump -26 |
| E6 | JR | 1 | Jump -25 |
| E7 | JR | 1 | Jump -24 |
| E8 | JR | 1 | Jump -23 |
| E9 | JR | 1 | Jump -22 |
| EA | JR | 1 | Jump -21 |
| EB | JR | 1 | Jump -20 |
| EC | JR | 1 | Jump -19 |
| ED | JR | 1 | Jump -18 |
| EE | JR | 1 | Jump -17 |
| EF | JR | 1 | Jump -16 |
| F0 | JR | 1 | Jump -15 |
| F1 | JR | 1 | Jump -14 |
| F2 | JR | 1 | Jump -13 |
| F3 | JR | 1 | Jump -12 |
| F4 | JR | 1 | Jump -11 |
| F5 | JR | 1 | Jump -10 |
| F6 | JR | 1 | Jump -9 |
| F7 | JR | 1 | Jump -8 |
| F8 | JR | 1 | Jump -7 |

| | | | |
|---|---|---|---|
| F9 | JR | 1 | Jump -6 |
| FA | JR | 1 | Jump -5 |
| FB | JR | 1 | Jump -4 |
| FC | JR | 1 | Jump -3 |
| FD | JR | 1 | Jump -3 |
| FE | JR | 1 | Jump -2 |
| FF | JR | 1 | Jump -0 |



# Modified Roland PG1000

## eForth Programming Tool

```
;==============================================================
;
;    eForth 1.0 by Bill Muench and C. H. Ting, 1990
;    Much of the code is derived from the following sources:
;         8086 figForth by Thomas Newman, 1981 and Joe smith, 1983
;         aFORTH by John Rible
;         bFORTH by Bill Muench
;
;    eForth is a small portable Forth design for a wide range of
;    microprocessors.
;
;    The goal of this implementation is to provide a simple eForth Model
;    which can be ported easily to many 8, 16, 24 and 32 bit CPU's.
;    The following attributes make it suitable for CPU's of the '90:
;
;         small machine dependent kernel and portable high level code
;         source code in the MASM format
;         direct threaded code
;         separated code and name dictionaries
;         simple vectored terminal and file interface to host computer
;         aligned with the proposed ANS Forth Standard
;         easy upgrade path to optimize for specific CPU
;
;    You are invited to implement this Model on your favorite CPU and
;    contribute it to the eForth Library for public use. You may use
;    a portable implementation to advertise more sophisticated and
;    optimized version for commercial purposes. However, you are
;    expected to implement the Model faithfully. The eForth Working
;    Group reserves the right to reject implementation which deviates
;    significantly from this Model.
;
;    As the ANS Forth Standard is still evolving, this Model will
;    change accordingly. Implementations must state clearly the
;    version number of the Model being tracked.
;
;    Representing the eForth Working Group in the Silicon Valley FIG Chapter.
;    Send contributions to:
;
;         Dr. C. H. Ting
;         156 14th Avenue
;         San Mateo, CA 94402
;         (415) 571-7639
;
```

This disk and the companion manual 'eForth Implementation Guide' are available from Offete enterprises, Inc., 1306 South B Street, San Mateo, CA 94402, (415)574-8250 for $25.  The other implementation 8051 eForth and its manual are also distributed by Offete for $25.

eForth Glossary

Derived from bFORTH by Bill Muench, 1990.

WARNING: Advanced information -- subject to change.

Attributes  Capitalized symbols.

C  the word may only be used during compilation of a colon definition.
D  the word is a defining word.
I  the word is IMMEDIATE and will execute during compilation, unless special action is taken.
U  a user value.

================================================================

Stack notes

( compile \ run \ child ;Return ;Float ; <input stream> )

( before -- after ;R before -- after ;F before -- after ; <string> )

================================================================

Glossary

!( w a -- )"store"
Store a 16-bit number at aligned address.

!CSP( -- )"set c s p"
Save the values of the current stack pointers.

!IO( -- )"store i o"
Initialize the serial I/O device.

#( d -- d )"number sign"
Convert one digit of a number using the current base. Must be used within <# and #> .

#>( d -- b u )"number sign greater"
Terminate a numeric conversion.

#S( ud -- 0 0 )"number sign s"
Convert all digits of a number using the current base.

#TIB( -- a )"number t i b"
The system double variable which holds the size and aligned address of the terminal input buffer.

$"( -- ; <string> \ -- $ )I,C"string quote"
Used only within a definition to compile an inline packed string terminated by the " double quote character.
At run-time the address of the packed string is pushed on the data stack.

$"|( -- $ )C"string quote primitive"
Return the address of a compiled inline packed string. The run-time primitive compiled by " .

$,"( -- ; <string> )"string comma quote"
Compile an inline packed character string into the code area, terminated by the " double quote character.

$,n( $ -- )"string comma n"
Create a name for a definition using string.  Set the code pointer to the next free cell in the code area, no code is compiled.
The name is not linked into the dictionary.

$COMPILE( $ -- )
Convert a string to a word address.  Execute the word in interpreting mode or compile it if in compiling mode.

$INTERPRET( $ -- )"string interpret"
At the interactive level, if a word is defined perform its action. If not, try to convert it to a number, if

that fails, issue an error message.

'( -- ca ; <string> )"tick"
Return the code address of the word following.

'?KEY( -- a )U"tick question key"
The system input device status vector.

'BOOT( -- a )
Return the address of a system boot-up routine.

'ECHO( -- a )U"tick echo"
The system echo device vector.

'EMIT( -- a )U"tick emit"
The system output device vector.

'EVAL( -- a )"tick eval"
The system interpret/compile vector.

'EXPECT( -- a )U"tick expect"
The system line input vector.

'NUMBER( -- a )"tick number"
The system number conversion vector.

'PROMPT( -- a )U"tick prompt"
The system prompt vector.

'TAP( -- a )U"tick tap"
The input case function vector.

(( -- ; <string> )I"paren"
Begin a comment. The comment is terminated by the )character. May be used inside or outside a definition.

*( n n -- n )"star"
Multiply two signed numbers. Return a 16-bit signed number.

*/( n1 n2 n3 -- q )"star slash"
Multiply n1 by n2 producing the 32-bit intermediate product d. Divide d by n3 producing a 16-bit quotient.

*/MOD( n1 n2 n3 -- r q )"star slash mod"
Multiply n1 by n2 producing the 32-bit intermediate product d. Divide d by n3 producing a 16-bit remainder and a 16-bit quotient.

+( w w -- w )"plus"
Addition.

+!( n a -- )"plus store"
Increment the 16-bit value at address by n.

,( w -- )"comma"
Compile a 16-bit value into the code area.

-( w w -- w )"minus"
Subtract the top from the second element on the data stack.

-TRAILING( b u -- b u )"dash trailing"
Adjust the count to eliminate any trailing white-space in the string.

.( n -- )"dot"
Display the single value, use the current base. If BASE is DECIMAL , display as a signed number.

."( -- ; <string> )I,C"dot quote"
Used only within a definition to compile an inline packed string terminated by the " double quote character. At run-time the string is displayed on the current output device.

."|( -- )C"dot quote primitive"
Display a compiled inline packed string to the current output device. This run-time primitive is compiled by ." .

.(( -- ; <string> )I"dot paren"
Begin a comment that is displayed to the current output device. May be used inside or outside a definition.

.ID( na -- )"dot i d"
Display the packed string at address.

.OK( -- )"dot o k"
Display the standard system prompt.

.R( n +n -- )"dot r"
Display the single value right-justified in a field of width +n, use the current base.

.S( ? -- ? )"dot s"
Display the contents of the data stack.

/( n n -- q )"slash"
Floored division for 16-bit numbers. Returns only the 16-bit quotient.

/MOD( n n -- r q )"slash mod"
Floored division for 16-bit numbers. 16-bit remainder and 16-bit quotient.

0<( n -- t )"zero less"
Return true if n is less than 0, negative. Comparison is signed. Also used for sign extension.

0=( w -- t )"zero equals"
Return true if w is equal to 0.

2!( d a -- )"two store"
Store a 32-bit value at aligned address.

2@( a -- d )"two fetch"
Return the 32-bit value stored at aligned address.

2DROP( d -- )"two drop"
Pop the 32-bit number, or the top two 16-bit numbers, from the data stack.

2DUP( d -- d d )"two dupe"
Duplicate the 32-bit number, or the top two 16-bit numbers, on the data stack.

:( -- ; <string> )D"colon"
Begin a colon definition to be added to the current vocabulary.

;( -- )I,C"semicolon"
Terminate a colon definition begun with : .

<( n1 n2 -- t )"less than"
Return true if n1 is less than n2. Comparison is signed.

<#( -- )"start number""less number sign"
Begin a numeric conversion.

=( w w -- t )"equals"
Return true if w1 is equal to w2.

>CHAR( u -- c )"to character"
Convert a value to a printable character. Replace an unprintable character with the _ underscore character.

>IN( -- a )"to in"
The pointer into the input stream.

>NAME( ca -- na, F )"to name"

If possible, convert a code address to a name address. If not possible, return a false flag.

>R( w -- ;R -- w )C"to r"
Pop the top element of the data stack and Push it on the return stack.

?( a -- )"question"
Display the single value stored at address, use the current base. If BASE is DECIMAL , display as a signed number.

?branch( f -- )"question branch"
Run time rouitne to redirect execution to the address in the next cell if flag is false.

?CSP( -- )"question c s p"
Compare the current value of the stack pointers with the saved values. ABORT with an error message if different.

?DUP( w -- w w, 0 )"question dupe"
Duplicate the number on top of the data stack only if it is non-zero.

?KEY( -- t )"question key"
Return the status of the current input device.

?RX( -- c T, F )"question r x"
Return a character from the input device and true.  Return false only if no character is pending.

?STACK( -- )"question stack"
Display an error message if the stack limits have been exceeded.

?UNIQUE( $ -- $ )"question unique"
Display a warning massage for a duplicate definition.

@( a -- w )"fetch"
Return the 16-bit value stored at aligned address.

@EXECUTE( a -- )"fetch execute"
Fetch the execution token stored at address and execute it, ie indirect execution. If the value contained in address is zero, do nothing.

ABORT( -- )
Reset the data stack and perform the function of QUIT . Note, no message is displayed.

ABORT"( -- ; <string> \ f -- )I,C"abort quote"
Used only within a definition to compile an inline packed string terminated the " double quote character. At run-time, if the flag
is false, execute the sequence of words following the string. Otherwise, the string is displayed on the current output ce,
execution is then passed to an error handling routine.

abort"( f -- )C"abort quote primitive"
The run-time primitive compiled by ABORT" .

ABS( n -- +n )
Return the absolute value of n.

accept( b u -- b u )
Receive a line of u characters maximum to the an input buffer at byte address. Terminate input if a carriage return is received. Return the actual count of received characters. Perform any currently defined keyboard macros. Use the current input device.
AFT( a -- a a \ -- )I,C
Used within a loop structure to unconditional skip a portion of code the first time thru the loop. AFT compiles the machine unconditional branch instruction and leaves an address to be resolved by THEN .

AGAIN( a -- \ -- )I,C
Terminate an infinite loop structure. AGAIN compiles an unconditional branch instruction, and uses the address left by BEGIN to resolve this backward branch.

AHEAD( -- a \ -- )I,C
Mark the beginning of a forward branching, unconditional branch structure. AHEAD compiles the machine unconditional branch instruction and leaves an address to be resolved by THEN .

ALIGNED( b -- a )
Convert a byte address to a word aligned address.

ALLOT( n -- )
Adjust the code area pointer by n.

AND( w w -- w )
A bitwise logical AND.

BASE( -- a )U
The system variable which holds the current numeric conversion radix.

BEGIN( -- a \ -- )I,C
Mark the beginning of an indefinite loop structure. Leave an address to be resolved by UNTIL, or WHILE and REPEAT .

BL( -- c )"b l"
Push the value of a space, the blank character, on the data stack.

branch( -- )C
Run time routine to redirect execution to the address in the next cell.

BYE( -- )
Exit Forth and return to the underlying environment or DOS.

C!( v b -- )"c store"
Store an byte value at byte address.

C@( b -- v )"c fetch"
Return the byte value stored at byte address.

CALL,( a -- )C"call comma"
Assemble a 4 byte subroutine call to the designated address.

CATCH( ca -- err#/0 )
Setup a local error frame and execute the word referenced by the execution token ca. Return a non-zero error number or zero for no error.

CELL+( a1 -- a2 )"cell plus"
Add cell size in bytes to address a1.

CELL-( a1 -- a2 )"cell minus"
Subtract cell size in bytes to address a1.

CELLS( n1 -- n2 )
Multiply n1 by the cell size in byte.

CHAR( -- c ; <string> )
Return the value of the first character in <string>. If used within a defintion, use the phrase [ CHAR <string> ] LITERAL.

CHARS( +n c -- )
Display +n of character to the current output device.

CMOVE( b1 b2 u -- )"c move"
Move u byte values from byte address b1 to b2, proceeding from lower to higher memory. Overwrite occurs if b1<b2<b1+u .

COLD( -- )
Completely re-initialize the system, but does not re-load the system from ROM.

COMPILE( -- )C

Used only within a definition. At run-time the word following COMPILE is not executed, but its code address is copied into the code area.

CONSOLE( -- )
Initialize the vectored input and output devices to a terminal.

CONTEXT( -- a )
The variable used to specify the dictionary search order.

COUNT( $ -- b +n )
Return the byte address and byte count of a packed string.

CP( -- a )"c p"
The pointer to the next available dictionary location in code space. Since code and names are seperated, the traditional DP, dictionary pointer, had to be split into CP, code pointer, and NP, name pointer.

CR( -- )"carriage return"
Position the cursor at the beginning of the next line of the current output device.

CREATE( -- ; <string> \ -- a )D
Build a named definition. At run-time the address pointing to next availabe code space is pushed on the data stack.

CSP( -- a )"c s p"
The system variable which holds the current stack pointer. Used for error checking.

CURRENT( -- a )
The variable used to specify the vocabulary in which new definitions are compiled.

DECIMAL( -- )
Set decimal as the current BASE . Base 10.

DEPTH( -- n )
The number of elements on the data stack, does not include n .

DIGIT( u -- c )
Convert a single digit number to its character value.

DIGIT?( c base -- v t )"digit question"
Try to convert a character to binary digit. Return true if the digit is valid for the current base.

dm+( a u -- p a+ )"d m plus"
Display the 16-bit values starting at the aligned address a.

DNEGATE( d -- -d )"d negate"
Return the two's complement a double number. Change the sign of a double number.

do$( -- $ )C"do string"
Return the address of a compiled inline packed string.

doLIST( a -- )C"do list"
The run-time routine which executes the list in a colon definition pointed to by a.

doLIT( -- n )C"do literal"
Return the in-line literal compiled by LITERAL.

doUSER( -- )C"do user variable"
The run-time action of user variables.

doVAR( -- a )C"do variable"
The run-time action of variable.

DROP( w -- )
Remove the top element on the data stack.

DUMP( a u -- )

Display the HEX and character values starting at aligned address a, for count u.

DUP( w -- w w )"dupe"
Duplicate the top element on the data stack.

ELSE( -- \ a -- a )I,C
Used within a conditional branch structure. ELSE resolves a forward conditional branch compiled by IF . ELSE then compiles an unconditional branch instruction, leaving an address to be resolve by THEN .

EMIT( w -- )
Output a character to the current output device.

EVAL( -- )
Interpret or compile the tokens from the input stream.

EXECUTE( w -- ;R -- w )
Execute the word definition indicated by the execution token w.

EXIT( -- ;R w -- )
Compile a subroutine return.

EXPECT( b u -- )
Receive a line of u characters maximum to the an input buffer at byte address. Terminate input if a carriage return is received. The count of received characters is saved in the variable SPAN. Use the current input device. This word is vectored.

EXTRACT( d base -- d' c )
Used incrementally to convert each digit in a number to its character value.

FILE( -- )
Specify system input from a file using pace handshake. File input is not echoed, all output messages are displayed.

FILL( b u v -- )
Fill an area at byte address of length u using the byte value v.

find( $ va -- ca f, $ F )"find primitive"
Given a string and a dictionary entry thread, search for a name match. If found, return the code address and a true flag. If not
found, the string address and a false flag.

FOR( u -- )I,C
Begin a down-counting loop.  Repeat the loop till NEXT u+1 times from u to 0.

FORTH( -- )
Make the default system vocabulary FORTH the context vocabulary.

HAND( -- )
Specify system input from keyboard, no handshake. All input is echoed.

HANDLER( -- a )
The current error handler frame pointer.

HERE( -- a )
Push the address of the next free cell in the code area on the data stack.

HEX( -- )
Set hexadecimal as the current BASE . Base 16.

hi( -- )
Display the sign-on message.

HLD( -- a )"h l d"
The pointer to a formatted numeric output string.

HOLD( c -- )

Insert the character in the formatted numeric output string.

I/O( -- a )"i slash o"
An array used by CONSOLE to initialize the system input and output vectors. The vector order is 'KEY? 'KEY and 'EMIT.

IF( -- a \ f -- )I,C
Mark the beginning of a forward branching, conditional branch structure. IF compiles the machine conditional branch instruction and leaves an address to be resolved by THEN or ELSE .

IMMEDIATE( -- )
Mark the most recently created dictionary entry as a word which will execute during compilation.

INVERT( w -- w )
Bitwise logical invert. Equivalent to -1 XOR. The one's complement.

KEY( -- c )
Return a character from the current input device. If no key is ready, wait until one is available.

kTAP( b b b c -- b b b )"k tap"
The 'tap routine used for file input.

LAST( -- a )
The pointer to the name of the most recently created dictionary entry.

LITERAL( w -- \ -- w )I
Compile a number as an inline value.

M*( n n -- d )"m star"
Multiply two signed numbers. Return a 32-bit signed number.

M/MOD( d n -- r q )"m slash mod"
Floored division of a 32-bit number divided by a 16-bit number. Return a 16-bit quotient and a 16-bit remainder.

MAX( n n -- n )
Leave the greater of the two signed values.

MIN( n n -- n )
Leave the smaller of the two signed values.

MOD( n n -- r )
Floored division for 16-bit numbers. Returns only the 16-bit remainder.

NAME>( na -- ca )"name to code"
Convert a name address to a code address.

NAME?( $ -- ca f, $ F )"name question"
Given a string, search for a name match. If found, return the code address and a true flag. If not found, the string address and a
false flag.

NEGATE( n -- -n )
Equivalent to 0 SWAP-. The two's complement of a number. Change the sign of a number.

NEXT( a -- \ -- ;R u -- [u-1] )I,C
Terminate a down-counting loop structure. NEXT compiles the machine loop instruction, pointing to the address left by FOR . The
loop count is held on the return stack. Looping continues until the count is equal to zero.

next( -- )C
Run-time routine to terminate a down-counting FOR-NEXT loop.  See NEXT.

NP( -- a )"n p"
The pointer to the next available dictionary location in name space.

NUF?( -- t )"nuf question"
Continue until paused or terminated by user. Any key will pause, while paused any key except 'enter' will restart and return
false, enter will return true.

NULL$( -- $ )"null string"
The address of a string with a zero count.

NUMBER?( $ -- d T, $ F )"number question"
Try to convert a packed string to binary number. If possible return the number and a true. Otherwise, return the string address
and false. A leading '$' for hexidecimal, a leading '-' for negative, and/or the decimal point for a double number.

OR( w w -- w )
A bitwise logical OR.

OVER( w1 w2 -- w1 w2 w1 )
Copy the second element to the top of the data stack.

OVERT( -- )
Used by ; to link a successfully defined word into the search order.

PACE( -- )
Send the file transfer handshake character.

PACK$( b u $ -- $ )"pack string"
Move and convert the string at byte address with byte count to a packed string at address $ .

PAD( -- a )
Short for scratch pad. Address of a temporary buffer.

PARSE( c -- b u ; <string> )
Scan the current input stream for the given character as a delimiter. Return the beginning byte address and count of the delimited string.

parse( b u c -- b u delta ; <string> )
Scan string for the given character as a delimiter. Return the beginning byte address and count of the delimited string. Delta is the beginning to current offset.

PICK( +n -- w )
Copy the +nth data stack value to the top of the data stack.

PRESET( -- )C
Clear the data stack, the return stack and initialize system.

QUERY( -- )
Receive a line to the current input buffer from current input device.

QUIT( -- )
Clear the return stack, set interpret state, and return control to the current command line interpreter.

R>( -- w ;R w -- )C"r from"
Pop the top element of the return stack and Push it on the data stack.

R@( -- w ;R w -- w )"r fetch"
Copy the top element of the return stack and Push it on the data stack.

RECURSE( -- \ -- ;R -- a )I,C
Used only within the word currently being defined to allow self reference. Recursion.

REPEAT( a a -- \ -- )I,C
Terminate an indefinite loop structure. REPEAT compiles an unconditional branch instruction, and uses the address left by WHILE to resolve this backward branch.

ROT( w1 w2 w3 -- w2 w3 w1 )"rote"

Rotate the top three elements on the data stack. Third element to top and all other shifted down.

RP!( a -- )C"r p store"
Set the return stack pointer to address.

RP0( -- a )"r p zero"
Return the bottom address of the return stack pointer.

RP@( -- a )"r p fetch"
Return the address of the return stack pointer.

SAME?( a1 a2 u -- a1' f \ -0+ )"same question"
Compare the two strings, return the beginning address of the first string and a truth flag.

SIGN( n -- )
Display a minus sign if n is negative. Must be used within <# and #> .

SP!( a -- )"s p store"
Set the data stack pointer to address.

SP0( -- a )"s p zero"
Return the bottom address of the data stack pointer.

SP@( -- a )"s p fetch"
Return the address of the data stack pointer.

SPACE( -- )
Display one space, blank character, to the current output device.

SPACES( +n -- )
Display +n spaces, blank characters, to the current output device.

SPAN( -- a )
The system variable which holds the count of characters input by EXPECT.

str( d -- b u )"s t r"???
Convert number to a string in current BASE . Signed if DECIMAL .

SWAP( w1 w2 -- w2 w1 )
Exchange the top two elements on the data stack.

TAP( b b b c -- b b b' )
Echo and store the keystroke, and update the cursor position.

temp( -- a )U
Return address of a user variable for temporary storage.

THEN( a -- \ -- )I,C
Terminate a conditional branch structure. Resolves a forward branch compiled by IF, ELSE, AHEAD, or AFT.

THROW( err# -- err# )
Reset the state of the system to the current local error frame, and update the error flag.

TIB( -- a )"t i b"
Address of the terminal input buffer.

TOKEN( -- $ ; <string> )
Scan the current input stream for a blank delimited word. Move the word to the end of the names area as a packed string. Return the address of the packed string.

TX!( c -- )"t x store"
Send a character to the output device.  Primitive of EMIT.

TYPE( b u -- )
Output u characters of the string at b address to the current output device.

U.( u -- )"u dot"
Display the unsigned single value, use the current base.

U.R( u +n -- )"u dot r"
Display the unsigned single value right-justified in a field of width +n, use the current base.

U<( u1 u2 -- t )"u less"
Return true if u1 is less than u2. Comparison is unsigned.

UM*( u u -- ud )"u m star"
Multiply two unsigned 16-bit numbers. Return an unsigned 32-bit number.

UM+( u u -- ud )"u m plus"
Add two unsigned numbers and return a 32-bit sum.

UM/MOD( ud u -- ur uq )"u m slash mod"
Unsigned division of a 32-bit number divided by a 16-bit number. Return an unsigned 16-bit quotient and an unsigned 16-bit remainder.

UNTIL( a -- \ f -- )I,C
Terminate an indefinite loop structure. Condition testing is done after executing the code within the loop. UNTIL compiles the machine conditional branch instruction, and uses the address left by BEGIN to resolve this backward branch.

UP( -- a )"u p"
Return the address of the current user area.

USER( u -- ; <string> \ -- a )D
Build a named user variable with an offset from the current user base. At run-time the address of the variable is pushed on the
data stack.

VARIABLE( -- ; <string> \ -- a )D
Build a named variable. At run-time the address of the variable is pushed on the data stack.

VER( -- n )
Return the version code.  Major revision is in the high byte and minor release in the low byte.

VOCABS( -- a )
Return the address of the first vocabulary FORTH in the vocabulary area.

WHILE( a -- a a \ f -- )I,C
Used within an indefinite loop structure. Condition testing is done before executing the code within the loop. WHILE compiles the machine conditional branch instruction and leaves an address to be resolved by REPEAT .

WITHIN( u lo hi -- t )
Return true if lo <= u < hi. Comparison is unsigned and circular.

WORD( c -- $ ; <string> )
Scan the current input stream for the string delimited by 'c'. Return the address of the packed string.

WORDS( -- )
Display the words in the CONTEXT vocabulary. Display continues until paused or terminated by user.

XIO( a1 a2 a3 -- )"x i o"
Revector 'prompt, 'echo and 'tap to the code addresses on the stack.

XOR( w w -- w )
Bitwise logical Exclusive OR.

[( -- )I"left bracket"
Begin interpreting text from the input stream. Change from compiling to interpreting.

[COMPILE]( -- ; <string> \ -- )I"bracket compile"
Used only within a definition to force the compilation of the following IMMEDIATE word.

\( -- ; <string> )I"backslash"
Begin a comment. The comment is terminated by the system end-of-line character. May be used inside or outside a definition.

]( -- )"right bracket"
Change from interpreting to compiling.

^H( b b b -- b b b' ; <backspace> )"control h"
A keyboard macro to delete characters from the current input stream. No action is taken if the beginning of the input stream is reached.

_TYPE( b u -- )"printable type"
Display the the string starting at the byte address b, for count u. Substitute _ the underscore character, for unprintable charact!_TY

# 78C10 EFORTH
# Base Machine Coded Words

| | |
|---|---|
| **Interpreter Pointer** | **DE** |
| **Data Stack Pointer** | **SP** |
| **Return Stack Pntr** | **HL** |

Free to use: **BC, EA, VA, Alternate Registers**

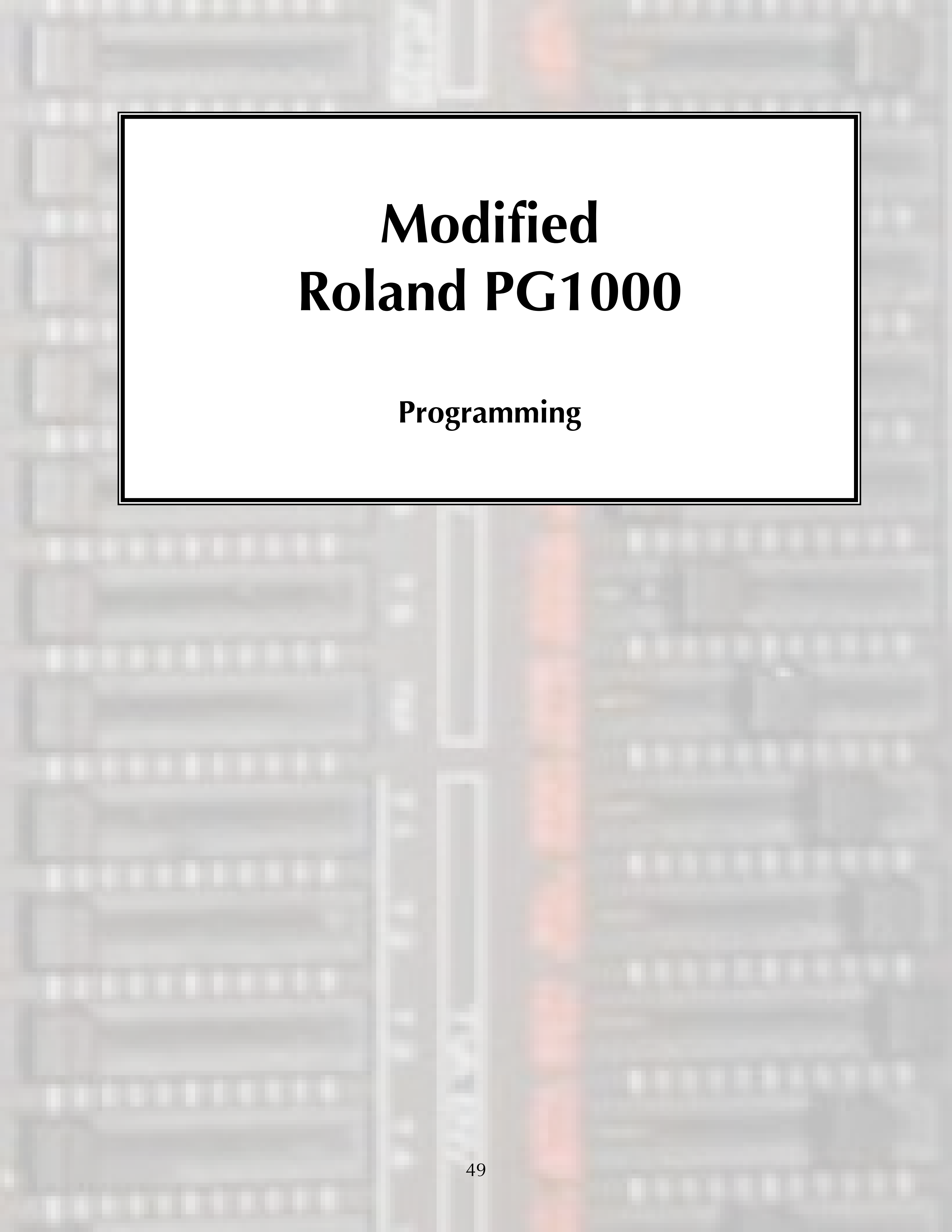
```
$NEXT       48 84           EA < (DE)++
            48 28           JMP EA

doLIT       48 84           EA < (DE)++
            B4              PUSH  EA
            $NEXT

doLIST      33              HL < HL -1
            33              HL < HL -1
            A6              EA < DE
            48 93           (HL) < EA
            A2              POP  DE
            $NEXT

COLD        54 0000 JMP  Reset Vector
BYE         54 0000 JMP  Reset Vector

EXECUTE     A1              POP  BC
            21              JMP   BC

EXIT        48 85           EA  < (HL)++
            B6              DE  <  EA
            $NEXT

next        6A 00           B  <  00
            6B 01           C  <  01
            48 83           EA  <  (HL)
            74 B5           EA  <  EA - BC  Skip if no borrow
            C9              JMP  NEXT1
            48 93           (HL)  <  EA
            48 82           EA  <  (DE)
            B6              DE  <  EA
            $NEXT
   NEXT1    22 22           DE  <  DE + 2
            32 32           HL  <  HL  + 2
            $NEXT
```

```
?branch         6A FF           B  <  FF
                6B FF           C  <  FF
                A4              POP  EA
                74 CD           EA AND BC  Skip if no zero
                C6              JMP BRAN1
                22 22           DE  <  DE  +  2
                $NEXT
    BRAN1       48 82           EA  <  (DE)
                B6              DE  <  EA
                $NEXT

branch 48 82            EA  <  (DE)
                B6              DE <  EA
                $NEXT

! (w a --)      A6              EA  <  DE
                B5              BC  <  EA
                A2              POP  DE  (address)
                A4              POP  EA  (data)
                48 92           (DE)  < EA
                A5              EA  <  BC
                B6              DE  <  EA
                $NEXT

@  (a -- w)     A6              EA  <  DE
                B5              BC  <  EA
                A2              POP DE
                48 82           EA  < (DE)
                B4              PUSH EA
                A5              EA  <  BC
                B6              DE  <  EA
                $NEXT

C!  (w b --)    A1              POP BC  (address)
                A4              POP AE  (data)
                09              A  <  EAL
                39              (BC)  < A
                $NEXT

C@  (b -- c)    A1              POP BC
                29              A  < (BC)
                6A 00           B  < 00
                1B              C  <  A
                B1              PUSH BC
                $NEXT

RP@  (--a)      B3              PUSH HL
                $NEXT

RP!  (a--)      A3              POP HL
                $NEXT

R>  (--w)       48 85           EA  < (HL)++
                B4              PUSH EA
                $NEXT

R@  (--w)       48 83           EA  <  (HL)
```

```
                B4              PUSH EA
                $NEXT

>R  (w--)       33 33           HL  <  HL - 2
                A4              POP EA
                48 93           (HL)  <  EA
                $NEXT

SP@  (--a)      70 0E FEFF      (FFFE)  <  SP
                70 1F FEFF      BC  <  (FFFE)
                B1              PUSH BC
                $NEXT

SP!  (a--)      A1              POP BC
                70 1E FEFF      (FFFE)  <  BC
                70 0F FEFF      PC  <  (FFFE)
                $NEXT

DROP            A4              POP EA
                $NEXT

DUP             A4              POP EA
                B4              PUSH EA
                B4              PUSH EA
                $NEXT

SWAP            A4              POP EA
                A1              POP BC
                B4              PUSH EA
                B1              PUSH BC
                $NEXT

OVER            A4              POP AE
                A1              POP BC
                B1              PUSH BC
                B4              PUSH AE
                B1              PUSH BC
                $NEXT
```

```
0<  (n--t)      A1              POP BC
                69 FF           A  < FF
                48 06           B Shift Left,  Skip if carry
                69 00           A  <  00
                1A              B  < A
                1B              C  <  A
                B1              PUSH BC
                $NEXT

AND             A1              POP BC
                A4              POP AE
                74 8D           EA  < EA AND BC
                B4              PUSH EA
                $NEXT

OR              A1              POP BC
                A4              POP EA
                74 9D           EA  <  EA OR BC
                B4              PUSH EA
                $NEXT

XOR             A1              POP BC
                A4              POP EA
                74 95           EA  <  EA EX-OR BC
                B4              PUSH EA
                $NEXT

INVERT          A1              POP BC
                69 FF           A  <  FF
                60 12           B  <  B EX-OR A
                60 13           C  <  C EX-OR A
                B1              PUSH BC
                $NEXT

UM+             A1              POP BC
                A4              POP EA
                69 00           A  < 00
                74 A5           EA  <  EA + BC  Skip if no carry
                69 01           A  <  01
                1B              C  <  A
                6A 00           B  <  00
                B4              PUSH EA
                B1              PUSH BC
                $NEXT
```

```
+             A1          POP BC
              A4          POP EA
              74A5        EA  <  EA + BC   Skip
              00          NOP
              B4          PUSH EA
              $NEXT

NEGATE        A1          POP BC
              69 FF       A  <  FF
              60 12       B  <  B EX-OR A
              60 13       C  <  C EX-OR A
              12          BC  < BC + 1
              B1          PUSH BC
              $NEXT

-             A1          POP BC
              69 FF       A  <  FF
              60 12       B  < B EX-OR A
              60 13       C  < C EX-OR A
              12          BC < BC +1
              A4          POP EA
              74 A5       EA < EA + BC   Skip
              00          NOP
              B4          PUSH EA
              $NEXT

0=            A4          POP EA
              A9 FF       A  <  FF
              1A          B  <  A
              1B          C  <  A
              74 CD       EA AND BC   Skip if not zero
              C4          JMP  BRAN2
              A9 FF       A  <  00
              1A          B  <  A
              1B          C  <  A
   BRAN2      B1          PUSH BC
              $NEXT

=             A4          POP EA
              A1          POP BC
              69 FF       A  <  FF
              74 FD       EA - BC  Skip if zero
              69 00       A  <  00
              1A          B  <  A
              1B          C  <  A
              B1          PUSH BC
              $NEXT

doUSER        48 83       EA  < (HL)
              70 1F up    BC  <  (up)
              74 A5       EA  <  EA +BC   SKIP
              00          NOP
              B4          PUSH EA
              $NEXT
```



# Modified Roland PG1000

## Programming

# ***Machine Code***

# PUSHBUTTONS AND LED's

```
8(4)             4(3)         X            X
MIDI             LOAD        XX           XX

40(7)            80(8)      10(5)        20(6)
LEFT             RIGHT       DOWN        UP

2(2)
SLD UP

1(1)
SLD DWN
```

Each button is associated with a bit in the PA port. The number above the button is the hex value of the PA input port for that button. Note that two of the switches have no numbers associated with them.

There are 6 LED's located in the 6 non-xx buttons. These are turned on and off through the PB output port. The same port numbers as for the buttons apply to port B outputs for the LED's.

Bit zero of port B is used for serial transmission. Any serial transmission will automatically turn off all 6 LEDs. Bit one of port B is used to select between the bank of 8 numbered switches shown above and the bank of two currently unused ones in the upper right corner. PB1 must remain low to enable the 8 buttons above that are numbered.

```
CODE   SW@       ( --- n, Read the 8 switch values in a byte. Switches are
            normally high.)
            4C  C0      A < PA
            6A  0       B < 0
            1B          C < A
            B1          PUSH BC
ENDCODE


CODE   S@     (--- n, Return # of lowest switch on. n = 0,1,2,3,...,8)
            4C C0       A < PA
            6B 0        C < 0
            74 11 FF    A < A EXOR FF
            74 49 FF    A AND FF,  Skip if NO ZERO
            C4          JMP OUT
LOOP:       43          C < C+1
            48 01       A Shift Right, Skip if Carry
            FC          JMP LOOP
OUT:        6A 0        B<0
            B1          PUSH BC
ENDCODE


:  TST      ( --- )  CR BEGIN    SW@  FF  XOR  <# # # #>  TYPE
            200 DELAY D EMIT NUF? UNTIL ;
```

```
ORG 0200H
;       Interrupt routine for Analog to Digital Converters

        DB 10H                  ;EXA, use alternate registers
        DB 11H                  ;EXX
;  Load ADC Address and Counter into HL.  Uses FFF3.
        DB 68H,0FFH             ;V'<FF
        DB 69H,0C6H             ;A<C6
        DB 1EH                  ;H<A, H<C6, C6xx is ADC RAM buffer area
        DB 01H,0F3H             ;A<(V/F3)
        DB 1FH                  ;L<A, L<(FFF3) the slider interrupt count
;  Store ADC values.
        DB 4CH,0E0H             ;A<CR0
        DB 3DH                  ;(HL)+<A, store new value, increment count
        DB 4CH,0E1H             ;A<CR1
        DB 3DH                  ;(HL)+<A, store new value, increment count
        DB 4CH,0E2H             ;A<CR2
        DB 3DH                  ;(HL)+<A, store new value, increment count
        DB 4CH,0E3H             ;A<CR3
        DB 3DH                  ;(HL)+<A, store new value, increment count
;  Update Counters
        DB 0FH                  ;A<L
        DB 63H,0F3H             ;(V/F3)<A, update counter.
        DB 48H,25H              ;A shift logical left
        DB 48H,05H      ;A shift left, skip if carry, if count = 40H
        DB 0C7H         ;JMP AHEAD if all 64 values are not converted yet.

        DB 64H,1EH,01           ;MKH<MKH OR 1, disable INTAD
        DB 10H,11H,0AAH,62H     ;EXA,EXX,EI,RETI  return from interrupt

AHEAD:  DB 1AH                  ;B<A
        DB 74H,0AH,0E0H         ;B<B AND E0
        DB 4CH,0C2H             ;A<Pc
        DB 07H,1FH              ;A<A AND 1F
        DB 60H,9AH              ;A<A OR B
        DB 4DH,0C2H        ;Pc<A, Load  4051s' address select bits (3 bits).
        DB 64H,90H,08H     ;Invert ANM bit and start next ADC convert cycle.
;  Return from Interrupt.
        DB 10H                  ;EXA
        DB 11H                  ;EXX
        DB 0AAH                 ;EI
        DB 62H                  ;RETI
```

## SERIAL INTERFACES

A 9600 Baud, software driven serial I/O is provided.  PortB/bit0 is used for serial output and PortC/bit3 (INT2) is used for the serial input. The serial input is interrupt driven with a vectored interrupt routine located at 0A0H.  The code words  ?RX, TX!, and !IO make up the rest of the serial I/O code.  Three USER variables have been set up for use by these serial I/O routines: SERIN, which holds the received character and a flag; HAFBIT, which adjusts the software timing of the receiver to read in the middle of each bit frame  (set it for 1/2 the BITIME minus

5); and BITIME, which adjusts the software for a specific baud rate (17H for 9600 baud assuming a 12Mhz processor clock).

```
;    SERIN        ( -- a )
;            Point to host serial input. Flag in high, char in low byte.
             $USER   5,'SERIN',SERIN

;    HAFBIT       ( -- a )
;            Point to half bit time used by serial i/0 routines. (Equals 06H).
             $USER   6,'HAFBIT',HAFBIT

;    BITIME       ( -- a )
;            Point to bit time used to set serial i/o baud rate. (Equals 16H).
             $USER   6,'BITIME',BITIME

ORG     00A0H
; Vectored INT2 routine for Serial Input from Host Computer.
; Uses address FFF0 as a counter location - do not use elsewhere!
        DB 0B1H                 ;PUSH BC
        DB 0B2H                 ;PUSH DE
        DB 0B0H                 ;PUSH VA
        DB 68H,0FFH             ;MVI, V<FF
        DB 71H,0F0H,07H         ;MVIW, (V/F0)<07, number of bits to receive.
        DB 70H,1FH,04CH,0FFH    ;LBCD, BC<(FF4C), wait for a half bit.
LOOP1:  DB 53H                  ;DCR, C<C-1 skip if borrow
        DB 0FEH                 ;JR, Jump to loop1
        DB 52H                  ;DCR, B<B-1 skip if borrow
        DB 0FCH                 ;JR, Jump to loop1
LOOP2:  DB 70H,1FH,4EH,0FFH     ;LBCD, BC<(FF4E),wait 1 bit time
        DB 53H                  ;DCR, C<C-1 skip if borrow
        DB 0FEH                 ;JR, Jump to loop2
        DB 52H                  ;DCR, B<B-1 skip if borrow
        DB 0FCH                 ;JR, Jump to loop2
        DB 04CH,0C2H            ;MOV, A<PC, read serial input on pc3
        DB 48H,31H,48H,31H      ;Rotate PC3 bit into Cy
        DB 48H,31H,48H,31H      ;RLR, A rotate right 4xs
        DB 0CH                  ;MOV, A<D, D collects the bits
        DB 48H,31H              ;RLR, shift in next bit, CY to top of D
        DB 1CH                  ;MOV, D<A
        DB 30H,0F0H             ;DCRW, (V/F0)<(V/F0)-1 skip if borrow
        DB 0E7H                 ;JR, Jump to loop2 for next bit.
        DB 70H,1FH,4EH,0FFH     ;LBCD, BC<(FF4E)
        DB 53H,0FEH,52H,0FCH    ;DCR JR DCR JR, stop bit loop time.
        DB 71H,04BH,0FFH        ;MVIW, (V/4B)<FF, load flag
        DB 0CH,63H,04AH         ;MOV STAW, A<D (V/4A)<A, load data
        DB 0A0H,0A2H,0A1H       ;POP, restore AV DE and BC
        DB 48H,44H,0            ;SKIT,NOP
        DB 0AAH,062H            ;EI RETI, enable interrupts and return


;    '?KEY        ( -- a )
;                 Execution vector of ?KEY.
                  $USER   5,"'?KEY",TQKEY

;    'EMIT        ( -- a )
;                 Execution vector of EMIT. Points to TX! Code Word.
                  $USER   5,"'EMIT",TEMIT
```

```
;   ?RX          ( -- c T | F )
;               Return input character and true, or a false if no input.
;               Points to ?RX Code word.

                $CODE   3,'?RX',QRX
        DB 68H,0FFH             ;MVI, V<FF
        DB 01H,4BH              ;LDAW, A<(V/4B) read serial-in flag
        DB 47H,0FFH             ;ONI, A AND FF skip if flag not zero
        DB 0CAH                 ;JR, jump ahead
        DB 71H,04BH,0           ;MVIW, (V/4B)<0, reset flag to zero
        DB 70H,1FH,4AH,0FFH     ;LBCD, BC<(FF4A), read serin data
        DB 0B1H                 ;PUSH BC, push serial input data to stack
        DB 69H,0FFH             ;A<FF
AHEAD:  DB 1BH                  ;C<A,
        DB 6AH,0                ;B<0
        DB 0B1H                 ;PUSH BC, push serial input flag to stack
        $NEXT


;   TX!          ( c -- )
;               Send character c to the output device.

                $CODE   3,'TX!',TXSTO
        DB 0BAH                 ;Disable Interrupts
        DB 0A1H                 ;POP BC, pop char into C
        DB 0B2H                 ;PUSH DE, store interpreter pointer
        DB 0BH,1CH              ;A<C, D<A, char in A and D
        DB 68H,0FFH             ;V<FF
        DB 71H,0F0H,07H         ;(V/F0)<7
        DB 60H,91H              ;A<A EXOR A
        DB 6DH,01H              ;E<01
        DB 4DH,0C1H             ;PB<A
LOOP1:  DB 70H,1FH,04EH,0FFH    ;BC<(FF4E) set baud
        DB 53H,0FEH,52H,0FCH    ;C<C-1, JR, B<B-1, JR, jr to loop1
        DB 0CH                  ;A<D
        DB 07H,01H              ;A<A AND 01
        DB 4DH,0C1H             ;PB<A, send a bit
        DB 0CH                  ;A<D
        DB 48H,31H              ;A rotate logical right
        DB 1CH                  ;D<A
        DB 0,0,0,0              ;NOPs to make rec loop = transmit loop.
        DB 30H,0F0H             ;(V/F0)<(V/F0)-1 skip if borrow
        DB 0E8H                 ;JR, jump to loop1
        DB 0DH                  ;A<E
        DB 51H                  ;A<A-1 skip if borrow
        DB 0C6H                 ;JR, jump to loop2
        DB 0A2H                 ;POP DE, restore interpreter pointer
        DB 0AAH                 ;Enable Interrupts
        $NEXT                   ;End of routine

LOOP2:  DB 6CH,03H              ;D<03
        DB 1DH                  ;E<A
        DB 71H,0F0H,01          ;(V/F0)<01
        DB 4FH,0D7H             ;JRE, jump to loop1



;   !IO          ( -- )
;               Initialize the serial I/O devices.
```

```
        $CODE   3,'!IO',STOIO
DB 69H,0EFH,4DH,0C7H    ;MKL<EF, enable int2 interrupt and
DB 69H,0FFH,4DH,0C6H    ;MKH<FF, disable all others with mask
DB 0AAH                 ;EI, enable interrupt
$NEXT
```

## MIDI INTERFACE

PC0 is the MIDI serial output. PC1 is the MIDI serial input. Both use the 78C10 microprocessor's internal serial I/O device. The following is set in the Cold Start Routine:

```
69 0B 4D D1       MCC < 0B    PC0,PC1,PC3 set for I/O (4-8)
69 0A 4D D4       MC < 0A     PC1 and PC3 set as inputs (4-9)
64 81 06          SMH < 6     Receive disabled, Transmit enb (7-7)
69 4E 4D CA       SML < 4E    Clk x16,8 bits,no parity,1 stop (7-9)
```

To transmit midi data xx, code it as follows: 69 xx 4D D8 (A < xx, TXB < A). When transmission is done, an INTST interrupt is generated. This software does not use an interrupt. Instead, it checks the INTFST flag using SKIT FST to wait until the flag goes high before transmitting the data.

Because of this wait period, when coding, it will save processor time to put operations between TM commands - i.e. the following code

```
90 TM 40 TM 40 TM      OP1 OP2 OP3
```

is optimized by placing it in following order:

```
OP1 90 TM     OP2 40 TM      OP3 40 TM
```

```
;   TM        ( n -- )
;               Wait for last transmit, then send midi byte n.
                $CODE 2,'TM',TM
                DB 0A1H                 ;POP BC
                DB 0BH                  ;A<C
                DB 48H,4AH              ;SKIT FST, skip if interrupt
                DB 0FDH                 ;JMP TO SKIT
                DB 4DH,0D8H             ;MOV TXB,A
                $NEXT

:  ENBREC   ( ---, Enable Midi Receive)
                $CODE
                DB 64H,81H,0EH            ;SMH<E
                $NEXT

:  RM       ( --- Midi Receive: If received leave - char, FF;
                                      If nothing there leave - 00 .)
                $CODE
                  6A,0                    ;B<0
                  6B,0                    ;C<0
                  48,49                   ;SKIT FSR, Skip if Interrupt flag
                  C6                      ;JMP AHEAD
                  4C,D9                   ;A<RXB
                  1B                      ;C<A
                  B1                      ;PUSH BC, push received data
                  6B FF                   ;C<FF
AHEAD:          B1                      ;PUSH BC, push flag
                  $NEXT

:  TST      ENBREC BEGIN  RM IF . THEN NUF? UNTIL ;
```

# MEMORY BUFFERS AND REGISTERS:

| | |
|---|---|
| C600 - C800 | SLIDER RAM for the ADC/EDIT/MIDI routines. |
| C600-C63F | ADC data, 8-bits. |
| C640-C67F | SLAST. Last ADC value read. Used only in some operations. |
| C680-C6B7 | Midi Byte 2 (Key#, Controller#, Program#, etc.) |
| C6C0-C6FF | Midi Byte 1 (Status and Channel number). Disabled if bit7=0. |
| C700-C73F | FLAG to keep track of current state of Midi operation. |

Each of the 64 Sliders has a 5-byte buffer. For example, Slider #1 uses C600, C640, C680, C6C0 and C700. This buffer is serviced by the ADC interrupt routine and the main program's EDIT routines. The MIDI routineS read from it to transmit Midi data.

**Serial Input Registers**

| | |
|---|---|
| FFF0 | Timing counter. |
| FF4A | USER value SERIN |
| FF4C | USER value HAFBIT |
| FF4E | USER value BITIME |

**ADC Interrupt routine registers:**

| | |
|---|---|
| FFF3 | ADC interrupt slider counter |

**EDIT Routine registers:**

| | | |
|---|---|---|
| FF00 | eSLD# | Slider number being edited. |
| FF01 | eFLD | LCD field being edited. |
| FF02 | eBYTE1 | Midi Byte with Status/Channel data. ENB flag. |
| FF03 | eBYTE2 | Midi Byte with Key#, Controller#, or Program#. |
| FF04 | eBYTE3 | 8-bit Slider value. |
| FF05 | eSET | MODE: 0 = Slider Edit, FF = Setup mode. |
| FF06 | eSET# | Holds Setup number. Used to address Rom setups. |

```
:  eSLD#   FF00 ;       Edit Buffer Slider Number.
:  eFLD    FF01 ;       Edit Buffer LCD field.
:  eBYTE1  FF02 ;       Edit Buffer Midi status byte.
:  eBYTE2  FF03 ;       Edit Buffer Midi data byte.
:  eBYTE3  FF04 ;       Edit Buffer Slider value.
:  eSET    FF05 ;
:  eSET#   FF06 ;
```

**MIDI Routine registers:**

| | | |
|---|---|---|
| FFE0 | LCNT | Midi Loop count. |
| FFE1 | LST | Last Midi Status sent. |

**Microprocessor Ram:**

```
      FF08 - FF80       USER Variables
RPP             EQU     0C2F0H            ;start of return stack (RP0)
TIBB            EQU     0C200H            ;terminal input buffer (TIB)
SPP             EQU     0C1F0H            ;start of data stack (SP0)
UPP             EQU     0FF00H            ;start of user area (UP0)
CTOP            EQU     0C390H            ;RAM code dict. expansion
NTOP            EQU     0C7FFH            ;RAM name dict. expansion
PADD            EQU     0C300H            ;PAD area
NAMEE           EQU     01FF0H            ;start of Name dictionary
CODEE           EQU     00300H            ;start of Code dictionary
COLD            EQU     00100H            ;Cold Start code
```

## Tables:

The sliders are not converted in the same order in which they are physically laid out in the box. A table of 64 has been created in ROM at address 00200H to translate the slider numbers to physical position numbers:

```
48 56 40 37 53 61 45 35
51 59 43 33 49 57 41 38
54 62 46 30 32 16 08 00
24 21 13 05 29 19 11 03       (numbers in decimal)
44 27 17 09 01 25 22 14
06 34 50 60 52 36 20 12
04 28 18 10 02 26 42 58
07 15 23 31 39 47 55 63
```

The following chart shows the physical layout of the sliders on the Roland PG1000 box:

```
07 15 23 31 39 47 55 63     (External)
56 57 58 59 60 61 62 63     (External)


                                 60 52 36 20 12 04|28 18 10 02 26 42 58
                                 43 44 45 46 47 48|49 50 51 52 53 54 55


   32 16 08 00 24 21 13 05 29 19 11|03 44 27 17 09 01|25 22 14 06 34 50
   20 21 22 23 24 25 26 27 28 29 30|31 32 33 34 35 36|37 38 39 40 41 42


            48 56 40 37 53 61 45 35|51 59 43 33 49 57|41 38 54 62 46 30
            00 01 02 03 04 05 06 07|08 09 10 11 12 13|14 15 16 17 18 19
```

# ***Utility Words***

# UTILITY WORDS

```
:  CASE      ( n ---  ,  Use 'n' as a pointer to following list of words, execute
                  the pointed word, then leave the current word )
      R>          ( Remove return stack pointer to next token, put on data stack )
      SWAP        ( pointer 'n' to the top )
      2* +        ( pointer + 2n )
      @EXECUTE    ( execute token at pointer + 2n, leave current word )
;
```

The CASE word is used as follows:

```
      : XXX      ( n --- )   ANYWORDS   CASE   PG0   PG1   PG2   ;
```

If n=0, PG0 is executed after CASE. If n=1, PG1 is executed after CASE. If n=2, PG2 is executed after CASE. Only the one PG is executed after which XXX terminates.

Warning!! If n is greater than the number of words between CASE and ';' minus one, the program will bomb.

********************************************

```
: INCR      ( n, nmax  --- n+1,   Increment n but set to zero if greater than nmax )
      OVER   1+   <      IF    DROP  0    ELSE    1+    THEN  ;

: DECR      ( n, nmax --- n-1,  Decrement n but set to nmax if less than zero )
      OVER   1-   0<     IF     SWAP  DROP    ELSE    DROP 1-   THEN  ;
```

**********************************************

```
CODE  DELAY  ( n --- )
      A1    POP BC
      53    C < C-1,  Skip if borrow
      FE    JMP back 1
      52    B < B-1,  Skip if borrow
      FC    JMP back 3
ENDCODE
```

*********************************************

```
CODE  TM          ( n -- , Transmit Midi, Wait for last transmit, then send n )
      A1          POP BC
      0B          A<C
      48,4A       SKIT FST, Skip if interrupt
      FD          JMP TO SKIT
      4D,D8       MOV TXB,A
ENDCODE
```

*********************************************

```
:  SEE      ( -- word --, Decompiles word )
      '  CR  1+  BEGIN        ( Code address of word plus one )
      DUP DUP SPACE . 7C EMIT @ DUP
      IF  >NAME  THEN  ?DUP
      IF .ID   ELSE DUP @ U.   THEN 2+
      NUF? UNTIL DROP
;
```

```
:  DUMMY ; ( -- , Do nothing word for filling in CASE definitions )
```

## REMOTE FILE LOADING:

Build a TEXT-ONLY file in Word (or other) of the words you want to load. When using White Knight, go under Custom / Otions / Text Transfer and set the "Wait after each line sent for the ^K character (the Pacing character used in Eforth). Type in the Eforth word FILE. Character echoes are now turned off. Go under File to Send a Text File. Make sure there is the HAND command at the end of your text file to return control back to the console. Type WORDS to see if your text was loaded.

## ***LCD Screen***

# The HD44780 LCD Controller

Display is 2 Lines of 16 Characters. Position addresses are 0 to F for the top line, and 40 to 4F for the bottom line. Cursor automatically increments to the next position after a character write, except for the jump between the end of the top line and beginning of the bottom line.

Characters can be taken from internal ROM which holds all the ASCII characters plus other special characters (see the chart) or from an internal RAM which must be loaded at power on by the user. This project uses only the ROM.

There are two Write modes controlled by the RS input line:
RS = 0, LCD setup commands such as Cursor on/off/ position, Clear, etc.
RS = 1, write character to cursor position.

# Core LCD Words:

```
CODE  LLI         ( ---   ,  Sets RS=0 for LCD setup commands )
      64 0A EF    Pc < Pc AND EF
ENDCODE

CODE LLC          ( ---  , Sets RS=1 for character displaying )
      64 1A 10    Pc < Pc OR 10
ENDCODE

CODE LCD          (n---  ,  Loads  LCD command 'n')
      A1          POP BC
      0B          A < C
      14 00 A0    BC < A000
      39          (BC) < A
ENDCODE


:  LI       (n --, Load LCD setup command 'n'.
             Exit with RS=1 for char writes.)
      LLI  LCD  LLC  1FF DELAY ;
```

# Example LCD Display Commands:

```
1 LI    Clear LCD Screen.           C  LI       Turn off the Cursor
F LI    Turn on the Cursor          80 LI       Position cursor at start

C0 LI       Position cursor at start of 2nd line.
41 LCD      Display ASCII 'A' at current cursor position,
            increment cursor.
```

## Power Up Reset Routine

```
:  LCDINIT        ( Initialize LCD display )

      D7A   DELAY   38 LI ( Function Set-8 bit input, 2 lines, 5x7 char )

      47E   DELAY   38 LI

      017   DELAY   38 LI

      017   DELAY   38 LI

      017   DELAY   08 LI ( Display off, cursor off, blink off )

      017   DELAY   01 LI ( Clear display, home the cursor )

      1CC   DELAY   02 LI ( Cursor at home - top left position )

      1CC   DELAY   06 LI ( Entry Mode Set - cursor auto
                            increment,shift off )
      017   DELAY   0F LI ( Display on, cursor on, blink on )

      017   DELAY   ;
```

## Display Routines

```
:  #DISP    ( n,p ---  , Display 'n' as a 3-digit number in current base at LCD
              position 'p' and reset cursor to start of number )

      DUP  LI  SWAP                ( Move cursor to 'p', and save )
      <#  #  #  #  #>              ( Convert 'n' to 3 ascii digits.
                                     Leave address and 3 on stack )
      DROP DUP C@ LCD  1+  DUP     ( Locations of the 3 digits in TIB)
      C@  LCD  1+  C@  LCD  LI     ( Display  3 digits and reset cursor )
;

:  #2DISP   DUP LI SWAP <# # # #> DROP DUP C@ LCD 1+ C@ LCD LI ;

:  DISP     (a,p ---,  Display string from address 'a' in LCD position 'p' )

      LI DUP C@  1- >R  (Set cursor. First byte at string address is a count.)
      FOR 1+  DUP  C@  LCD  NEXT  DROP    (Display 'count' string characters )
;
```

## MASM Macro to Compile a Stored String

```
SD$     MACRO   STRNG
        DW DOLIT
        _LEN    = $ + 4                       ;;save address of count byte
        DW      _LEN,EXIT                     ;;save cnt address on stack
        DB      0,STRNG                         ;;count byte and string
        _CODE   = $                             ;;save code pointer
ORG     _LEN                                    ;;point to count byte
        DB      _CODE-_LEN-1                    ;;set count
ORG     _CODE                                   ;;restore code pointer
        ENDM
;
```

```
EXAMPLE Stored String      ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  2,'Example',Example
                SD$ 'Slider'
```

## String Data for DISP

Can be built with the SD$ Macro in MASM, or from FORTH in the following manner:

```
      :  STRING1   $" Slider "   ;
```

The word above is loaded into code space as follows:

```
 DoList$"|  Count    S     l    i     d   e    r  Space     EXIT
 80   84  A   7     53    6C    69   64   65  72   20       94  3
```

This needs some explanation: The word $" is an immediate word which acts in compilation mode to set up the word's code area as shown. When STRING1 is executed the word $"| found in the code area is first to execute. This word puts the address of 'Count' on the data stack and rearranges the return stack so that the next word to execute is EXIT.

The word $" cannot be used when forming the ROM code with MASM. The string creating macro 'SD$' is used instead. It leaves the code area looking like this:

```
 doLit      addr-of-count  EXIT  Count  S    l    i   d    e    r   Space
   80          xxxx          94 3  7    53   6C   69  64   65   72  20
```

# LCD DISPLAY FIELDS

```
( **** Labels, ---- Numbers )
```

```
0 1 2 3 4 5 6 7 8 9 A B C D E F

* * * * * * _ _ _   * * * _ _ _
FLD0        FLD1    FLD2  FLD3

* * * * * * * *   _ _ _   _ _ _
FLD4              FLD5    FLD6
```

```
: FLD0 80 ;       (Slider, Setup#, * MIDI Running *)
: FLD1 86 ;       (Slider number 0 to 55 )
: FLD2 88 ;       (Ch(Midi Channel), Off(Slider disabled))
: FLD3 8D ;       (Midi Channel number 0 to 15)

: FLD4 C0 ;       (Midi Status - KEY#, KEY# AT, CONTROL#, PROGRAM#, CH PRESS,
                   PTCH WHL, ********)
: FLD5 C9 ;       (Midi byte value 0 to 127)
: FLD6 CD ;       (Slider value 0 to 127)


: FLDCASE         (n---f,  Choose an LCD field position )
            7 AND CASE   FLD0 FLD1 FLD2 FLD3 FLD4 FLD5 FLD6 FLD0
;
```

# LCD Displayed Strings

```
;  L0            ( --- a )
;                Packed string. 'a' is addr of count byte.
                 $COLON  2,'L0',L0
                 SD$ 'Slider'

;  L1            ( --- a )
;                Packed string. 'a' is addr of count byte.
                 $COLON  2,'L1',L1
                 SD$ 'Setup#'

;  L2            ( --- a )
;                Packed string. 'a' is addr of count byte.
                 $COLON  2,'L2',L2
                 SD$ '* MIDI Running *'

;  L20           ( --- a )
;                Packed string. 'a' is addr of count byte.
                 $COLON  3,'L20',L20
                 SD$ ' chl'

;  L21           ( --- a )
;                Packed string. 'a' is addr of count byte.
```

```
                $COLON  3,'L21',L21
                SD$ ' off'

;  L40          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L40',L40
                SD$ 'Key#    '

;  L41          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L41',L41
                SD$ 'Key# A-T'

;  L42          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L42',L42
                SD$ 'Control#'

;  L43          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L43',L43
                SD$ 'Program#'

;  L44          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L44',L44
                SD$ 'Ch Press'

;  L45          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L45',L45
                SD$ 'Ptch Whl'


;  L4X          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L4X',L4X
                SD$ '********'

;  L50          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L50',L50
                SD$ '***'


:  LSTAT          (n---, Choose a Midi Status Label)
            CASE   L4X L40 L41 L42 L43 L44 L45 L4X
;
```

## LCD Hardware Interface

```
14 pin ribbon cable:
      1.    GND
      2.    +5 v
      3.    Resistor to Gnd, Sets LCD back light contrast
```

4. RS = Pc4, 78C10/21
5. R/W = Gnd, Writes only, no reads used.
6. E, Write pulse derived from address decoder - Axxx / Bxxx, ***
7. Data 0 = Pd0, 78C10/55
8. Data 1 = Pd1, 78C10/56
9. Data 2 = Pd2, 78C10/57
10. Data 3 = Pd3, 78C10/58
11. Data 4 = Pd4, 78C10/59
12. Data 5 = Pd5, 78C10/60
13. Data 6 = Pd6, 78C10/61
14. Data 7 = Pd7, 78C10/62

# ***EDIT Words***

# EDIT BUFFER UTILITY ROUTINES

```
;  eUPDAT        ( --- )
;               Move data from Slider Ram to Edit Buffer.
                $CODE   6,'eUPDAT',EUPDAT
                DB      68H,0FFH        ;;V<FF
                DB      6AH,2           ;;B<2
                DB      1,0             ;;A<(V/00) Read eSLD#
                DB      1BH             ;;C<A
                DB      29H             ;;A<(BC) Read Translation Table
                DB      6AH,0C6H        ;;B<C6

                DB      1BH             ;;C<A
                DB      29H             ;;A<(BC)
                DB      48H,21H         ;;A SHIFT RIGHT
                DB      63H,4           ;;(V/04)<A, eBYTE3 (7bits) to FF04

                DB      69H,80H         ;;A<80
                DB      60H,43H         ;;C<C+A
                DB      29H             ;;A<(BC)
                DB      63H,3H          ;;(V/03)<A, eBYTE2 to FF03

                DB      69H,40H         ;;A<40
                DB      60H,43H         ;;C<C+A
                DB      29H             ;;A<(BC)
                DB      63H,2H          ;;(V/02)<A, eBYTE1 to FF02
                $NEXT

;  eLOAD         ( --- )
;               Load Edit Buffer data into Slider Memory.
                $CODE   5,'eLOAD',ELOAD
                DB      68H,0FFH        ;;V<FF
                DB      6AH,2           ;;B<2
                DB      1,0             ;;A<(V/00) Read eSLD#
                DB      1BH             ;;C<A
                DB      29H             ;;A<(BC) Read Translation Table
                DB      6AH,0C6H        ;;B<C6
                DB      1BH             ;;C<A

                DB      69H,40H         ;;A<40
                DB      60H,43H         ;;C<C+A
                DB      49H,0           ;;(BC)<0, Zero to SLAST

                DB      69H,40H         ;;A<40
                DB      60H,43H         ;;C<C+A
                DB      1,3             ;;A<(V/03)
                DB      39H             ;;(BC)<A, (FF03) to Midi byte 2

                DB      69H,40H         ;;A<40
                DB      60H,43H         ;;C<C+A
                DB      1,2             ;;A<(V/02)
                DB      39H             ;;(BC)<A, (FF02) to Midi byte 1
                $NEXT
```

```
;  esUPDAT      ( --- )
;               Update only the Slider data of the Edit Buffer.
                $CODE   7,'esUPDAT',ESUPDAT
                DB      68H,0FFH        ;;V<FF
                DB      6AH,2           ;;B<2
                DB      1,0             ;;A<(V/00) Read eSLD#
                DB      1BH             ;;C<A
                DB      29H             ;;A<(BC) Read Translation Table
                DB      6AH,0C6H        ;;B<C6
                DB      1BH             ;;C<A

                DB      29H             ;;A<(BC)
                DB      48H,21H         ;;A SHIFT RIGHT
                DB      63H,4           ;;(V/04)<A, 7-bit Slider value to FF04
                $NEXT
```

# LCD DISPLAY ROUTINES

```
:  FLDAT   ( --- , Return LCD cursor to current edit field )

      eFLD C@ FLDCASE LI
;

:   SDISP        ( ---, Display the Setup operation on the LCD)
      1 LI BDEL
      L1 FLD0 DISP
      eSET# C@ FLD1 #2DISP     FLDAT
;

:  SLDISP  ( --- , Update and display Slider data )

      esUPDATE                                  (Get latest slide value)
      eFLD C@ FLDCASE                           (Get current field position)
      eBYTE3 C@ 7F AND
      <# # # # #> DROP LLI FLD6 LCD LLC         (Display Slide value)
      DUP C@ LCD 1+ DUP C@ LCD 1+ C@ LCD LI
;

:  eDISP    ( --- ,  Display Edit Buffer data on the LCD )

      L0  FLD0  DISP                            ( SLIDER )
      eSLD#   C@ FLD1 #2DISP                    ( Slider # )
      eBYTE3  C@ 80 AND    IF    L20 FLD2 DISP  ( OFF )
                           ELSE  L21 FLD2 DISP  ( CHL )
                           THEN
      eBYTE1  C@  DUP F AND FLD3  #DISP         ( Midi Channel # )
      2/  2/  2/  2/   7 AND LSTAT FLD4 DISP    ( Midi  Status )

      CF eBYTE1 C@ F0 AND <
            IF   L50 FLD5 DISP                  ( *** in Fld 5 )
            ELSE eBYTE2 C@ FLD5 #DISP           ( Number in Fld 5 )
            THEN
      SLDISP FLDAT                              ( Slider Data # )
;

:     MNDISP      ( ---, MAIN DISPLAY UPDATE used in EDIT word )
      eSET C@  IF SDISP    ELSE eDISP      THEN
;
```

## LCD CURSOR CONTROL

```
:  BDEL    ( --- , Long delay for poky LCD )

      8000 DELAY
;

:  BL/R    ( fld---pos, Translates LCD field number to LCD position)

      DUP eFLD C! FLDCASE
;

:  SL/R    ( --- , If in setup mode, toggle between fields 0 and 1 )
      eFLD C@ 01 AND 01 XOR DUP eFLD C!   BL/R LI BDEL ;

:  BLEFT   ( --- , Move cursor left & update eFLD)

      40 LED!
      eSET C@ IF SL/R ELSE
      eFLD C@ 5 DECR BL/R LI BDEL THEN
;

:  BRIGHT  ( --- , Move cursor right & update eFLD)

      80 LED!
      eSET C@ IF SL/R ELSE
      eFLD C@ 5 INCR BL/R LI BDEL THEN
;
```

## LCD FIELD INCREMENT/DECREMENT

```
;  UDCASE  ( n---, Choose field dependent up/down routine)
      eFLD C@ 7 AND
      CASE  U/D0 U/D1 U/D2 U/D3 U/D4 U/D5 U/D6 U/D7
;

:  BUP     ( --- ,  Increment value at cursor field )
      10 LED!     1 UDCASE BDEL
;
```

```
:  BDOWN     ( --- ,  Decrement value at cursor field )
      20 LED!     0 UDCASE BDEL
;

:  U/D0     (flg---, inc/dec field 0, SLIDER#/SETUP)
      DROP eSET C@   IF    0 eSET C!  eDISP
                     ELSE FF eSET C!  SDISP THEN
;

:  U/D1     (flg---, Inc/Dec fLd 1 which shows the Slider OR SETUP #)
      eSET C@  IF eSET# ELSE eSLD# THEN
      C@  3F ROT                    (slider#, max value, up/dwn flag)
      IF INCR ELSE DECR THEN        ( slider# + 1 or -1)
      CFLD1
;

:  CFLD1    (slider# --- , Change Slider/SETUP# in Fld1. Update Edit Buffer & LCD)
      eSET C@  IF   eSET# C!  SDISP
               ELSE eSLD# C!  eUPDAT eDISP   THEN   FLDAT
;

:  U/D2     (flg ---, Change Chnl or Off label in Field 2)
      IF     eBYTE1 C@ 80 OR    eBYTE1  C! L20  FLD2  DISP  ( display 'ch ' )
      ELSE   eBYTE1 C@ 7F AND   eBYTE1  C! L21  FLD2  DISP  ( display 'off'  )
      THEN   FLDAT
;

:  U/D3     (flg ---,  Change midi channel in Field 3 )
      eBYTE1 C@  F  AND  F  ROT           ( chnl#, F, u/d flg )
      IF INCR ELSE DECR THEN              ( chnl# +1 or -1 )
      CFLD3
;

:  CFLD3    (channel # ---, Change midi channel in Field 3 )
      DUP  eBYTE1  C@ F0 AND OR           (Construct eByte1 with new Chnl # )
      eBYTE1 C!    FLD3 #DISP             (Load into Edit buffer, Display it )
;

:  U/D4     (flg ---,   Change Midi operation in the status byte1 )
      eBYTE1 C@   70 AND  2/ 2/ 2/ 2/  7 ROT    ( stat, 7, u/d flg )
      IF INCR ELSE DECR THEN                    ( stat +1 or -1 )
      DUP 0 = OVER 7 = OR   IF DROP 1 THEN      ( avoid status bytes 0x and Fx )
      CFLD4
;

:  CFLD4          ( status# ---,  Change Midi operation label in field 4 )
      DUP   2* 2* 2* 2*   80  OR
      eBYTE1 C@   F  AND  OR              (Construct eByte1 with new Stat#)
      eBYTE1 C!   LSTAT  FLD4   DISP      (Load into Edit buffer, Display it )
      FLDAT
;


:  U/D5     (flg---,  Change Midi data byte2 )
      eBYTE2 C@  7F  ROT                  ( data, 7F, u/d flg )
      IF INCR ELSE DECR THEN              ( data +1 or -1 )
      CFLD5
;
```

```
:  CFLD5   (midi data ---, Change Midi Data Byte2 in field 5 )
     CF  eBYTE1 C@   F0 AND  <          (If chnl press or ptch whl, no data here)
     IF    L50  FLD5 DISP    FLD5 LI  DROP     ( display '***' in field 5 )
     ELSE  DUP eBYTE2 C!  FLD5  #DISP          (Load into Edit buffer, Display it )
     THEN
;

:  U/D6    (flg---, Do nothing with Slider value field)
     DROP
;

:  U/D7    (flg---, bogus field. Does not exist)
     DROP
;


: TST  BEGIN  KEY  DUP      ( 1 = UP,  0 = DWN,  any other key = quit )
     31  =  IF  1  U/D3  DROP  0  ELSE
     30  =  IF  0  U/D3  0              ELSE
     1  THEN  THEN  UNTIL  ;
```

## EDIT BUTTON ROUTINES

```
8(4)            4(3)         X            X
MIDI            LOAD        XX           XX

40(7)           80(8)      10(5)        20(6)
LEFT            RIGHT       UP          DOWN

2(2)
SLD UP

1(1)
SLIDE DWN
```

```
:  MNCASE  ( --- , Main Case statement for button routines)
     S@
     CASE  DUMMY BSDWN BSUP BLOAD BMIDI BUP BDOWN BLEFT BRIGHT
;

:  BSDWN   ( ---, Button 1 decrements the slider number)
     0 UD1 BDEL
;

:  BSUP    ( ---, Button 2 increments slider number)
     1 UD1 BDEL
;
```

```
:  SETUP   ( ---, Setup Slider Ram Buffer from ROM locations 2000H)
      eSET# C@ 2000 +    C680   80 CMOVE
;

:  BLOAD   ( ---, Button 3 loads data shown on LCD into Slider Memory)
      4 LED!
      eSET C@   IF   SETUP 0 eSET C!eUPDAT eDISP BDEL
                ELSE eLOAD eDISP BDEL   THEN
;

:  BMIDI   ( ---, Button 4 starts the Midi program)
      1 LI BDEL
      L2 FLD0 DISP
      MIDI
;

: EDIT     (MAIN EDIT PROGRAM)

      CR DECIMAL 1 LI BDEL
      eUPDATE eDISP

      BEGIN
            ADCINIT SLDISP
            0 LED!  MNCASE
      NUF?   UNTIL HEX
;
```

# ***MIDI Words***

# PG1000 MIDI

The main MIDI loop rotates through the 64 ADC Slider values until an enabled one is found. The loop count is stored in register FFE0. Then the Midi status is checked for the following operations:

| | | |
|---|---|---|
| 1 | KEYN | Key On or Key Off |
| 2 | KEYAT | Key On or Key Off with After Touch |
| 3 | CNTRL | Control Change |
| 4 | PRG | Program Change |
| 5 | CHAT | Channel After Touch |
| 6 | PWHL | Pitch Wheel |

# MIDI UTILITY ROUTINES

```
;  MLOOP        ( --- stat)
;               Loop thru ADC values until an enabled one is found.
                $CODE   5,'MLOOP',MLOOP
                DB 68H,0FFH             ;V<FF
                DB 6AH,0C6H             ;B<C6
LOOPBACK:       DB 1,0E0H               ;A<(V/E0)
                DB 41H                  ;A<A+1 skip if carry (never carries)
                DB 07H,3FH              ;A<A AND 3F
                DB 63H,0E0H             ;(V/E0)<A, incremented count to FFE0

                DB 46H,0C0H             ;A<A+C0
                DB 1BH                  ;C<A
                DB 29H                  ;A<(BC), get midi byte1
                DB 47H,80H              ;A AND 80, skip if no zero
                DB 0F2H                 ;JMP LOOPBACK, if disabled

                DB 7H,7FH               ;A<A AND 7F
                DB 48H,21H              ;A shift right
                DB 48H,21H              ;A shift right
                DB 48H,21H              ;A shift right
                DB 48H,21H              ;A shift right
                DB 1BH                  ;C<A, Midi status number
                DB 6AH,0                ;B<0
                DB 0B1H                 ;PUSH BC, push status# on stack
                $NEXT

;  ADCV          ( --- adc value)
;               Push stack with current adc value for MIDI operation.
                $CODE   4,'ADCV',ADCV
                DB 1,0E0H               ;A<(V/E0), Midi loop count.
                DB 1BH                  ;C<A
                DB 6AH,0C6H             ;B<C6
                DB 29H                  ;A<(BC)
                DB 1BH                  ;C<A
                DB 6AH,0                ;B<0
                DB 0B1H                 ;PUSH BC
                $NEXT
```

```
;  SLAST         ( --- slast value)
;                Push stack with last adc value for MIDI operation.
                 $CODE   4,'DIFF',DIFF
                 DB 1,0E0H                ;A<(V/E0), Midi loop count.
                 DB 46H,40H               ;A<A+40
                 DB 1BH                   ;C<A
                 DB 6AH,0C6H              ;B<C6
                 DB 29H                   ;A<(BC)
                 DB 1BH                   ;C<A
                 DB 6AH,0                 ;B<0
                 DB 0B1H                  ;PUSH BC
                 $NEXT

;  BYT2           ( --- byt2 value)
;                Push stack with current BYTE2 value for MIDI operation.
                 $CODE   4,'BYT2',BYT2
                 DB 1,0E0H                ;A<(V/E0), Midi loop count.
                 DB 46H,80H               ;A<A+80
                 DB 1BH                   ;C<A
                 DB 6AH,0C6H              ;B<C6
                 DB 29H                   ;A<(BC)
                 DB 1BH                   ;C<A
                 DB 6AH,0                 ;B<0
                 DB 0B1H                  ;PUSH BC
                 $NEXT

;  BYT1           ( --- byt1 value)
;                Push stack with current BYTE1 value for MIDI operation.
                 $CODE   4,'BYT1',BYT1
                 DB 1,0E0H                ;A<(V/E0), Midi loop count.
                 DB 46H,0C0H              ;A<A+C0
                 DB 1BH                   ;C<A
                 DB 6AH,0C6H              ;B<C6
                 DB 29H                   ;A<(BC)
                 DB 1BH                   ;C<A
                 DB 6AH,0                 ;B<0
                 DB 0B1H                  ;PUSH BC
                 $NEXT

;  FLAG           ( --- flag value)
;                Push stack with current FLAG value for MIDI operation.
                 $CODE   4,'FLAG',FLAG
                 DB 1,0E0H                ;A<(V/E0), Midi loop count.
                 DB 1BH                   ;C<A
                 DB 6AH,0C7H              ;B<C7
                 DB 29H                   ;A<(BC)
                 DB 1BH                   ;C<A
                 DB 6AH,0                 ;B<0
                 DB 0B1H                  ;PUSH BC
                 $NEXT
```

```
; FLGON            ( --- )
;               Store FF in FLAG of current slider.
                $CODE   5,'FLGON',FLGON
                DB 1,0E0H               ;A<(V/E0)
                DB 1BH                  ;C<A
                DB 6AH,0C7H             ;B<C7
                DB 69H,0FFH             ;A<FF
                DB 39H                  ;(BC)<A
                $NEXT

; FLGOFF           ( --- )
;               Store 0 in FLAG of current slider.
                $CODE   6,'FLGOFF',FLGOFF
                DB 1,0E0H               ;A<(V/E0)
                DB 1BH                  ;C<A
                DB 6AH,0C7H             ;B<C7
                DB 69H,0                ;A<0
                DB 39H                  ;(BC)<A
                $NEXT

; ?DIFF         (old,new --- |shifted new,FF|  or |00|)
;               If |old-new| > 1, then push 7-bit new and a flag of FFH.
;               Else push flag of zero.

                $CODE   5,'?DIFF',QDIFF
                DB 0A4H                 ;POP EA, new
                DB 0A1H                 ;POP BC, old
                DB 09H                  ;A<EAL
                DB 60H,0E3H             ;A<A-C

                DB 6BH,0FFH             ;C<FF
                DB 60H,0EBH             ;A-C, skip if no zero, check diff=0.
                DB 69H,0                ;A<0
                DB 6BH,0                ;C<0, flag = 00
                DB 47H,0FEH             ;A AND FE, skip if no zero
                DB 0C7H                 ;JMP AHEAD if |old-new| < 1.
                DB 9H                   ;A<EAL
                DB 48H,21H              ;A SHIFT RIGHT, change 8bit to 7bit.
                DB 19H                  ;EAL<A
                DB 0B4H                 ;PUSH EA, Push 7-bit "new" value
                DB 6BH,0FFH             ;C<FF, flag = FF

AHEAD:          DB 6AH,0                ;B<0
                DB 0B1H                 ;PUSH BC, Push flag.
                $NEXT

; LDLAST        ( --- )
;               Moves ADC value to SLAST value
                of the slider specified in MLOOP counter FFE0.

                $CODE   6,'LDLAST',LDLAST
                DB 1,0E0H               ;A<(V/E0)
                DB 1BH                  ;C<A
                DB 6AH,0C6H             ;B<C6
                DB 29H                  ;A<(BC)
                DB 19H                  ;EAL<A
                DB 0BH                  ;A<C
                DB 46H,40H              ;A<A+40
                DB 1BH                  ;C<A
                DB 09H                  ;A<EAL
                DB 39H                  ;(BC)<A
                $NEXT


:  LDSTAT   ( --- )
                  (Load current Byte1 to FFE1, last Midi status sent)
      BYT1 FFE1 C!
;

:  TSTAT          ( --- )
                  (Check last Midi status sent & send new one if not =)
      BYT1 DUP FFE1 C@ =
      IF DROP
      ELSE TM LDSTAT
      THEN
;
```

# MIDI OPERATIONS

```
:  MCASE    ( --- , Midi routines Case statement)

      CASE  DUMMY KEYN KEYAT CNTRL PRG CHAT PWHL DUMMY
;

:  KEYN     (Midi routine for Key On and Key Off.
                  If the slider goes below the top of its travel and the
            note is off (as indicated by FLAG=0) then send a MIDI Note
            On message.
                  If ADC=0 and the note is on (indicated by FLAG=FF)
            then send a Midi Note Off.)

      ADCV 0 =
      IF  LDLAST FLAG
            IF BYT1 TM LDSTAT BYT2 TM FLGOFF 0 TM     (Midi Note Off)
            ELSE  EXIT
            THEN

      ELSE  FLAG
            IF    EXIT
            ELSE  ADCV SLAST - 0<

                  IF BYT1 TM LDSTAT BYT2 TM FLGON     (Midi Note on)
                     ADCV 2/ TM
                  THEN LDLAST
            THEN
      THEN
;
```

```
:  KEYAT    (Midi routine for Key On and Key Off with Polyphonic After
            Touch.
                  Turn on Note when the slider drops below the top of
            its rise.
                  Continue sending polyphonic After Touch.
                  Turn the Note off when the slider is brought back
            down to zero.)

      ADCV 0 =
      IF  LDLAST FLAG
            IF  BYT1 0F AND 90 OR TM                  (Midi Note Off)
                90 FFE1 C!  (Load LST, last status)
                BYT2 TM FLGOFF 0 TM  EXIT
            ELSE  EXIT
            THEN

      ELSE  FLAG
            IF    SLAST ADCV ?DIFF

                  IF TSTAT BYTE2 TM LDLAST TM EXIT (Midi After Touch)
                  ELSE EXIT
                  THEN

            ELSE  ADCV SLAST - 0<

                  IF BYT1 F0 AND 90 OR TM             (Midi Note On)
                     90 FFE1 C! (Load LST, last status)
                     BYT2 TM FLGON ADCV 2/ TM
                  THEN LDLAST
            THEN
      THEN
;


:  CNTRL    (Midi routine for Controller Data.  If the slider value has
            changed, then send the new value)

      SLAST ADCV ?DIFF              (Do nothing if no change)
      IF TSTAT BYT2 TM LDLAST TM    (Send Controller data)
      THEN
;


:  PRG      (Midi routine for Program Changes.  When the slider goes
            above a set threshold then send a Midi Program Change once.)

      40 ADCV <
      IF  FLAG
            IF EXIT
            ELSE BYT1 TM LDSTAT FLGON BYT2 TM  (Send Midi Program)
            THEN
      ELSE FLGOFF       (If ADCV goes below threshold turn off FLAG)
      THEN


;
```

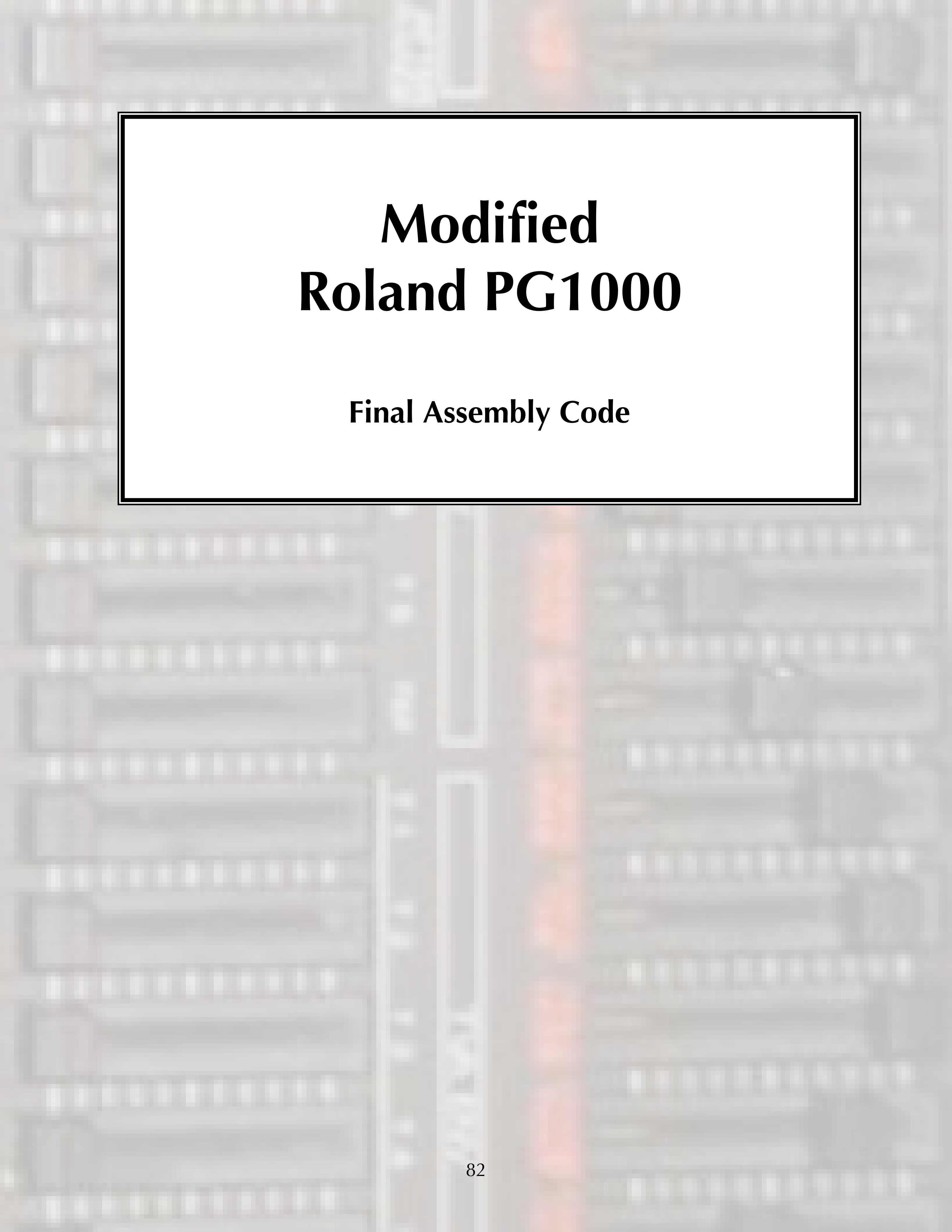
```
:  CHAT     (Midi routine for Channel After Touch.  If the slider value
            has changed, send the new value.)

      SLAST ADCV ?DIFF              (Do nothing if no change)
      IF TSTAT LDLAST TM            (Send Midi Channel Pressure)
      THEN
;


:  PWHL     (Midi routine for Pitch Wheel data.  If the slider value has
            changed, send the new value.)

      SLAST ADCV ?DIFF              (Do nothing if no change)
      IF TSTAT 0 TM LDLAST TM       (Send Midi Pitch Wheel)
      THEN
;
```

```
            ***********************************************
```

```
:  MIDI     ( --- , Main Midi loop)

      C700 40 0 FILL                            (Reset FLAGs)
      C640 40 0 FILL                            (Reset SLASTs)

      BEGIN   ADCINIT MLOOP MCASE
              SW@ NOT 7 AND  (Leave loop by pushing buttons 1,2 or 3)
      UNTIL                  (Returns to originating EDIT program)
;
```

## Main Program

```
HEX
: BDOWN 20 LED! 0 eFLD C@ 7 AND CASE U/D0 U/D1 U/D2 U/D3
U/D3 U/D4 U/D5 U/D6 U/D7 ;

: DUMMY ;

: MCASE CASE DUMMY DUMMY DUMMY BLOAD BMIDI BUP BDOWN
        BLEFT BRIGHT ;

: MAIN CR 1 LI DECIMAL 1 LI eUPDAT eDISP
       BEGIN   0 LED!   S@ MCASE    FFFF DELAY
       NUF? UNTIL  ." END MAIN " CR ;

HAND
```



# Modified Roland PG1000

## Final Assembly Code

```
Page 60,100
;===============================================================
;
;   eForth 1.0 by Bill Muench and C. H. Ting, 1990
;
;   This is an implementation for the NEC 78C10 microcomputer by
;   John Talbert, 1994, Oberlin Conservatory.
;
;   Register Use:       Interpreter Pointer = DE
;                       Data Stack Pointer  = SP
;                       Return Stack Pointer  = HL

;                       Free to use: BC, EA, VA, Alternate Registers.
;
;   'doList'  is accessed as a subroutine through a CALT instruction
;            (Call to Jump Table).  This shows up as a 'DB 80H' line
;            in the $COLON and $USER Macros.  When executed the
;            processor jumps to an address vector located at 80H.  The
;            vectored 'doList' code is then located at 0F0H. The word
;            'call,' was changed to load 80H into the code area for a
;            doLST assembly.
;
;   A 9600 Baud serial I/O is provided.  PortB/bit0 is used for serial
;       output and PortC/bit3 (INT2) is used for the serial input.  The
;       serial input is interrupt driven with a vectored interrupt routine
;       located at 0A0H.  The code words ?RX, TX!, and !IO make up the
;       rest of the serial I/O code.  Three USER variables have been set
;       up for use by these serial I/O routines:  SERIN, which holds the
;       received character and a flag; HAFBIT, which adjusts the software
;       timing of the receiver to read in the middle of each bit frame
;       (set it for 1/2 the BITIME minus 5); and BITIME, which adjusts the
;       software for a specific baud rate (17H for 9600 baud assuming a 12Mhz
;       processor clock).
;
;   The 78C10 is an 8-bit micro, therefore cell aligning to even addresses
;       is unnecessary. The $ALIGN Macro was taken out along with the NOP's
;       used for cell alignment in the other Macros.  All occurrences of the
;       word ALGND were erased also. The word SEE no longer works because it
;       relies on cell alignment.
;
;   All of the system FORTH code is to be stored in ROM (up to 32K) starting
;       at address 0000H. Then there is 2K of RAM starting at address COOOH.
;       This memory setup required the following changes:
;               1) Return and Data stacks and TIB moved to RAM.
;                  (See the Memory allocation EQU assignments.)
;               2) The USER variables were moved to the micro's
;                  internal RAM at FF00H to FFFFH.
;               3) PAD word was changed to move the temporary buffer
;                  area to RAM space.
;               4) The vocabulary pointers found in the word FORTH were
;                  moved to RAM space by creating two new USER variables,
;                  FHEAD and FLINK and changing DOVOC to read:
;                  DW FHEAD,CNTXT,STORE,EXIT.
;               5) NTOP and CTOP were moved to RAM space to allow dictionary
;                  expansion into RAM space.
;
;   Several words were added to the ROM Dictionary.  The simple operators
;       1+,1-,2+,2-,2*,2/, were defined in machine code.  The words C, ,
;       CCOMPILE, CODE, and ENDCODE were created to enable the creation
;       of code definition.
;
;    The NEC78C10 offers the following advantages:
;               1) Ten 16-bit internal registers and a 16-bit ALU.
;                  Many 16-bit instructions for those FORTH stack operations.
;               2) Three 8-bit I/O ports.
;               3) Eight 8-bit Analog to Digital Converters.
;               4) Internal counters and programmable clock generators.
;               5) Internal hardware serial I/O.  (can be used for MIDI I/O).
;               6) 64K address space including 256 bytes of internal RAM.
;
;
;==================================================================
;; Version control
VER             EQU     01H                     ;major release version
EXT             EQU     01H                     ;minor extension

;; Constants
COMPO           EQU     040H                    ;lexicon compile only bit
IMEDD           EQU     080H                    ;lexicon immediate bit
MASKK           EQU     07F1FH                  ;lexicon bit mask

CELLL           EQU     2                       ;size of a cell
BASEE           EQU     10                      ;default radix
VOCSS           EQU     6                       ;depth of vocabulary stack

BKSPP           EQU     8                       ;backspace
LF              EQU     10                      ;line feed
CRR             EQU     13                      ;carriage return
ERR             EQU     27                      ;error escape
TIC             EQU     39                      ;tick

CALLL           EQU     80H                     ;CALT opcodes

;; Memory allocation    0//code>--//--<name//up>--<sp//tib>--rp//em

COLDD           EQU     00100H                  ;cold start
RPP             EQU     0C2F0H                  ;start of return stack (RP0)
TIBB            EQU     0C200H                  ;terminal input buffer (TIB)
SPP             EQU     0C1F0H                  ;start of data stack (SP0)
UPP             EQU     0FF00H                  ;start of user area (UP0)
NAMEE           EQU     03FFDH                  ;name dictionary
CODEE           EQU     00300H                  ;code dictionary
CTOP            EQU     0C390H                  ;RAM code dict. expansion
NTOP            EQU     0C7FFH                  ;RAM name dict. expansion
PADD            EQU     0C300H                  ;PAD area
SLDTR           EQU     00200H                  ;Table for Slider# translate
ADCINT          EQU     00280H                  ;ADC Interrupt routine

;; Initialize assembly variables

_LINK   = 0                                     ;force a null link
_NAME   = NAMEE                                 ;initialize name pointer
_CODE   = CODEE                                 ;initialize code pointer
_USER   = 4*CELLL                               ;first user variable offset

;; Define assembly macros
```

```
;       Compile a code definition header.

$CODE   MACRO   LEX,NAME,LABEL
LABEL:                                          ;;assembly label
        _CODE   = $                             ;;save code pointer
        _LEN    = (LEX AND 01FH)/CELLL          ;;string cell count, round down
        _NAME   = _NAME-((_LEN+3)*CELLL)        ;;new header on cell boundary
ORG     _NAME                                   ;;set name pointer
        DW       _CODE,_LINK                    ;;token pointer and link
        _LINK   = $                             ;;link points to a name string
        DB      LEX,NAME                        ;;name string
ORG     _CODE                                   ;;restore code pointer
        ENDM

;       Compile a colon definition header.

$COLON  MACRO   LEX,NAME,LABEL
        $CODE   LEX,NAME,LABEL
        DB 80H                                  ;;include CALT doLIST
        ENDM

;       Compile a user variable header.

$USER   MACRO   LEX,NAME,LABEL
        $CODE   LEX,NAME,LABEL
        DB 80H                                  ;;include CALT doLIST
        DW      DOUSE,_USER                     ;;followed by doUSER and offset
        _USER   = _USER+CELLL                   ;;update user area offset
        ENDM

;       Compile an inline string.

D$      MACRO   FUNCT,STRNG
        DW      FUNCT                           ;;function
        _LEN    = $                             ;;save address of count byte
        DB      0,STRNG                         ;;count byte and string
        _CODE   = $                             ;;save code pointer
ORG     _LEN                                    ;;point to count byte
        DB      _CODE-_LEN-1                    ;;set count
ORG     _CODE                                   ;;restore code pointer
        ENDM

;       Compile a stored string.

SD$     MACRO   STRNG
        DW DOLIT
        _LEN    = $ + 4                         ;;save address of count byte
        DW      _LEN,EXIT                       ;;save cnt address on stack
        DB      0,STRNG                         ;;count byte and string
        _CODE   = $                             ;;save code pointer
ORG     _LEN                                    ;;point to count byte
        DB      _CODE-_LEN-1                    ;;set count
ORG     _CODE                                   ;;restore code pointer
        ENDM

;       Assemble inline direct threaded code ending.
```

```
$NEXT   MACRO
        DB 48H,84H                              ;;EA<(DE)++,next code address
into AX
        DB 48H,28H                              ;;JMP EA,jump directly to code
address
        ENDM

;; Main entry points and COLD start data

MAIN    SEGMENT
ASSUME  CS:MAIN,DS:MAIN,ES:MAIN,SS:MAIN

ORG     0000H

ORIG:   DB 54H,00,01,00                         ;RESET vector, JMP 0100H
        DB 0AAH,62H,0,0                         ;NMI vector, EI RETI
        DB 8 DUP(0)                             ;INT T0/T1 vector
        DB 54H,0A0H,00H, 5 DUP(0)               ;INT1/2 vector, JMP 00A0H
        DB 8 DUP(0)                             ;INT E1/E0 vector
        DB 54H,80H,02, 5 DUP(0)                 ;INT EIN/AD vector, JMP 0280H
        DB 8 DUP(0)                             ;INT SR/ST vector
        DB 48 DUP(0)                            ;FREE
        DB 32 DUP(0)                            ;SOFTI vector at 0060H

ORG     00A0H

; Vectored INT2 routine for Serial Input from Host Computer.
; Uses address FFF0 as a counter location - do not use elsewhere!
        DB 0B1H                 ;PUSH BC
        DB 0B2H                 ;PUSH DE
        DB 0B0H                 ;PUSH VA
        DB 68H,0FFH             ;MVI, V<FF
        DB 71H,0F0H,07H         ;MVIW, (V/F0)<07, number of bits to receive.
        DB 70H,1FH,04CH,0FFH    ;LBCD, BC<(FF4C), wait for a half bit.
        DB 53H                  ;DCR, C<C-1 skip, LOOP1
        DB 0FEH                 ;JR, Jump to loop1
        DB 52H                  ;DCR, B<B-1 skip
        DB 0FCH                 ;JR, Jump to loop1
        DB 70H,1FH,4EH,0FFH     ;LBCD, BC<(FF4E),wait 1 bit time,  LOOP2
        DB 53H                  ;DCR, C<C-1 skip
        DB 0FEH                 ;JR, Jump to loop2
        DB 52H                  ;DCR, B<B-1 skip
        DB 0FCH                 ;JR, Jump to loop2
        DB 04CH,0C2H            ;MOV, A<PC, read serial input on pc3
        DB 48H,31H,48H,31H      ;Rotate PC3 bit into Cy
        DB 48H,31H,48H,31H      ;RLR, A rotate right 4xs
        DB 0CH                  ;MOV, A<D, D collects the bits
        DB 48H,31H              ;RLR, shift in next bit, CY to top of D
        DB 1CH                  ;MOV, D<A
        DB 30H,0F0H             ;DCRW, (V/F0)<(V/F0)-1 skip
        DB 0E7H                 ;JR, Jump to loop2 for next bit.
        DB 70H,1FH,4EH,0FFH     ;LBCD, BC<(FF4E)
        DB 53H,0FEH,52H,0FCH    ;DCR JR DCR JR, stop bit loop time.
        DB 71H,04BH,0FFH        ;MVIW, (V/4B)<FF, load flag
        DB 0CH,63H,04AH         ;MOV STAW, A<D (V/4A)<A, load data
        DB 0A0H,0A2H,0A1H       ;POP, restore AV DE and BC
        DB 48H,44H,0            ;SKIT,NOP
        DB 0AAH,062H            ;EI RETI, enable interrupts and return
```

```
;; Kernel doLST routine.  Always accessed by the CALT instruction: 80H
;; which is a Call Subroutine to jump to address vector located at 0080H.

ORG     00F0H
        DB 33H,33H              ;HL<HL-2
        DB 0A6H                 ;EA<DE
        DB 48H,93H              ;(HL)<EA
        DB 0A2H                 ;POP DE previously pushed by CALT
        DB 48H,84H              ;EA<(DE)++, $NEXT
        DB 48H,28H              ;JMP EA
ORG     0080H
        DB 0F0H,0               ; set up vector to doLST

;; Table for translating Slider numbers into an orderly sequence as
;; physically set up on the Roland PG1000 board.

ORG     SLDTR
        DB 48,56,40,37,53,61,45,35
        DB 51,59,43,33,49,57,41,38
        DB 54,62,46,30,32,16,08,00
        DB 24,21,13,05,29,19,11,03
        DB 44,27,17,09,01,25,22,14
        DB 06,34,50,60,52,36,20,12
        DB 04,28,18,10,02,26,42,58
        DB 07,15,23,31,39,47,55,63


ORG     COLDD                   ;Beginning of Cold Boot
        DB 69H,0FH,4DH,0D0H     ;MM<0F, memory map (11-8)
        DB 69H,0FFH,4DH,0D2H    ;MA<FF, pa inputs (4-2)
        DB 69H,00H,4DH,0D3H     ;MB<00, pb outputs (4-6)
        DB 64H,01H,05H          ;PB<5
        DB 4DH,0D7H             ;MF<00, pf outputs (4-15)
        DB 69H,0AH,4DH,0D4H     ;MC<0A, pc1/3 inputs (4-9)
        DB 69H,0BH,4DH,0D1H     ;MCC<0B, pc mode (4-8)
        DB 64H,02H,04H          ;PC<04
        DB 64H,81H,06H          ;SMH<06, serial mode (7-7)
        DB 69H,4EH,4DH,0CAH     ;SML<4E, serial mode (7-9)
        DB 04H                  ;SP<SPP, stack pointer=data stack
        DB LOW SPP
        DB HIGH SPP
        DB 34H                  ;HL<RPP, HL=return stack pointer
        DB LOW RPP
        DB HIGH RPP
        DB 69H,00H,4DH,0E8H     ;ZCM<0, zero cross disabled (3-26)
        DB 68H,0FFH             ;V<FF
        DB 10H,68H,0FFH,69H,0   ;V'<FF, A"<0, V<FF, A<0

;; timer setups for Midi and LCD use
        DB 69H,64H,4DH,0DAH     ;TM0<64, timer0 (5-1)
        DB 69H,0FFH,4DH,0DBH    ;TM1<FF, timer1 (5-1)
        DB 64H,85H,0B3H         ;TMM<B3, timer mode (5-6)
        DB 44H,60H,0EAH,48H,0D3H        ;ETM1<EA = EA60 (6-2)
        DB 64H,83H,0CCH         ;EOM<CC, timer event mode (6-14)
        DB 69H,5CH,4DH,0CCH     ;ETMM<5C, timer event mode (6-11)

        DB 54H,00,03H           ;JMP to 0300, high level cold start
```

```
                              ;COLD WORD MOVED TO THE START OF CODE AREA.
                              ;ATTEMPTED TO AUTOMATE-JMP COLD-WITH $JUMP
                              ;BUT MACRO PRODUCES ERROR CODES.

; COLD start moves the following to USER variables.
; MUST BE IN SAME ORDER AS USER VARIABLES.

UZERO:          DW      4 DUP (0)               ;reserved
                DW      SPP                     ;SP0
                DW      RPP                     ;RP0
                DW      QRX                     ;'?KEY
                DW      TXSTO                   ;'EMIT
                DW      ACCEP                   ;'EXPECT
                DW      KTAP                    ;'TAP
                DW      TXSTO                   ;'ECHO
                DW      DOTOK                   ;'PROMPT
                DW      BASEE                   ;BASE
                DW      0                       ;tmp
                DW      0                       ;SPAN
                DW      0                       ;>IN
                DW      0                       ;#TIB
                DW      TIBB                    ;TIB
                DW      0                       ;CSP
                DW      INTER                   ;'EVAL
                DW      NUMBQ                   ;'NUMBER
                DW      0                       ;HLD
                DW      0                       ;HANDLER
                DW      0                       ;CONTEXT pointer
                DW      VOCSS DUP (0)           ;vocabulary stack
                DW      0                       ;CURRENT pointer
                DW      0                       ;vocabulary link pointer
                DW      0                       ;FORTH HEAD
                DW      0                       ;FORTH LINK
                DW      CTOP                    ;CP
                DW      NTOP                    ;NP
                DW      LASTN                   ;LAST
                DW      0                       ;SERIN host receive char & flag
                DW      06H                     ;HAFBIT time for serial host,
                                                ; (1/2 BITIME - 5)
                DW      16H                     ;BITIME baud for serial host

ULAST:

ORG ADCINT

;       Interrupt routine for Analog to Digital Converters
        DB 10H                  ;EXA
        DB 11H                  ;EXX
;  Load ADC Address and Counter into HL.  Uses FFF2 and FFF3.
        DB 68H,0FFH             ;V'<FF
        DB 69H,0C6H             ;A<C6
        DB 1EH                  ;H<A
        DB 01H,0F3H             ;A<(V/F3)
        DB 1FH                  ;L<A
;  Store ADC 0.
        DB 4CH,0E0H             ;A<CR0
        DB 3DH                  ;(HL)+<A, store new value
;  Store ADC 1.
```

```
        DB 4CH,0E1H             ;A<CR1
        DB 3DH                  ;(HL)+<A, store new value
;  Store ADC 2.
        DB 4CH,0E2H             ;A<CR2
        DB 3DH                  ;(HL)+<A, store new value
;  Store ADC 3.
        DB 4CH,0E3H             ;A<CR3
        DB 3DH                  ;(HL)+<A, store new value
;  Update Counters
        DB 0FH                  ;A<L
        DB 63H,0F3H             ;(V/F3)<A, Load counter.
        DB 48H,25H              ;A shift logical left
        DB 48H,05H              ;A shift left, skip if carry (if end count)
        DB 0C7H                 ;JMP AHEAD
        DB 64H,1EH,01           ;MKH<MKH OR 1, disable interrupts
        DB 10H,11H,0AAH,62H     ;Return from interrupts

        DB 1AH                  ;B<A, "AHEAD"
        DB 74H,0AH,0E0H         ;B<B AND E0
        DB 4CH,0C2H             ;A<Pc
        DB 07H,1FH              ;A<A AND 1F
        DB 60H,9AH              ;A<A OR B
        DB 4DH,0C2H             ;Pc<A, Load high 3 bits of slider select.
        DB 64H,90H,08H          ;Invert ANM bit and restart conversion.

;  Return from Interrupt.
        DB 10H                  ;EXA
        DB 11H                  ;EXX
        DB 0AAH                 ;EI
        DB 62H                  ;RETI

ORG     CODEE                                   ;start code dictionary

;   COLD        ( -- )
;               The hilevel cold start sequence.
                CCOLD = $
                $COLON  4,'COLD',COLD
COLD1:          DW      DOLIT,UZERO,DOLIT,UPP
                DW      DOLIT,ULAST-UZERO,CMOVE ;initialize user area
                DW      PRESE                   ;initialize stack and TIB
                DW      TBOOT,ATEXE             ;application boot
                DW      FORTH,CNTXT,AT,DUPP     ;initialize search order
                DW      CRRNT,DSTOR,OVERT
                DW      LCDIN                   ;initialize LCD
                DW      EDIT                    ;Autostart EDIT
                DW      QUIT                    ;start interpretation
                DW      BRAN,COLD1              ;just in case


;; Device dependent I/O

;   BYE         ( -- )
;               Exit eForth.
                $CODE   3,'BYE',BYE
                DB 54H,0,0                    ;JMP Reset Vector

;   ?RX         ( -- c T | F )
;               Return input character and true, or a false if no input.
```

```
                $CODE   3,'?RX',QRX
        DB 68H,0FFH             ;MVI, V<FF
        DB 01H,4BH              ;LDAW, A<(V/4B) read serial-in flag
        DB 47H,0FFH             ;ONI, A AND FF skip if flag not zero
        DB 0CAH                 ;JR, jump ahead1
        DB 71H,04BH,0           ;MVIW, (V/4B)<0, reset flag to zero
        DB 70H,1FH,4AH,0FFH     ;LBCD, BC<(FF4A), read serin data
        DB 0B1H                 ;PUSH BC, push serial input data to stack
        DB 69H,0FFH             ;A<FF
        DB 1BH                  ;C<A, AHEAD1
        DB 6AH,0                ;B<0
        DB 0B1H                 ;PUSH BC, push serial input flag to stack
        $NEXT


;   TX!         ( c -- )
;               Send character c to the output device.

                $CODE   3,'TX!',TXSTO
        DB 0BAH                 ;Disable Interrupts
        DB 0A1H                 ;POP BC, pop char into C
        DB 0B2H                 ;PUSH DE, store interpreter pointer
        DB 0BH,1CH              ;A<C, D<A, char in A and D
        DB 68H,0FFH             ;V<FF
        DB 71H,0F0H,07H         ;(V/F0)<7
        DB 60H,91H              ;A<A EXOR A
        DB 6DH,01H              ;E<01
        DB 4DH,0C1H             ;PB<A
        DB 70H,1FH,04EH,0FFH    ;BC<(FF4E) set baud, LOOP1
        DB 53H,0FEH,52H,0FCH    ;C<C-1, JR, B<B-1, JR, jr to loop1
        DB 0CH                  ;A<D
        DB 07H,01H              ;A<A AND 01
        DB 4DH,0C1H             ;PB<A, send a bit
        DB 0CH                  ;A<D
        DB 48H,31H              ;A rotate logical right
        DB 1CH                  ;D<A
        DB 0,0,0,0              ;NOPs to make rec loop = transmit loop.
        DB 30H,0F0H             ;(V/F0)<(V/F0)-1 skip
        DB 0E8H                 ;JR, jump to loop1
        DB 0DH                  ;A<E
        DB 51H                  ;A<A-1 skip
        DB 0C6H                 ;JR, jump to loop2
        DB 0A2H                 ;POP DE, restore interpreter pointer
        DB 0AAH                 ;Enable Interrupts
        $NEXT                   ;End of routine

        DB 6CH,03H              ;D<03, LOOP2
        DB 1DH                  ;E<A
        DB 71H,0F0H,01          ;(V/F0)<01
        DB 4FH,0D7H             ;JRE, jump to loop1

;   !IO         ( -- )
;               Initialize the serial I/O devices.

                $CODE   3,'!IO',STOIO
        DB 69H,0EFH,4DH,0C7H    ;MKL<EF, enable int2 interrupt and
        DB 69H,0FFH,4DH,0C6H    ;MKH<FF, disable all others with mask
        DB 0AAH                 ;EI, enable interrupt
        $NEXT


;; The kernel

;   doLIT       ( -- w )
;               Push an inline literal.

                $CODE   COMPO+5,'doLIT',DOLIT
                DB 48H,84H                      ;EA<(DE)++
                DB 0B4H                         ;PUSH EA
                $NEXT

;   EXIT        ( -- )
;               Terminate a colon definition.

                $CODE   4,'EXIT',EXIT
                DB 48H,85H                      ;EA<(HL)++
                DB 0B6H                         ;DE<EA
                $NEXT

;   EXECUTE     ( ca -- )
;               Execute the word at ca.

                $CODE   7,'EXECUTE',EXECU
                DB 0A1H                         ;POP BC
                DB 21H                          ;JMP BC

;   next        ( -- )
;               Run time code for the single index loop.
;               : next ( -- ) \ hilevel model
;                 r> r> dup if 1 - >r @ >r exit then drop cell+ >r ;

                $CODE   COMPO+4,'next',DONXT
                DB 6AH,0                        ;B<00
                DB 6BH,1                        ;C<01
                DB 48H,83H                      ;EA<(HL)
                DB 74H,0B5H                     ;EA<EA-BC Skip if no borrow
                DB 0C9H                         ;JMP NEXT1
                DB 48H,93H                      ;(HL)<EA
                DB 48H,82H                      ;EA<(DE)
                DB 0B6H                         ;DE<EA
                $NEXT
NEXT1:          DB 22H,22H                      ;DE<DE+2
                DB 32H,32H                      ;HL<HL+2
                $NEXT

;   ?branch     ( f -- )
;               Branch if flag is zero.

                $CODE   COMPO+7,'?branch',QBRAN
                DB 6AH,0FFH                     ;B<FF
                DB 6BH,0FFH                     ;C<FF
                DB 0A4H                         ;POP EA
                DB 74H,0CDH                     ;EA AND BC Skip if not zero
                DB 0C6H                         ;JMP BRAN1
                DB 22H,22H                      ;DE<DE+2
                $NEXT
BRAN1:          DB 48H,82H                      ;EA<(DE)
                DB 0B6H                         ;DE<EA
                $NEXT

;   branch      ( -- )
;               Branch to an inline address.

                $CODE   COMPO+6,'branch',BRAN
                DB 48H,82H                      ;EA<(DE)
                DB 0B6H                         ;DE<EA
                $NEXT

;   !           ( w a -- )
;               Pop the data stack to memory.

                $CODE   1,'!',STORE
                DB 0A1H                         ;POP BC, address
                DB 0A4H                         ;POP EA, data
                DB 09H                          ;A<EAL
                DB 39H                          ;(BC)<A
                DB 12H                          ;BC<BC+1
                DB 08H                          ;A<EAH
                DB 39H                          ;(BC)<A
                $NEXT

;   @           ( a -- w )
;               Push data at memory location to the data stack.

                $CODE   1,'@',AT
                DB 0A1H                         ;POP BC
                DB 29H                          ;A<(BC)
                DB 19H                          ;EAL<A
                DB 12H                          ;BC<BC+1
                DB 29H                          ;A<(BC)
                DB 18H                          ;EAH<A
                DB 0B4H                         ;PUSH EA
                $NEXT

;   C!          ( c b -- )
;               Pop the data stack to byte memory.

                $CODE   2,'C!',CSTOR
                DB 0A1H                         ;POP BC address
                DB 0A4H                         ;POP AE data
                DB 09H                          ;A<EAL
                DB 39H                          ;(BC)<A
                $NEXT

;   C@          ( b -- c )
;               Push byte memory location to the data stack.

                $CODE   2,'C@',CAT
                DB 0A1H                         ;POP BC
                DB 29H                          ;A<(BC)
                DB 6AH,0                        ;B<00
                DB 1BH                          ;C<A
                DB 0B1H                         ;PUSH BC
                $NEXT

;   RP@         ( -- a )
;               Push the current RP to the data stack.

                $CODE   3,'RP@',RPAT
                DB 0B3H                         ;PUSH HL
                $NEXT

;   RP!         ( a -- )
;               Set the return stack pointer.

                $CODE   COMPO+3,'RP!',RPSTO
                DB 0A3H                         ;POP HL
                $NEXT

;   R>          ( -- w )
;               Pop the return stack to the data stack.

                $CODE   2,'R>',RFROM
                DB 48H,85H                      ;EA<(HL)++
                DB 0B4H                         ;PUSH EA
                $NEXT

;   R@          ( -- w )
;               Copy top of return stack to the data stack.

                $CODE   2,'R@',RAT
                DB 48H,83H                      ;EA<(HL)
                DB 0B4H                         ;PUSH EA
                $NEXT

;   >R          ( w -- )
;               Push the data stack to the return stack.

                $CODE   COMPO+2,'>R',TOR
                DB 33H,33H                      ;HL<HL-2
                DB 0A4H                         ;POP EA
                DB 48H,93H                      ;(HL)<EA
                $NEXT

;   SP@         ( -- a )
;               Push the current data stack pointer.

                $CODE   3,'SP@',SPAT
                DB 70H,0EH,0FEH,0FFH            ;(FFFE)<SP
                DB 70H,1FH,0FEH,0FFH            ;BC<(FFFE)
                DB 0B1H                         ;PUSH BC
                $NEXT

;   SP!         ( a -- )
;               Set the data stack pointer.

                $CODE   3,'SP!',SPSTO
                DB 0A1H                         ;POP BC
                DB 70H,1EH,0FEH,0FFH            ;(FFFE)<BC
                DB 70H,0FH,0FEH,0FFH            ;PC<(FFFE)
                $NEXT
```

```
;    DROP        ( w -- )
;                Discard top stack item.

                 $CODE   4,'DROP',DROP
                 DB 0A4H                         ;POP EA
                 $NEXT

;    DUP         ( w -- w w )
;                Duplicate the top stack item.

                 $CODE   3,'DUP',DUPP
                 DB 0A4H                         ;POP EA
                 DB 0B4H                         ;PUSH EA
                 DB 0B4H                         ;PUSH EA
                 $NEXT

;    SWAP        ( w1 w2 -- w2 w1 )
;                Exchange top two stack items.

                 $CODE   4,'SWAP',SWAP
                 DB 0A4H                         ;POP EA
                 DB 0A1H                         ;POP BC
                 DB 0B4H                         ;PUSH EA
                 DB 0B1H                         ;PUSH BC
                 $NEXT

;    OVER        ( w1 w2 -- w1 w2 w1 )
;                Copy second stack item to top.

                 $CODE   4,'OVER',OVER
                 DB 0A4H                         ;POP AE
                 DB 0A1H                         ;POP BC
                 DB 0B1H                         ;PUSH BC
                 DB 0B4H                         ;PUSH AE
                 DB 0B1H                         ;PUSH BC
                 $NEXT

;    0<          ( n -- t )
;                Return true if n is negative.

                 $CODE   2,'0<',ZLESS
                 DB 0A1H                         ;POP BC
                 DB 69H,0FFH                     ;A<FF
                 DB 48H,06H                      ;B Shift Left, Skip if carry
                 DB 69H,0                        ;A<00
                 DB 1AH                          ;B<A
                 DB 1BH                          ;C<A
                 DB 0B1H                         ;PUSH BC
                 $NEXT

;    AND         ( w w -- w )
;                Bitwise AND.

                 $CODE   3,'AND',ANDD
                 DB 0A1H                         ;POP BC
                 DB 0A4H                         ;POP AE
                 DB 74H,8DH                      ;EA<EA AND BC
```

```
                DB 0B4H                         ;PUSH EA
                $NEXT

;   OR          ( w w -- w )
;               Bitwise inclusive OR.

                $CODE   2,'OR',ORR
                DB 0A1H                         ;POP BC
                DB 0A4H                         ;POP EA
                DB 74H,9DH                      ;EA<EA OR BC
                DB 0B4H                          ;PUSH EA
                $NEXT

;   XOR         ( w w -- w )
;               Bitwise exclusive OR.

                $CODE   3,'XOR',XORR
                DB 0A1H                         ;POP BC
                DB 0A4H                         ;POP EA
                DB 74H,95H                      ;EA<EA EX-OR BC
                DB 0B4H                         ;PUSH EA
                $NEXT

;   UM+         ( w w -- w cy )
;               Add two numbers, return the sum and carry flag.

                $CODE   3,'UM+',UPLUS
                DB 0A1H                         ;POP BC
                DB 0A4H                         ;POP EA
                DB 69H,0                        ;A<00
                DB 74H,0A5H                     ;EA<EA+BC Skip if no carry
                DB 41H                          ;A<A+1
                DB 1BH                          ;C<A
                DB 6AH,0                        ;B<00
                DB 0B4H                         ;PUSH EA
                DB 0B1H                         ;PUSH BC
                $NEXT

;; System and user variables

;   doVAR       ( -- a )
;               Run time routine for VARIABLE and CREATE.

                $COLON  COMPO+5,'doVAR',DOVAR
                DW      RFROM,EXIT

;   UP          ( -- a )
;               Pointer to the user area.

                $COLON  2,'UP',UP
                DW      DOVAR
                DW      UPP

;   doUSER      ( -- a )
;               Run time routine for user variables.

                $COLON  COMPO+6,'doUSER',DOUSE
                DW      RFROM,AT,UP,AT,PLUS,EXIT
```

```
;   SP0         ( -- a )
;               Pointer to bottom of the data stack.

                $USER   3,'SP0',SZERO

;   RP0         ( -- a )
;               Pointer to bottom of the return stack.

                $USER   3,'RP0',RZERO

;   '?KEY       ( -- a )
;               Execution vector of ?KEY.

                $USER   5,"'?KEY",TQKEY

;   'EMIT       ( -- a )
;               Execution vector of EMIT.

                $USER   5,"'EMIT",TEMIT

;   'EXPECT     ( -- a )
;               Execution vector of EXPECT.

                $USER   7,"'EXPECT",TEXPE

;   'TAP        ( -- a )
;               Execution vector of TAP.

                $USER   4,"'TAP",TTAP

;   'ECHO       ( -- a )
;               Execution vector of ECHO.

                $USER   5,"'ECHO",TECHO

;   'PROMPT     ( -- a )
;               Execution vector of PROMPT.

                $USER   7,"'PROMPT",TPROM

;   BASE        ( -- a )
;               Storage of the radix base for numeric I/O.

                $USER   4,'BASE',BASE

;   tmp         ( -- a )
;               A temporary storage location used in parse and find.

                $USER   COMPO+3,'tmp',TEMP

;   SPAN        ( -- a )
;               Hold character count received by EXPECT.

                $USER   4,'SPAN',SPAN

;   >IN         ( -- a )
;               Hold the character pointer while parsing input stream.
```

```
                $USER   3,'>IN',INN

;   #TIB        ( -- a )
;               Hold the current count and address of the terminal input buffer.

                $USER   4,'#TIB',NTIB
                _USER = _USER+CELLL

;   CSP         ( -- a )
;               Hold the stack pointer for error checking.

                $USER   3,'CSP',CSP

;   'EVAL       ( -- a )
;               Execution vector of EVAL.

                $USER   5,"'EVAL",TEVAL

;   'NUMBER     ( -- a )
;               Execution vector of NUMBER?.

                $USER   7,"'NUMBER",TNUMB

;   HLD         ( -- a )
;               Hold a pointer in building a numeric output string.

                $USER   3,'HLD',HLD

;   HANDLER     ( -- a )
;               Hold the return stack pointer for error handling.

                $USER   7,'HANDLER',HANDL

;   CONTEXT     ( -- a )
;               A area to specify vocabulary search order.

                $USER   7,'CONTEXT',CNTXT
                _USER = _USER+VOCSS*CELLL       ;vocabulary stack

;   CURRENT     ( -- a )
;               Point to the vocabulary to be extended.

                $USER   7,'CURRENT',CRRNT
                _USER = _USER+CELLL             ;vocabulary link pointer

;   FHEAD       ( -- a )
;               Point to the FORTH vocab head pointer.
                $USER   5,'FHEAD',FHEAD

;   FLINK       ( -- a )
;               Point to the FORTH vocab link pointer.
                $USER   5,'FLINK',FLINK

;   CP          ( -- a )
;               Point to the top of the code dictionary.

                $USER   2,'CP',CP
```

```
;   NP          ( -- a )
;               Point to the bottom of the name dictionary.

                $USER   2,'NP',NP

;   LAST        ( -- a )
;               Point to the last name in the name dictionary.

                $USER   4,'LAST',LAST

;   SERIN       ( -- a )
;               Point to host serial input. Flag in high, char in low byte.

                $USER   5,'SERIN',SERIN

;   HAFBIT      ( -- a )
;               Point to half bit time used by serial i/0 routines.

                $USER   6,'HAFBIT',HAFBIT

;   BITIME      ( -- a )
;               Point to bit time used to set serial i/o baud rate.

                $USER   6,'BITIME',BITIME

;; Common functions

;   doVOC       ( -- )
;               Run time action of VOCABULARY's.

                $COLON  COMPO+5,'doVOC',DOVOC
                DW      FHEAD,CNTXT,STORE,EXIT

;   FORTH       ( -- )
;               Make FORTH the context vocabulary.

                $COLON  5,'FORTH',FORTH
                DW      DOVOC,EXIT
                ; Head and Link pointers normally here were moved to User Ram.

;   ?DUP        ( w -- w w | 0 )
;               Dup tos if its is not zero.

                $CODE  4,'?DUP',QDUP
                DB 6AH,0FFH             ;B<FF
                DB 6BH,0FFH             ;C<FF
                DB 0A4H                 ;POP EA
                DB 74H,0DDH             ;EA AND BC, Skip if zero
                DB 0B4H                 ;PUSH EA
                DB 0B4H                 ;PUSH EA
                $NEXT

;   ROT         ( w1 w2 w3 -- w2 w3 w1 )
;               Rot 3rd item to top.

                $COLON  3,'ROT',ROT
                DW      TOR,SWAP,RFROM,SWAP,EXIT
```

```
;   2DROP       ( w w -- )
;               Discard two items on stack.

                $CODE  5,'2DROP',DDROP
                DB 0A4H,0A4H            ;POP EA, POP EA
                $NEXT

;   2DUP        ( w1 w2 -- w1 w2 w1 w2 )
;               Duplicate top two items.

                $CODE  4,'2DUP',DDUP
                DB 0A4H,0A1H            ;POP EA, POP BC
                DB 0B1H,0B4H            ;PUSH BC, PUSH EA
                DB 0B1H,0B4H            ;PUSH BC, PUSH EA
                $NEXT

;   +           ( w w -- sum )
;               Add top two items.

                $CODE  1,'+',PLUS
                DB 0A1H,0A4H            ;POP BC, POP EA
                DB 74H,0A5H             ;EA<EA+BC, Skip
                DB 0                    ;NOP
                DB 0B4H                 ;PUSH EA
                $NEXT

;   D+          ( d d -- d )
;               Double addition, as an example using UM+.
;
;               $COLON  2,'D+',DPLUS
;               DW      TOR,SWAP,TOR,UPLUS
;               DW      RFROM,RFROM,PLUS,PLUS,EXIT

;   NOT         ( w -- w )
;               One's complement of tos.

                $CODE  3,'NOT',INVER
                DB 0A1H                 ;POP BC
                DB 69H,0FFH             ;A<FF
                DB 60H,12H              ;B<B EX-OR A
                DB 60H,13H              ;C<C EX-OR A
                DB 0B1H                 ;PUSH BC
                $NEXT

;   NEGATE      ( n -- -n )
;               Two's complement of tos.

                $CODE  6,'NEGATE',NEGAT
                DB 0A1H                 ;POP BC
                DB 69H,0FFH             ;A<FF
                DB 60H,12H              ;B<B EX-OR A
                DB 60H,13H              ;C<C EX-OR A
                DB 12H                  ;BC<BC+1
                DB 0B1H                 ;PUSH BC
                $NEXT
```

```
;   DNEGATE     ( d -- -d )
;               Two's complement of top double.

                $COLON  7,'DNEGATE',DNEGA
                DW      INVER,TOR,INVER
                DW      DOLIT,1,UPLUS
                DW      RFROM,PLUS,EXIT

;   -           ( n1 n2 -- n1-n2 )
;               Subtraction.

                $CODE  1,'-',SUBB
                DB 0A1H                 ;POP BC
                DB 069H,0FFH            ;A<FF
                DB 060H,12H             ;B<B EX-OR A
                DB 060H,13H             ;C<C EX-OR A
                DB 12H                  ;BC<BC+1
                DB 0A4H                 ;POP EA
                DB 74H,0A5H             ;EA<EA+BC Skip
                DB 0                    ;NOP
                DB 0B4H                 ;PUSH EA
                $NEXT

;   ABS         ( n -- n )
;               Return the absolute value of n.

                $COLON  3,'ABS',ABSS
                DW      DUPP,ZLESS
                DW      QBRAN,ABS1
                DW      NEGAT
ABS1:           DW      EXIT

;   =           ( w w -- t )
;               Return true if top two are equal.

                $CODE  1,'=',EQUAL
                DB 0A4H,0A1H            ;POP EA, POP BC
                DB 69H,0FFH             ;A<FF
                DB 74H,0FDH             ;EA-BC, Skip if zero
                DB 69H,00H              ;A<00
                DB 1AH,1BH              ;B<A, C<A
                DB 0B1H                 ;PUSH BC
                $NEXT

;   U<          ( u u -- t )
;               Unsigned compare of top two items.

                $COLON  2,'U<',ULESS
                DW      DDUP,XORR,ZLESS
                DW      QBRAN,ULES1
                DW      SWAP,DROP,ZLESS,EXIT
ULES1:          DW      SUBB,ZLESS,EXIT

;   <           ( n1 n2 -- t )
;               Signed compare of top two items.

                $COLON  1,'<',LESS
                DW      DDUP,XORR,ZLESS
                DW      QBRAN,LESS1
                DW      DROP,ZLESS,EXIT
LESS1:          DW      SUBB,ZLESS,EXIT

;   MAX         ( n n -- n )
;               Return the greater of two top stack items.

                $CODE  3,'MAX',MAX
                DB 0A4H,0A1H            ;POP EA, POP BC
                DB 74H,0BDH             ;EA-BC, Skip if borrow
                DB 0C2H                 ;Jump to Push EA
                DB 0B1H                 ;PUSH BC
                DB 0C1H                 ;Jump to next
                DB 0B4H                 ;PUSH EA
                $NEXT

;   MIN         ( n n -- n )
;               Return the smaller of top two stack items.

                $CODE  3,'MIN',MIN
                DB 0A4H,0A1H            ;POP EA, POP BC
                DB 74H,0BDH             ;EA-BC, Skip if borrow
                DB 0C2H                 ;Jump to Push EA
                DB 0B4H                 ;PUSH EA
                DB 0C1H                 ;Jump to next
                DB 0B1H                 ;PUSH BC
                $NEXT

;   WITHIN      ( u ul uh -- t )
;               Return true if u is within the range of ul and uh.

                $COLON  6,'WITHIN',WITHI
                DW      OVER,SUBB,TOR                   ;ul <= u < uh
                DW      SUBB,RFROM,ULESS,EXIT

;; Quick Operators

;



;   1+          ( n -- n+1 )
                $CODE 2,'1+',ONEP
                DB 0A1H                 ;POP BC
                DB 12H                  ;BC<BC+1
                DB 0B1H                 ;PUSH BC
                $NEXT

;   1-          ( n -- n-1 )
                $CODE 2,'1-',ONEM
                DB 0A1H                 ;POP BC
                DB 013H                 ;BC<BC-1
                DB 0B1H                 ;PUSH BC
                $NEXT

;   2+          ( n -- n+2 )
                $CODE 2,'2+',TWOP
                DB 0A1H                 ;POP BC
                DB 12H,12H              ;BC<BC+2
                DB 0B1H                 ;PUSH BC
                $NEXT

;   2-          ( n -- n-2 )
                $CODE 2,'2-',TWOM
                DB 0A1H                 ;POP BC
                DB 13H,13H              ;BC<BC-2
                DB 0B1H                 ;PUSH BC
                $NEXT

;   2*          ( n -- n*2 )
                $CODE 2,'2*',TWOSL
                DB 0A4H                 ;POP EA
                DB 48H,0A4H             ;EA Logical Shift Left
                DB 0B4H                 ;PUSH EA
                $NEXT

;   2/          ( n -- n/2 )
                $CODE 2,'2/',TWOSR
                DB 0A4H                 ;POP EA
                DB 48H,0A0H             ;EA Logical Shift Right
                DB 0B4H                 ;PUSH EA
                $NEXT

;; Divide

;   UM/MOD      ( udl udh u -- ur uq )
;               Unsigned divide of a double by a single. Return mod and quotient.

                $COLON  6,'UM/MOD',UMMOD
                DW      DDUP,ULESS
                DW      QBRAN,UMM4
                DW      NEGAT,DOLIT,15,TOR
UMM1:           DW      TOR,DUPP,UPLUS
                DW      TOR,TOR,DUPP,UPLUS
                DW      RFROM,PLUS,DUPP
                DW      RFROM,RAT,SWAP,TOR
                DW      UPLUS,RFROM,ORR
                DW      QBRAN,UMM2
                DW      TOR,DROP,ONEP,RFROM
                DW      BRAN,UMM3
UMM2:           DW      DROP
UMM3:           DW      RFROM
                DW      DONXT,UMM1
                DW      DROP,SWAP,EXIT
UMM4:           DW      DROP,DDROP
                DW      DOLIT,-1,DUPP,EXIT      ;overflow, return max

;   M/MOD       ( d n -- r q )
;               Signed floored divide of double by single. Return mod and
quotient.

                $COLON  5,'M/MOD',MSMOD
                DW      DUPP,ZLESS,DUPP,TOR
                DW      QBRAN,MMOD1
                DW      NEGAT,TOR,DNEGA,RFROM
```

```
MMOD1:          DW      TOR,DUPP,ZLESS
                DW      QBRAN,MMOD2
                DW      RAT,PLUS
MMOD2:          DW      RFROM,UMMOD,RFROM
                DW      QBRAN,MMOD3
                DW      SWAP,NEGAT,SWAP
MMOD3:          DW      EXIT

;   /MOD        ( n n -- r q )
;               Signed divide. Return mod and quotient.

                $COLON  4,'/MOD',SLMOD
                DW      OVER,ZLESS,SWAP,MSMOD,EXIT

;   MOD         ( n n -- r )
;               Signed divide. Return mod only.

                $COLON  3,'MOD',MODD
                DW      SLMOD,DROP,EXIT

;   /           ( n n -- q )
;               Signed divide. Return quotient only.

                $COLON  1,'/',SLASH
                DW      SLMOD,SWAP,DROP,EXIT

;; Multiply

;   UM*         ( u u -- ud )
;               Unsigned multiply. Return double product.

                $COLON  3,'UM*',UMSTA
                DW      DOLIT,0,SWAP,DOLIT,15,TOR
UMST1:          DW      DUPP,UPLUS,TOR,TOR
                DW      DUPP,UPLUS,RFROM,PLUS,RFROM
                DW      QBRAN,UMST2
                DW      TOR,OVER,UPLUS,RFROM,PLUS
UMST2:          DW      DONXT,UMST1
                DW      ROT,DROP,EXIT

;   *           ( n n -- n )
;               Signed multiply. Return single product.

                $COLON  1,'*',STAR
                DW      UMSTA,DROP,EXIT

;   M*          ( n n -- d )
;               Signed multiply. Return double product.

                $COLON  2,'M*',MSTAR
                DW      DDUP,XORR,ZLESS,TOR
                DW      ABSS,SWAP,ABSS,UMSTA
                DW      RFROM
                DW      QBRAN,MSTA1
                DW      DNEGA
MSTA1:          DW      EXIT

;   */MOD       ( n1 n2 n3 -- r q )
;               Multiply n1 and n2, then divide by n3. Return mod and quotient.

                $COLON  5,'*/MOD',SSMOD
                DW      TOR,MSTAR,RFROM,MSMOD,EXIT

;   */          ( n1 n2 n3 -- q )
;               Multiply n1 by n2, then divide by n3. Return quotient only.

                $COLON  2,'*/',STASL
                DW      SSMOD,SWAP,DROP,EXIT

;; Miscellaneous

;   BL          ( -- 32 )
;               Return 32, the blank character.

                $COLON  2,'BL',BLANK
                DW      DOLIT,' ',EXIT

;   >CHAR       ( c -- c )
;               Filter non-printing characters.

                $COLON  5,'>CHAR',TCHAR
                DW      DOLIT,07FH,ANDD,DUPP    ;mask msb
                DW      DOLIT,127,BLANK,WITHI   ;check for printable
                DW      QBRAN,TCHA1
                DW      DROP,DOLIT,'_'          ;replace non-printables
TCHA1:          DW      EXIT

;   DEPTH       ( -- n )
;               Return the depth of the data stack.

                $COLON  5,'DEPTH',DEPTH
                DW      SPAT,SZERO,AT,SWAP,SUBB
                DW      DOLIT,CELLL,SLASH,EXIT

;   PICK        ( ... +n -- ... w )
;               Copy the nth stack item to tos.

                $COLON  4,'PICK',PICK
                DW      ONEP,TWOSL
                DW      SPAT,PLUS,AT,EXIT

;; Memory access

;   +!          ( n a -- )
;               Add n to the contents at address a.

                $COLON  2,'+!',PSTOR
                DW      SWAP,OVER,AT,PLUS
                DW      SWAP,STORE,EXIT

;   2!          ( d a -- )
;               Store the double integer to address a.

                $COLON  2,'2!',DSTOR
                DW      SWAP,OVER,STORE
                DW      TWOP,STORE,EXIT
```

```
;   2@          ( a -- d )
;               Fetch double integer from address a.

                $COLON  2,'2@',DAT
                DW      DUPP,TWOP,AT
                DW      SWAP,AT,EXIT

;   COUNT       ( b -- b +n )
;               Return count byte of a string and add 1 to byte address.

                $COLON  5,'COUNT',COUNT
                DW      DUPP,ONEP
                DW      SWAP,CAT,EXIT

;   HERE        ( -- a )
;               Return the top of the code dictionary.

                $COLON  4,'HERE',HERE
                DW      CP,AT,EXIT

;   PAD         ( -- a )
;               Return the address of a temporary buffer.

                $COLON  3,'PAD',PAD
                DW      DOLIT,PADD,EXIT

;   TIB         ( -- a )
;               Return the address of the terminal input buffer.

                $COLON  3,'TIB',TIB
                DW      NTIB,TWOP,AT,EXIT

;   @EXECUTE    ( a -- )
;               Execute vector stored in address a.

                $COLON  8,'@EXECUTE',ATEXE
                DW      AT,QDUP                 ;?address or zero
                DW      QBRAN,EXE1
                DW      EXECU                   ;execute if non-zero
EXE1:           DW      EXIT                    ;do nothing if zero

;   CMOVE       ( b1 b2 u -- )
;               Copy u bytes from b1 to b2.

                $COLON  5,'CMOVE',CMOVE
                DW      TOR
                DW      BRAN,CMOV2
CMOV1:          DW      TOR,DUPP,CAT
                DW      RAT,CSTOR
                DW      ONEP
                DW      RFROM,ONEP
CMOV2:          DW      DONXT,CMOV1
                DW      DDROP,EXIT

;   FILL        ( b u c -- )
;               Fill u bytes of character c to area beginning at b.
```

```
                $COLON  4,'FILL',FILL
                DW      SWAP,TOR,SWAP
                DW      BRAN,FILL2
FILL1:          DW      DDUP,CSTOR,ONEP
FILL2:          DW      DONXT,FILL1
                DW      DDROP,EXIT

;   -TRAILING   ( b u -- b u )
;               Adjust the count to eliminate trailing white space.

                $COLON  9,'-TRAILING',DTRAI
                DW      TOR
                DW      BRAN,DTRA2
DTRA1:          DW      BLANK,OVER,RAT,PLUS,CAT,LESS
                DW      QBRAN,DTRA2
                DW      RFROM,ONEP,EXIT           ;adjusted count
DTRA2:          DW      DONXT,DTRA1
                DW      DOLIT,0,EXIT            ;count=0

;   PACK$       ( b u a -- a )
;               Build a counted string with u characters from b. Null fill.

                $COLON  5,'PACK$',PACKS
                DW      DUPP,TOR          ;strings only on cell boundary
                DW      OVER,DUPP,DOLIT,0
                DW      DOLIT,CELLL,UMMOD,DROP  ;count mod cell
                DW      SUBB,OVER,PLUS
                DW      DOLIT,0,SWAP,STORE      ;null fill cell
                DW      DDUP,CSTOR,ONEP           ;save count
                DW      SWAP,CMOVE,RFROM,EXIT   ;move string

;; Numeric output, single precision

;   DIGIT       ( u -- c )
;               Convert digit u to a character.

                $COLON  5,'DIGIT',DIGIT
                DW      DOLIT,9,OVER,LESS
                DW      DOLIT,7,ANDD,PLUS
                DW      DOLIT,'0',PLUS,EXIT

;   EXTRACT     ( n base -- n c )
;               Extract the least significant digit from n.

                $COLON  7,'EXTRACT',EXTRC
                DW      DOLIT,0,SWAP,UMMOD
                DW      SWAP,DIGIT,EXIT

;   <#          ( -- )
;               Initiate the numeric output process.

                $COLON  2,'<#',BDIGS
                DW      PAD,HLD,STORE,EXIT

;   HOLD        ( c -- )
;               Insert a character into the numeric output string.

                $COLON  4,'HOLD',HOLD
                DW      HLD,AT,ONEM
                DW      DUPP,HLD,STORE,CSTOR,EXIT

;   #           ( u -- u )
;               Extract one digit from u and append the digit to output string.

                $COLON  1,'#',DIG
                DW      BASE,AT,EXTRC,HOLD,EXIT

;   #S          ( u -- 0 )
;               Convert u until all digits are added to the output string.

                $COLON  2,'#S',DIGS
DIGS1:          DW      DIG,DUPP
                DW      QBRAN,DIGS2
                DW      BRAN,DIGS1
DIGS2:          DW      EXIT

;   SIGN        ( n -- )
;               Add a minus sign to the numeric output string.

                $COLON  4,'SIGN',SIGN
                DW      ZLESS
                DW      QBRAN,SIGN1
                DW      DOLIT,'-',HOLD
SIGN1:          DW      EXIT

;   #>          ( w -- b u )
;               Prepare the output string to be TYPE'd.

                $COLON  2,'#>',EDIGS
                DW      DROP,HLD,AT
                DW      PAD,OVER,SUBB,EXIT

;   str         ( n -- b u )
;               Convert a signed integer to a numeric string.

                $COLON  3,'str',STR
                DW      DUPP,TOR,ABSS
                DW      BDIGS,DIGS,RFROM
                DW      SIGN,EDIGS,EXIT

;   HEX         ( -- )
;               Use radix 16 as base for numeric conversions.

                $COLON  3,'HEX',HEX
                DW      DOLIT,16,BASE,STORE,EXIT

;   DECIMAL     ( -- )
;               Use radix 10 as base for numeric conversions.

                $COLON  7,'DECIMAL',DECIM
                DW      DOLIT,10,BASE,STORE,EXIT

;; Numeric input, single precision

;   DIGIT?      ( c base -- u t )
;               Convert a character to its numeric value. A flag indicates
success.

                $COLON  6,'DIGIT?',DIGTQ
                DW      TOR,DOLIT,'0',SUBB
                DW      DOLIT,9,OVER,LESS
                DW      QBRAN,DGTQ1
                DW      DOLIT,7,SUBB
                DW      DUPP,DOLIT,10,LESS,ORR
DGTQ1:          DW      DUPP,RFROM,ULESS,EXIT

;   NUMBER?     ( a -- n T | a F )
;               Convert a number string to integer. Push a flag on tos.

                $COLON  7,'NUMBER?',NUMBQ
                DW      BASE,AT,TOR,DOLIT,0,OVER,COUNT
                DW      OVER,CAT,DOLIT,'$',EQUAL
                DW      QBRAN,NUMQ1
                DW      HEX,SWAP,ONEP
                DW      SWAP,ONEM
NUMQ1:          DW      OVER,CAT,DOLIT,'-',EQUAL,TOR
                DW      SWAP,RAT,SUBB,SWAP,RAT,PLUS,QDUP
                DW      QBRAN,NUMQ6
                DW      ONEM,TOR
NUMQ2:          DW      DUPP,TOR,CAT,BASE,AT,DIGTQ
                DW      QBRAN,NUMQ4
                DW      SWAP,BASE,AT,STAR,PLUS,RFROM
                DW      ONEP
                DW      DONXT,NUMQ2
                DW      RAT,SWAP,DROP
                DW      QBRAN,NUMQ3
                DW      NEGAT
NUMQ3:          DW      SWAP
                DW      BRAN,NUMQ5
NUMQ4:          DW      RFROM,RFROM,DDROP,DDROP,DOLIT,0
NUMQ5:          DW      DUPP
NUMQ6:          DW      RFROM,DDROP
                DW      RFROM,BASE,STORE,EXIT

;; Basic I/O

;   ?KEY        ( -- c T | F )
;               Return input character and true, or a false if no input.

                $COLON  4,'?KEY',QKEY
                DW      TQKEY,ATEXE,EXIT

;   KEY         ( -- c )
;               Wait for and return an input character.

                $COLON  3,'KEY',KEY
KEY1:           DW      QKEY
                DW      QBRAN,KEY1
                DW      EXIT

;   EMIT        ( c -- )
;               Send a character to the output device.
```

```
                $COLON  4,'EMIT',EMIT
                DW      TEMIT,ATEXE,EXIT

;   NUF?        ( -- t )
;               Return false if no input, else pause and if CR return true.

                $COLON  4,'NUF?',NUFQ
                DW      QKEY,DUPP
                DW      QBRAN,NUFQ1
                DW      DDROP,KEY,DOLIT,CRR,EQUAL
NUFQ1:          DW      EXIT

;   PACE        ( -- )
;               Send a pace character for the file downloading process.

                $COLON  4,'PACE',PACE
                DW      DOLIT,11,EMIT,EXIT

;   SPACE       ( -- )
;               Send the blank character to the output device.

                $COLON  5,'SPACE',SPACE
                DW      BLANK,EMIT,EXIT

;   SPACES      ( +n -- )
;               Send n spaces to the output device.

                $COLON  6,'SPACES',SPACS
                DW      DOLIT,0,MAX,TOR
                DW      BRAN,CHAR2
CHAR1:          DW      SPACE
CHAR2:          DW      DONXT,CHAR1
                DW      EXIT

;   TYPE        ( b u -- )
;               Output u characters from b.

                $COLON  4,'TYPE',TYPEE
                DW      TOR
                DW      BRAN,TYPE2
TYPE1:          DW      DUPP,CAT,EMIT
                DW      ONEP
TYPE2:          DW      DONXT,TYPE1
                DW      DROP,EXIT

;   CR          ( -- )
;               Output a carriage return and a line feed.

                $COLON  2,'CR',CR
                DW      DOLIT,CRR,EMIT
                DW      DOLIT,LF,EMIT,EXIT

;   do$         ( -- a )
;               Return the address of a compiled string.

                $COLON  COMPO+3,'do$',DOSTR
                DW      RFROM,RAT,RFROM,COUNT,PLUS
                DW      TOR,SWAP,TOR,EXIT
```

```
;   $"|         ( -- a )
;               Run time routine compiled by $". Return address of a compiled
string.

                $COLON  COMPO+3,'$"|',STRQP
                DW      DOSTR,EXIT              ;force a call to do$

;   ."|         ( -- )
;               Run time routine of ." . Output a compiled string.

                $COLON  COMPO+3,'."|',DOTQP
                DW      DOSTR,COUNT,TYPEE,EXIT

;   .R          ( n +n -- )
;               Display an integer in a field of n columns, right justified.

                $COLON  2,'.R',DOTR
                DW      TOR,STR,RFROM,OVER,SUBB
                DW      SPACS,TYPEE,EXIT

;   U.R         ( u +n -- )
;               Display an unsigned integer in n column, right justified.

                $COLON  3,'U.R',UDOTR
                DW      TOR,BDIGS,DIGS,EDIGS
                DW      RFROM,OVER,SUBB
                DW      SPACS,TYPEE,EXIT

;   U.          ( u -- )
;               Display an unsigned integer in free format.

                $COLON  2,'U.',UDOT
                DW      BDIGS,DIGS,EDIGS
                DW      SPACE,TYPEE,EXIT

;   .           ( w -- )
;               Display an integer in free format, preceeded by a space.

                $COLON  1,'.',DOT
                DW      BASE,AT,DOLIT,10,XORR   ;?decimal
                DW      QBRAN,DOT1
                DW      UDOT,EXIT               ;no, display unsigned
DOT1:           DW      STR,SPACE,TYPEE,EXIT    ;yes, display signed

;   ?           ( a -- )
;               Display the contents in a memory cell.

                $COLON  1,'?',QUEST
                DW      AT,DOT,EXIT

;; Parsing

;   parse       ( b u c -- b u delta ; <string> )
;               Scan string delimited by c. Return found string and its offset.

                $COLON  5,'parse',PARS
                DW      TEMP,STORE,OVER,TOR,DUPP
                DW      QBRAN,PARS8
                DW      ONEM,TEMP,AT,BLANK,EQUAL
                DW      QBRAN,PARS3
                DW      TOR
PARS1:          DW      BLANK,OVER,CAT          ;skip leading blanks ONLY
                DW      SUBB,ZLESS,INVER
                DW      QBRAN,PARS2
                DW      ONEP
                DW      DONXT,PARS1
                DW      RFROM,DROP,DOLIT,0,DUPP,EXIT
PARS2:          DW      RFROM
PARS3:          DW      OVER,SWAP
                DW      TOR
PARS4:          DW      TEMP,AT,OVER,CAT,SUBB   ;scan for delimiter
                DW      TEMP,AT,BLANK,EQUAL
                DW      QBRAN,PARS5
                DW      ZLESS
PARS5:          DW      QBRAN,PARS6
                DW      ONEP
                DW      DONXT,PARS4
                DW      DUPP,TOR
                DW      BRAN,PARS7
PARS6:          DW      RFROM,DROP,DUPP
                DW      ONEP,TOR
PARS7:          DW      OVER,SUBB
                DW      RFROM,RFROM,SUBB,EXIT
PARS8:          DW      OVER,RFROM,SUBB,EXIT

;   PARSE       ( c -- b u ; <string> )
;               Scan input stream and return counted string delimited by c.

                $COLON  5,'PARSE',PARSE
                DW      TOR,TIB,INN,AT,PLUS     ;current input buffer pointer
                DW      NTIB,AT,INN,AT,SUBB     ;remaining count
                DW      RFROM,PARS,INN,PSTOR,EXIT

;   .(          ( -- )
;               Output following string up to next ) .

                $COLON  IMEDD+2,'.(',DOTPR
                DW      DOLIT,')',PARSE,TYPEE,EXIT

;   (           ( -- )
;               Ignore following string up to next ) . A comment.

                $COLON  IMEDD+1,'(',PAREN
                DW      DOLIT,')',PARSE,DDROP,EXIT

;   \           ( -- )
;               Ignore following text till the end of line.

                $COLON  IMEDD+1,'\',BKSLA
                DW      NTIB,AT,INN,STORE,EXIT

;   CHAR        ( -- c )
;               Parse next word and return its first character.

                $COLON  4,'CHAR',CHAR
                DW      BLANK,PARSE,DROP,CAT,EXIT

;   TOKEN       ( -- a ; <string> )
;               Parse a word from input stream and copy it to name dictionary.

                $COLON  5,'TOKEN',TOKEN
                DW      BLANK,PARSE,DOLIT,31,MIN
                DW      NP,AT,OVER,SUBB,TWOM
                DW      PACKS,EXIT

;   WORD        ( c -- a ; <string> )
;               Parse a word from input stream and copy it to code dictionary.

                $COLON  4,'WORD',WORDD
                DW      PARSE,HERE,PACKS,EXIT

;; Dictionary search

;   NAME>       ( na -- ca )
;               Return a code address given a name address.

                $COLON  5,'NAME>',NAMET
                DW      TWOM,TWOM,AT,EXIT

;   SAME?       ( a a u -- a a f \ -0+ )
;               Compare u cells in two strings. Return 0 if identical.

                $COLON  5,'SAME?',SAMEQ
                DW      TOR
                DW      BRAN,SAME2
SAME1:          DW      OVER,RAT,TWOSL,PLUS,AT
                DW      OVER,RAT,TWOSL,PLUS,AT
                DW      SUBB,QDUP
                DW      QBRAN,SAME2
                DW      RFROM,DROP,EXIT         ;strings not equal
SAME2:          DW      DONXT,SAME1
                DW      DOLIT,0,EXIT            ;strings equal

;   find        ( a va -- ca na | a F )
;               Search a vocabulary for a string. Return ca and na if succeeded.

                $COLON  4,'find',FIND
                DW      SWAP,DUPP,CAT
                DW      DOLIT,CELLL,SLASH,TEMP,STORE
                DW      DUPP,AT,TOR,TWOP,SWAP
FIND1:          DW      AT,DUPP
                DW      QBRAN,FIND6
                DW      DUPP,AT,DOLIT,MASKK,ANDD,RAT,XORR
                DW      QBRAN,FIND2
                DW      TWOP,DOLIT,-1          ;true flag
                DW      BRAN,FIND3
FIND2:          DW      TWOP,TEMP,AT,SAMEQ
FIND3:          DW      BRAN,FIND4
FIND6:          DW      RFROM,DROP
                DW      SWAP,TWOM,SWAP,EXIT
FIND4:          DW      QBRAN,FIND5
                DW      TWOM,TWOM
                DW      BRAN,FIND1
```

```
FIND5:          DW      RFROM,DROP,SWAP,DROP
                DW      TWOM
                DW      DUPP,NAMET,SWAP,EXIT

;   NAME?       ( a -- ca na | a F )
;               Search all context vocabularies for a string.

                $COLON  5,'NAME?',NAMEQ
                DW      CNTXT,DUPP,DAT,XORR     ;?context=also
                DW      QBRAN,NAMQ1
                DW      TWOM                   ;no, start with context
NAMQ1:          DW      TOR
NAMQ2:          DW      RFROM,TWOP,DUPP,TOR    ;next in search order
                DW      AT,QDUP
                DW      QBRAN,NAMQ3
                DW      FIND,QDUP               ;search vocabulary
                DW      QBRAN,NAMQ2
                DW      RFROM,DROP,EXIT         ;found name
NAMQ3:          DW      RFROM,DROP              ;name not found
                DW      DOLIT,0,EXIT            ;false flag

;; Terminal response

;   ^H          ( bot eot cur -- bot eot cur )
;               Backup the cursor by one character.

                $COLON  2,'^H',BKSP
                DW      TOR,OVER,RFROM,SWAP,OVER,XORR
                DW      QBRAN,BACK1
                DW      DOLIT,BKSPP,TECHO,ATEXE,ONEM
                DW      BLANK,TECHO,ATEXE
                DW      DOLIT,BKSPP,TECHO,ATEXE
BACK1:          DW      EXIT

;   TAP         ( bot eot cur c -- bot eot cur )
;               Accept and echo the key stroke and bump the cursor.

                $COLON  3,'TAP',TAP
                DW      DUPP,TECHO,ATEXE
                DW      OVER,CSTOR,ONEP,EXIT

;   kTAP        ( bot eot cur c -- bot eot cur )
;               Process a key stroke, CR or backspace.

                $COLON  4,'kTAP',KTAP
                DW      DUPP,DOLIT,CRR,XORR
                DW      QBRAN,KTAP2
                DW      DOLIT,BKSPP,XORR
                DW      QBRAN,KTAP1
                DW      BLANK,TAP,EXIT
KTAP1:          DW      BKSP,EXIT
KTAP2:          DW      DROP,SWAP,DROP,DUPP,EXIT

;   accept      ( b u -- b u )
;               Accept characters to input buffer. Return with actual count.

                $COLON  6,'accept',ACCEP
                DW      OVER,PLUS,OVER
```

```
ACCP1:          DW      DDUP,XORR
                DW      QBRAN,ACCP4
                DW      KEY,DUPP
;               DW      BLANK,SUBB,DOLIT,95,ULESS
                DW      BLANK,DOLIT,127,WITHI
                DW      QBRAN,ACCP2
                DW      TAP
                DW      BRAN,ACCP3
ACCP2:          DW      TTAP,ATEXE
ACCP3:          DW      BRAN,ACCP1
ACCP4:          DW      DROP,OVER,SUBB,EXIT

;   EXPECT      ( b u -- )
;               Accept input stream and store count in SPAN.

                $COLON  6,'EXPECT',EXPEC
                DW      TEXPE,ATEXE,SPAN,STORE,DROP,EXIT

;   QUERY       ( -- )
;               Accept input stream to terminal input buffer.

                $COLON  5,'QUERY',QUERY
                DW      TIB,DOLIT,80,TEXPE,ATEXE,NTIB,STORE
                DW      DROP,DOLIT,0,INN,STORE,EXIT

;; Error handling

;   CATCH       ( ca -- 0 | err# )
;               Execute word at ca and set up an error frame for it.

                $COLON  5,'CATCH',CATCH
                DW      SPAT,TOR,HANDL,AT,TOR   ;save error frame
                DW      RPAT,HANDL,STORE,EXECU  ;execute
                DW      RFROM,HANDL,STORE       ;restore error frame
                DW      RFROM,DROP,DOLIT,0,EXIT ;no error

;   THROW       ( err# -- err# )
;               Reset system to current local error frame an update error flag.

                $COLON  5,'THROW',THROW
                DW      HANDL,AT,RPSTO          ;restore return stack
                DW      RFROM,HANDL,STORE       ;restore handler frame
                DW      RFROM,SWAP,TOR,SPSTO    ;restore data stack
                DW      DROP,RFROM,EXIT

;   NULL$       ( -- a )
;               Return address of a null string with zero count.

                $COLON  5,'NULL$',NULLS
                DW      DOVAR                   ;emulate CREATE
                DW      0
                DB      99,111,121,111,116,101

;   ABORT       ( -- )
;               Reset data stack and jump to QUIT.

                $COLON  5,'ABORT',ABORT
                DW      NULLS,THROW
```

```
;   abort"      ( f -- )
;               Run time routine of ABORT" . Abort with a message.

                $COLON  COMPO+6,'abort"',ABORQ
                DW      QBRAN,ABOR1             ;text flag
                DW      DOSTR,THROW             ;pass error string
ABOR1:          DW      DOSTR,DROP,EXIT         ;drop error

;; The text interpreter

;   $INTERPRET  ( a -- )
;               Interpret a word. If failed, try to convert it to an integer.

                $COLON  10,'$INTERPRET',INTER
                DW      NAMEQ,QDUP              ;?defined
                DW      QBRAN,INTE1
                DW      AT,DOLIT,COMPO,ANDD     ;?compile only lexicon bits
                D$      ABORQ,' compile only'
                DW      EXECU,EXIT              ;execute defined word
INTE1:          DW      TNUMB,ATEXE             ;convert a number
                DW      QBRAN,INTE2
                DW      EXIT
INTE2:          DW      THROW                   ;error

;   [           ( -- )
;               Start the text interpreter.

                $COLON  IMEDD+1,'[',LBRAC
                DW      DOLIT,INTER,TEVAL,STORE,EXIT

;   .OK         ( -- )
;               Display 'ok' only while interpreting.

                $COLON  3,'.OK',DOTOK
                DW      DOLIT,INTER,TEVAL,AT,EQUAL
                DW      QBRAN,DOTO1
                D$      DOTQP,' ok'
DOTO1:          DW      CR,EXIT

;   ?STACK      ( -- )
;               Abort if the data stack underflows.

                $COLON  6,'?STACK',QSTAC
                DW      DEPTH,ZLESS             ;check only for underflow
                D$      ABORQ,' underflow'
                DW      EXIT

;   EVAL        ( -- )
;               Interpret the input stream.

                $COLON  4,'EVAL',EVAL
EVAL1:          DW      TOKEN,DUPP,CAT          ;?input stream empty
                DW      QBRAN,EVAL2
                DW      TEVAL,ATEXE,QSTAC       ;evaluate input, check stack
                DW      BRAN,EVAL1
EVAL2:          DW      DROP,TPROM,ATEXE,EXIT   ;prompt
```

```
;; Shell

;   PRESET      ( -- )
;               Reset data stack pointer and the terminal input buffer.

                $COLON  6,'PRESET',PRESE
                DW      SZERO,AT,SPSTO
                DW      DOLIT,TIBB,NTIB,TWOP,STORE,EXIT

;   xio         ( a a a -- )
;               Reset the I/O vectors 'EXPECT, 'TAP, 'ECHO and 'PROMPT.

                $COLON  COMPO+3,'xio',XIO
                DW      DOLIT,ACCEP,TEXPE,DSTOR
                DW      TECHO,DSTOR,EXIT

;   FILE        ( -- )
;               Select I/O vectors for file download.

                $COLON  4,'FILE',FILE
                DW      DOLIT,PACE,DOLIT,DROP
                DW      DOLIT,KTAP,XIO,EXIT

;   HAND        ( -- )
;               Select I/O vectors for terminal interface.

                $COLON  4,'HAND',HAND
                DW      DOLIT,DOTOK,DOLIT,EMIT
                DW      DOLIT,KTAP,XIO,EXIT

;   I/O         ( -- a )
;               Array to store default I/O vectors.

                $COLON  3,'I/O',ISLO
                DW      DOVAR                   ;emulate CREATE
                DW      QRX,TXSTO               ;default I/O vectors

;   CONSOLE     ( -- )
;               Initiate terminal interface.

                $COLON  7,'CONSOLE',CONSO
                DW      ISLO,DAT,TQKEY,DSTOR    ;restore default I/O device
                DW      HAND,EXIT               ;keyboard input

;   QUIT        ( -- )
;               Reset return stack pointer and start text interpreter.

                $COLON  4,'QUIT',QUIT
                DW      RZERO,AT,RPSTO          ;reset return stack pointer
QUIT1:          DW      LBRAC                   ;start interpretation
QUIT2:          DW      QUERY                   ;get input
                DW      DOLIT,EVAL,CATCH,QDUP   ;evaluate input
                DW      QBRAN,QUIT2             ;continue till error
                DW      TPROM,AT,SWAP           ;save input device
                DW      CONSO,NULLS,OVER,XORR   ;?display error message
                DW      QBRAN,QUIT3
                DW      SPACE,COUNT,TYPEE       ;error message
                D$      DOTQP,' ? '             ;error prompt
```

```
QUIT3:          DW      DOLIT,DOTOK,XORR        ;?file input
                DW      QBRAN,QUIT4
                DW      DOLIT,ERR,EMIT          ;file error, tell host
QUIT4:          DW      PRESE                   ;some cleanup
                DW      BRAN,QUIT1

;; The compiler

;   '           ( -- ca )
;               Search context vocabularies for the next word in input stream.

                $COLON  1,"'",TICK
                DW      TOKEN,NAMEQ             ;?defined
                DW      QBRAN,TICK1
                DW      EXIT                    ;yes, push code address
TICK1:          DW      THROW                   ;no, error

;   ALLOT       ( n -- )
;               Allocate n bytes to the code dictionary.

                $COLON  5,'ALLOT',ALLOT
                DW      CP,PSTOR,EXIT           ;adjust code pointer

;   ,           ( w -- )
;               Compile an integer into the code dictionary.

                $COLON  1,',',COMMA
                DW      HERE,DUPP,TWOP         ;cell boundary
                DW      CP,STORE,STORE,EXIT     ;adjust code pointer, compile

;   C,          ( b -- )
;               Compile a byte into the code dictionary

                $COLON  2,'C,',CCOMMA
                DW      HERE,DUPP,ONEP
                DW      CP,STORE,CSTOR,EXIT

;   [COMPILE]   ( -- ; <string> )
;               Compile the next immediate word into code dictionary.

                $COLON  IMEDD+9,'[COMPILE]',BCOMP
                DW      TICK,COMMA,EXIT

;   COMPILE     ( -- )
;               Compile the next address in colon list to code dictionary.

                $COLON  COMPO+7,'COMPILE',COMPI
                DW      RFROM,DUPP,AT,COMMA     ;compile address
                DW      TWOP,TOR,EXIT          ;adjust return address

;   LITERAL     ( w -- )
;               Compile tos to code dictionary as an integer literal.

                $COLON  IMEDD+7,'LITERAL',LITER
                DW      COMPI,DOLIT,COMMA,EXIT

;   $,"         ( -- )
;               Compile a literal string up to next " .
```

```
                $COLON  3,'$,"',STRCQ
                DW      DOLIT,'"',WORDD         ;move string to code dictionary
                DW      COUNT,PLUS        ;calculate aligned end of string
                DW      CP,STORE,EXIT           ;adjust the code pointer

;   RECURSE     ( -- )
;               Make the current word available for compilation.

                $COLON  IMEDD+7,'RECURSE',RECUR
                DW      LAST,AT,NAMET,COMMA,EXIT

;; Structures

;   FOR         ( -- a )
;               Start a FOR-NEXT loop structure in a colon definition.

                $COLON  IMEDD+3,'FOR',FOR
                DW      COMPI,TOR,HERE,EXIT

;   BEGIN       ( -- a )
;               Start an infinite or indefinite loop structure.

                $COLON  IMEDD+5,'BEGIN',BEGIN
                DW      HERE,EXIT

;   NEXT        ( a -- )
;               Terminate a FOR-NEXT loop structure.

                $COLON  IMEDD+4,'NEXT',NEXT
                DW      COMPI,DONXT,COMMA,EXIT

;   UNTIL       ( a -- )
;               Terminate a BEGIN-UNTIL indefinite loop structure.

                $COLON  IMEDD+5,'UNTIL',UNTIL
                DW      COMPI,QBRAN,COMMA,EXIT

;   AGAIN       ( a -- )
;               Terminate a BEGIN-AGAIN infinite loop structure.

                $COLON  IMEDD+5,'AGAIN',AGAIN
                DW      COMPI,BRAN,COMMA,EXIT

;   IF          ( -- A )
;               Begin a conditional branch structure.

                $COLON  IMEDD+2,'IF',IFF
                DW      COMPI,QBRAN,HERE
                DW      DOLIT,0,COMMA,EXIT

;   AHEAD       ( -- A )
;               Compile a forward branch instruction.

                $COLON  IMEDD+5,'AHEAD',AHEAD
                DW      COMPI,BRAN,HERE,DOLIT,0,COMMA,EXIT

;   REPEAT      ( A a -- )
;               Terminate a BEGIN-WHILE-REPEAT indefinite loop.

                $COLON  IMEDD+6,'REPEAT',REPEA
                DW      AGAIN,HERE,SWAP,STORE,EXIT

;   THEN        ( A -- )
;               Terminate a conditional branch structure.

                $COLON  IMEDD+4,'THEN',THENN
                DW      HERE,SWAP,STORE,EXIT

;   AFT         ( a -- a A )
;               Jump to THEN in a FOR-AFT-THEN-NEXT loop the first time through.

                $COLON  IMEDD+3,'AFT',AFT
                DW      DROP,AHEAD,BEGIN,SWAP,EXIT

;   ELSE        ( A -- A )
;               Start the false clause in an IF-ELSE-THEN structure.

                $COLON  IMEDD+4,'ELSE',ELSEE
                DW      AHEAD,SWAP,THENN,EXIT

;   WHILE       ( a -- A a )
;               Conditional branch out of a BEGIN-WHILE-REPEAT loop.

                $COLON  IMEDD+5,'WHILE',WHILE
                DW      IFF,SWAP,EXIT

;   ABORT"      ( -- ; <string> )
;               Conditional abort with an error message.

                $COLON  IMEDD+6,'ABORT"',ABRTQ
                DW      COMPI,ABORQ,STRCQ,EXIT

;   $"          ( -- ; <string> )
;               Compile an inline string literal.

                $COLON  IMEDD+2,'$"',STRQ
                DW      COMPI,STRQP,STRCQ,EXIT

;   ."          ( -- ; <string> )
;               Compile an inline string literal to be typed out at run time.

                $COLON  IMEDD+2,'."',DOTQ
                DW      COMPI,DOTQP,STRCQ,EXIT

;; Name compiler

;   ?UNIQUE     ( a -- a )
;               Display a warning message if the word already exists.

                $COLON  7,'?UNIQUE',UNIQU
                DW      DUPP,NAMEQ              ;?name exists
                DW      QBRAN,UNIQ1             ;redefinitions are OK
                D$      DOTQP,' reDef '         ;but warn the user
                DW      OVER,COUNT,TYPEE        ;just in case its not planned
UNIQ1:          DW      DROP,EXIT
```

```
;   $,n         ( na -- )
;               Build a new dictionary name using the string at na.

                $COLON  3,'$,n',SNAME
                DW      DUPP,CAT                ;?null input
                DW      QBRAN,PNAM1
                DW      UNIQU                   ;?redefinition
                DW      DUPP,LAST,STORE         ;save na for vocabulary link
                DW      HERE,SWAP               ;align code address
                DW      TWOM                   ;link address
                DW      CRRNT,AT,AT,OVER,STORE
                DW      TWOM,DUPP,NP,STORE     ;adjust name pointer
                DW      STORE,EXIT              ;save code pointer
PNAM1:          D$      STRQP,' name'           ;null input
                DW      THROW

;; FORTH compiler

;   $COMPILE    ( a -- )
;               Compile next word to code dictionary as a token or literal.

                $COLON  8,'$COMPILE',SCOMP
                DW      NAMEQ,QDUP              ;?defined
                DW      QBRAN,SCOM2
                DW      AT,DOLIT,IMEDD,ANDD     ;?immediate
                DW      QBRAN,SCOM1
                DW      EXECU,EXIT              ;its immediate, execute
SCOM1:          DW      COMMA,EXIT              ;its not immediate, compile
SCOM2:          DW      TNUMB,ATEXE             ;try to convert to number
                DW      QBRAN,SCOM3
                DW      LITER,EXIT              ;compile number as integer
SCOM3:          DW      THROW                   ;error

;   CCOMPILE    ( a -- )
;               Compile next byte to code dictionary as machine code.

                $COLON  8,'CCOMPILE',CCOMP
                DW      NAMEQ,QDUP              ;?defined
                DW      QBRAN,CCOM2
                DW      AT,DOLIT,IMEDD,ANDD     ;?immediate
                DW      QBRAN,CCOM1
                DW      EXECU,EXIT              ;its immediate, execute
CCOM1:          DW      DROP,EXIT               ;its not immediate,drop
CCOM2:          DW      TNUMB,ATEXE             ;try to convert to number
                DW      QBRAN,CCOM3
                DW      CCOMMA,EXIT             ;compile as code byte
CCOM3:          DW      THROW                   ;error

;   OVERT       ( -- )
;               Link a new word into the current vocabulary.

                $COLON  5,'OVERT',OVERT
                DW      LAST,AT,CRRNT,AT,STORE,EXIT

;   ;           ( -- )
;               Terminate a colon definition.
```

```
                $COLON  IMEDD+COMPO+1,';',SEMIS
                DW      COMPI,EXIT,LBRAC,OVERT,EXIT

;   ]           ( -- )
;               Start compiling the words in the input stream.

                $COLON  1,']',RBRAC
                DW      DOLIT,SCOMP,TEVAL,STORE,EXIT

;   call,       ( ca -- )
;               Assemble a call instruction to doLST.

                $COLON  5,'call,',CALLC
                DW      DOLIT,CALLL,CCOMMA,EXIT  ;Direct Threaded Code

;   :           ( -- ; <string> )
;               Start a new colon definition using next word as its name.

                $COLON  1,':',COLON
                DW      TOKEN,SNAME
                DW      CALLC,RBRAC,EXIT

;   IMMEDIATE   ( -- )
;               Make the last compiled word an immediate word.

                $COLON  9,'IMMEDIATE',IMMED
                DW      DOLIT,IMEDD,LAST,AT,AT,ORR
                DW      LAST,AT,STORE,EXIT

;; Defining words

;   USER        ( u -- ; <string> )
;               Compile a new user variable.

                $COLON  4,'USER',USER
                DW      TOKEN,SNAME,OVERT,CALLC
                DW      COMPI,DOUSE,COMMA,EXIT

;   CREATE      ( -- ; <string> )
;               Compile a new array entry without allocating code space.

                $COLON  6,'CREATE',CREAT
                DW      TOKEN,SNAME,OVERT,CALLC
                DW      COMPI,DOVAR,EXIT

;   VARIABLE    ( -- ; <string> )
;               Compile a new variable initialized to 0.

                $COLON  8,'VARIABLE',VARIA
                DW      CREAT,DOLIT,0,COMMA,EXIT

;   CODE        ( -- )
;               Start a new code definition using next word as its name.

                $COLON  4,'CODE',CODE
                DW      TOKEN,SNAME
                DW      DOLIT,CCOMP,TEVAL,STORE,EXIT
```

```
;   ENDCODE     ( -- )
;               Terminate a code definition

                $COLON  IMEDD+COMPO+7,'ENDCODE',ENDCD
                DW      DOLIT,48H,CCOMMA,DOLIT,84H,CCOMMA       ;$NEXT
                DW      DOLIT,48H,CCOMMA,DOLIT,28H,CCOMMA
                DW      LBRAC,OVERT,EXIT

;; Tools

;   _TYPE       ( b u -- )
;               Display a string. Filter non-printing characters.

                $COLON  5,'_TYPE',UTYPE
                DW      TOR                     ;start count down loop
                DW      BRAN,UTYP2              ;skip first pass
UTYP1:          DW      DUPP,CAT,TCHAR,EMIT     ;display only printable
                DW      ONEP                      ;increment address
UTYP2:          DW      DONXT,UTYP1             ;loop till done
                DW      DROP,EXIT

;   dm+         ( a u -- a )
;               Dump u bytes from , leaving a+u on the stack.

                $COLON  3,'dm+',DMP
                DW      OVER,DOLIT,4,UDOTR      ;display address
                DW      SPACE,TOR               ;start count down loop
                DW      BRAN,PDUM2              ;skip first pass
PDUM1:          DW      DUPP,CAT,DOLIT,3,UDOTR  ;display numeric data
                DW      ONEP                      ;increment address
PDUM2:          DW      DONXT,PDUM1             ;loop till done
                DW      EXIT

;   DUMP        ( a u -- )
;               Dump u bytes from a, in a formatted manner.

                $COLON  4,'DUMP',DUMP
                DW      BASE,AT,TOR,HEX         ;save radix, set hex
                DW      DOLIT,16,SLASH          ;change count to lines
                DW      TOR                     ;start count down loop
DUMP1:          DW      CR,DOLIT,16,DDUP,DMP    ;display numeric
                DW      ROT,ROT
                DW      SPACE,SPACE,UTYPE       ;display printable characters
                DW      NUFQ,INVER              ;user control
                DW      QBRAN,DUMP2
                DW      DONXT,DUMP1             ;loop till done
                DW      BRAN,DUMP3
DUMP2:          DW      RFROM,DROP              ;cleanup loop stack, early exit
DUMP3:          DW      DROP,RFROM,BASE,STORE   ;restore radix
                DW      EXIT

;   .S          ( ... -- ... )
;               Display the contents of the data stack.

                $COLON  2,'.S',DOTS
                DW      CR,DEPTH                ;stack depth
                DW      TOR                     ;start count down loop
                DW      BRAN,DOTS2              ;skip first pass
```

```
DOTS1:          DW      RAT,PICK,DOT            ;index stack, display contents
DOTS2:          DW      DONXT,DOTS1             ;loop till done
                D$      DOTQP,' <sp'
                DW      EXIT

;   !CSP        ( -- )
;               Save stack pointer in CSP for error checking.

                $COLON  4,'!CSP',STCSP
                DW      SPAT,CSP,STORE,EXIT     ;save pointer

;   ?CSP        ( -- )
;               Abort if stack pointer differs from that saved in CSP.

                $COLON  4,'?CSP',QCSP
                DW      SPAT,CSP,AT,XORR        ;compare pointers
                D$      ABORQ,'stacks'          ;abort if different
                DW      EXIT

;   >NAME       ( ca -- na | F )
;               Convert code address to a name address.

                $COLON  5,'>NAME',TNAME
                DW      CRRNT                   ;vocabulary link
TNAM1:          DW      TWOP,AT,QDUP           ;check all vocabularies
                DW      QBRAN,TNAM4
                DW      DDUP
TNAM2:          DW      AT,DUPP                 ;?last word in a vocabulary
                DW      QBRAN,TNAM3
                DW      DDUP,NAMET,XORR         ;compare
                DW      QBRAN,TNAM3
                DW      TWOM                   ;continue with next word
                DW      BRAN,TNAM2
TNAM3:          DW      SWAP,DROP,QDUP
                DW      QBRAN,TNAM1
                DW      SWAP,DROP,SWAP,DROP,EXIT
TNAM4:          DW      DROP,DOLIT,0,EXIT       ;false flag

;   .ID         ( na -- )
;               Display the name at address.

                $COLON  3,'.ID',DOTID
                DW      QDUP                    ;if zero no name
                DW      QBRAN,DOTI1
                DW      COUNT,DOLIT,01FH,ANDD   ;mask lexicon bits
                DW      UTYPE,EXIT              ;display name string
DOTI1:          D$      DOTQP,' {noName}'
                DW      EXIT

;   WORDS       ( -- )
;               Display the names in the context vocabulary.

                $COLON  5,'WORDS',WORDS
                DW      CR,CNTXT,AT             ;only in context
WORS1:          DW      AT,QDUP                 ;?at end of list
                DW      QBRAN,WORS2
                DW      DUPP,SPACE,DOTID        ;display a name
                DW      TWOM,NUFQ              ;user control
                DW      QBRAN,WORS1
                DW      DROP
WORS2:          DW      EXIT

;; Hardware reset

;   VER         ( -- n )
;               Return the version number of this implementation.

                $COLON  3,'VER',VERSN
                DW      DOLIT,VER*256+EXT,EXIT

;   hi          ( -- )
;               Display the sign-on message of eForth.

                $COLON  2,'hi',HI
                DW      STOIO,CR                ;initialize I/O
                D$      DOTQP,'eForth v'
                DW      BASE,AT,HEX
                DW      VERSN,BDIGS,DIG,DIG
                DW      DOLIT,'.',HOLD
                DW      DIGS,EDIGS,TYPEE
                DW      BASE,STORE,CR,EXIT

;   'BOOT       ( -- a )
;               The application startup vector.

                $COLON  5,"'BOOT",TBOOT
                DW      DOVAR
                DW      HI                      ;application to boot

;   SEE         ( --word-- )
;               Decompiles word.
                $COLON  3,'SEE',SEE
                DW      TICK
                DW      CR,ONEP
    SEE1:       DW      DUPP,DUPP,SPACE,DOT,DOLIT,07CH,EMIT,AT,DUPP
                DW      QBRAN,SEE2
                DW      TNAME
    SEE2:       DW      QDUP
                DW      QBRAN,SEE3
                DW      DOTID
                DW      BRAN,SEE4
    SEE3:       DW      DUPP,AT,UDOT
    SEE4:       DW      TWOP,NUFQ
                DW      QBRAN,SEE1
                DW      DROP,EXIT


;   ADCINIT     ( -- )
;               Init routine for starting ADC Interrupts
                $CODE 7,'ADCINIT',ADCIN
                DB 64H,4EH,1            ;MKH AND 1, skip if not zero
                DB 0D1H                 ;JUMP TO $NEXT
                DB 64H,0AH,1FH          ;PC<PC AND 1F
                DB 68H,0FFH             ;V<FF
                DB 69H,0                ;A<0
                DB 63H,0F3H             ;(V/F3)<A
                DB 4DH,0C8H             ;ANM <A
                DB 48H,48H              ;SKIT FAD, reset INTFAD
                DB 00                   ;NOP
                DB 64H,0EH,0FEH         ;ENABLE INTAD
                $NEXT

;  ADCOFF       ( --- )
;               Disable ADC Interrupts.
                $CODE   6,'ADCOFF',ADCOF
                DB 64H,1EH,1            ;;MKH < MKH OR 1
                $NEXT

;   TM       ( n -- )
;               Wait for last transmit, then send midi byte n.
                $CODE 2,'TM',TM
                DB 0A1H                 ;POP BC
                DB 0BH                  ;A<C
                DB 48H,4AH              ;SKIT FST, skip if interrupt
                DB 0FDH                 ;JMP TO SKIT
                DB 4DH,0D8H             ;MOV TXB,A
                $NEXT

;   DELAY        ( n -- )
;               Wait for n loops.
                $CODE 5,'DELAY',DELAY
                DB 0A1H                 ;POP BC
                DB 53H                  ;C<C-1, Skip if borrow
                DB 0FEH                 ;JMP
                DB 52H                  ;B<B-1, Skip if borrow
                DB 0FCH                 ;JMP
                $NEXT

;   LCD         ( n -- )
;               Load control n to LCD display.
                $CODE 3,'LCD',LCD
                DB 0A1H                 ;POP BC
                DB 0BH                  ;A<C
                DB 14H,0,0A0H           ;BC<A000
                DB 39H                  ;(BC)<A
                $NEXT

;  LLI          ( --- )
;               Sets RS=0 for LCD setup commands.
                $CODE 3,'LLI',LLI
                DB 64H,0AH,0EFH         ;Pc<Pc AND EF
                $NEXT

;  LLC          ( --- )
;               Sets RS=1 for LCD character loading
                $CODE 3,'LLC',LLC
                DB 64H,1AH,10H          ;Pc<Pc OR 10
                $NEXT

;  LI           ( n --- )
;               load LCD setup instruction n, exit ready for char loads
                $COLON 2,'LI',LI
                DW      LLI,LCD,LLC,DOLIT,01FFH,DELAY,EXIT
```

```
;   LCDINIT     ( -- )
;               Initialize LCD display.
                $COLON 7,'LCDINIT',LCDIN
                DW      DOLIT,0D7AH,DELAY
                DW      DOLIT,038H,LI
                DW      DOLIT,047EH,DELAY
                DW      DOLIT,038H,LI
                DW      DOLIT,017H,DELAY
                DW      DOLIT,038H,LI
                DW      DOLIT,017H,DELAY
                DW      DOLIT,038H,LI
                DW      DOLIT,017H,DELAY
                DW      DOLIT,08H,LI
                DW      DOLIT,017H,DELAY
                DW      DOLIT,01H,LI
                DW      DOLIT,01CCH,DELAY
                DW      DOLIT,02H,LI
                DW      DOLIT,01CCH,DELAY
                DW      DOLIT,06H,LI
                DW      DOLIT,17H,DELAY
                DW      DOLIT,0EH,LI
                DW      DOLIT,17H,DELAY
                DW      EXIT

;  #DISP        ( n,p --- )
;               Display n as a 3-digit number at LCD position p.
                $COLON  5,'#DISP',NDISP
                DW      DUPP,LI,SWAP
                DW      BDIGS,DIG,DIG,DIG,EDIGS
                DW      DROP,DUPP,CAT,LCD,ONEP
                DW      DUPP,CAT,LCD,ONEP,CAT,LCD,LI,EXIT

;  #2DISP        ( n,p --- )
;               Display n as a 3-digit number at LCD position p.
                $COLON  6,'#2DISP',N2DISP
                DW      DUPP,LI,SWAP
                DW      BDIGS,DIG,DIG,EDIGS
                DW      DROP,DUPP,CAT,LCD,ONEP
                DW      CAT,LCD,LI,EXIT



;  DISP         ( a,p --- )
;               Display packed string at a to LCD position p.
                $COLON  4,'DISP',DISP
                DW      LI,DUPP,CAT,ONEM,TOR
   DISP1:       DW      ONEP
                DW      DUPP,CAT,LCD
                DW      DONXT,DISP1
                DW      DROP,EXIT

;  CASE         ( n --- )
;               Execute one of a list of words pointed to by n.
                $COLON  4,'CASE',CASE
                DW      RFROM,SWAP,TWOSL,PLUS
                DW      ATEXE,EXIT
```

```
;  INCR         ( n,nmax --- n+1 )
;               Increment n mod nmax.
                $COLON  4,'INCR',INCR
                DW      OVER,ONEP,LESS
                DW      QBRAN,INCR1
                DW      DROP,DOLIT,0
                DW      BRAN,INCR2
   INCR1:       DW      ONEP
   INCR2:       DW      EXIT

;  DECR         ( n,nmax --- n-1 )
;               Decrement n mod nmax.
                $COLON  4,'DECR',DECR
                DW      OVER,ONEM,ZLESS
                DW      QBRAN,DECR1
                DW      SWAP,DROP
                DW      BRAN,DECR2
   DECR1:       DW      DROP
                DW      ONEM
   DECR2:       DW      EXIT

;  SW@          ( --- n )
;               Read Roland switches as a byte.
                $CODE   3,'SW@',SWAT
                DB      4CH,0C0H        ;;A<PA
                DB      6AH,0           ;;B<0
                DB      1BH             ;;C<A
                DB      0B1H            ;;PUSH BC
                $NEXT

;  S@           ( --- n )
;               Return number of the lowest Roland switch on.
                $CODE   2,'S@',SAT
                DB      4CH,0C0H        ;;A<PA
                DB      6BH,0           ;;C<0
                DB      74H,11H,0FFH    ;;A<A EXOR FF
                DB      74H,49H,0FFH    ;;A AND FF, SKIP IF NO ZERO
                DB      0C4H            ;; JMP OUT
                DB      43H             ;; C<C+1, LOOP1
                DB      48H,1           ;; A SHIFT RIGHT, SKIP IF CARRY
                DB      0FCH            ;; JMP LOOP1
                DB      6AH,0           ;;B<0, OUT
                DB      0B1H            ;;PUSH BC
                $NEXT

;  LED!         ( n --- )
;               Turn on/off Roland LED's.
                $CODE   4,'LED!',LEDB
                DB      0A1H            ;;POP BC
                DB      0BH             ;;A<C
                DB      74H,9H,0FCH     ;;A<A AND FC
                DB      74H,19H,1       ;;A<A OR 1
                DB      4DH,0C1H        ;;PB<A
                $NEXT

;  eUPDAT       ( --- )
;               Move data from Slider Ram to Edit Buffer.
                $CODE   6,'eUPDAT',EUPDAT
                DB      68H,0FFH        ;;V<FF
                DB      6AH,2           ;;B<2
                DB      1,0             ;;A<(V/00) Read eSLD#
                DB      1BH             ;;C<A
                DB      29H             ;;A<(BC) Read Translation Table
                DB      6AH,0C6H        ;;B<C6

                DB      1BH             ;;C<A
                DB      29H             ;;A<(BC)
                DB      48H,21H         ;;A SHIFT RIGHT
                DB      63H,4           ;;(V/04)<A, eBYTE3

                DB      69H,80H         ;;A<80
                DB      60H,43H         ;;C<C+A
                DB      29H             ;;A<(BC)
                DB      63H,3H          ;;(V/03)<A, eBYTE2

                DB      69H,40H         ;;A<40
                DB      60H,43H         ;;C<C+A
                DB      29H             ;;A<(BC)
                DB      63H,2H          ;;(V/02)<A, eBYTE1
                $NEXT

;  eLOAD        ( --- )
;               Load Edit Buffer data into Slider Memory.
                $CODE   5,'eLOAD',ELOAD
                DB      68H,0FFH        ;;V<FF
                DB      6AH,2           ;;B<2
                DB      1,0             ;;A<(V/00) Read eSLD#
                DB      1BH             ;;C<A
                DB      29H             ;;A<(BC) Read Translation Table
                DB      6AH,0C6H        ;;B<C6
                DB      1BH             ;;C<A

                DB      69H,40H         ;;A<40
                DB      60H,43H         ;;C<C+A
                DB      49H,0           ;;(BC)<0, LAST

                DB      69H,40H         ;;A<40
                DB      60H,43H         ;;C<C+A
                DB      1,3             ;;A<(V/03)
                DB      39H             ;;(BC)<A, eBYTE2

                DB      69H,40H         ;;A<40
                DB      60H,43H         ;;C<C+A
                DB      1,2             ;;A<(V/02)
                DB      39H             ;;(BC)<A, eBYTE1
                $NEXT

;  esUPDAT      ( --- )
;               Update only the Slider data of the Edit Buffer.
                $CODE   7,'esUPDAT',ESUPDAT
                DB      68H,0FFH        ;;V<FF
                DB      6AH,2           ;;B<2
                DB      1,0             ;;A<(V/00) Read eSLD#
                DB      1BH             ;;C<A
                DB      29H             ;;A<(BC) Read Translation Table
                DB      6AH,0C6H        ;;B<C6
                DB      1BH             ;;C<A

                DB      29H             ;;A<(BC)
                DB      48H,21H         ;;A SHIFT RIGHT
                DB      63H,4           ;;(V/04)<A
                $NEXT

;  eSLD#        ( --- FF00 )
;               Edit Buffer Slider number.
                $COLON  5,'eSLD#',ESLDN
                DW      DOLIT,0FF00H,EXIT

;  eFLD         ( --- FF01 )
;               Edit Buffer LCD Field.
                $COLON  4,'eFLD',EFLD
                DW      DOLIT,0FF01H,EXIT

;  eBYTE1       ( --- FF07 )
;               Edit Buffer Midi Status/Chnl byte.
                $COLON  6,'eBYTE1',EBYT1
                DW      DOLIT,0FF02H,EXIT

;  eBYTE2       ( --- FF06 )
;               Edit Buffer Midi Key#, Controller#, or Program# byte.
                $COLON  6,'eBYTE2',EBYT2
                DW      DOLIT,0FF03H,EXIT

;  eBYTE3       ( --- FF04 )
;               Edit Buffer Slider value.
                $COLON  6,'eBYTE3',EBYT3
                DW      DOLIT,0FF04H,EXIT

; eSET          ( --- FF05 )
;               Flag indicating Slider or Setup operation.
                $COLON  4,'eSET',ESET
                DW      DOLIT,0FF05H,EXIT

; eSET#         ( --- FF06 )
;               Holds Setup number.
                $COLON  5,'eSET#',ESETN
                DW      DOLIT,0FF06H,EXIT

;  FLD0         ( --- 80 )
;               LCD Field start.
                $COLON  4,'FLD0',FLD0
                DW      DOLIT,080H,EXIT

;  FLD1         ( --- 86 )
;               LCD Field start.
                $COLON  4,'FLD1',FLD01
                DW      DOLIT,086H,EXIT

;  FLD2         ( --- 8A )
;               LCD Field start.
                $COLON  4,'FLD2',FLD2
                DW      DOLIT,088H,EXIT

;  FLD3         ( --- 8D )
;               LCD Field start.
                $COLON  4,'FLD3',FLD3
                DW      DOLIT,08DH,EXIT

;  FLD4         ( --- C0 )
;               LCD Field start.
                $COLON  4,'FLD4',FLD4
                DW      DOLIT,0C0H,EXIT

;  FLD5         ( --- C9 )
;               LCD Field start.
                $COLON  4,'FLD5',FLD5
                DW      DOLIT,0C9H,EXIT

;  FLD6         ( --- CD )
;               LCD Field start.
                $COLON  4,'FLD6',FLD6
                DW      DOLIT,0CDH,EXIT

;  L0           ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  2,'L0',L0
                SD$ 'Slider'

;  L1           ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  2,'L1',L1
                SD$ 'Setup#'

;  L2           ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  2,'L2',L2
                SD$ '* MIDI Running *'

;  L20          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L20',L20
                SD$ ' chl '

;  L21          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L21',L21
                SD$ ' off '

;  L40          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L40',L40
                SD$ 'Key#    '

;  L41          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L41',L41
                SD$ 'Key# A-T'

;  L42          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L42',L42
                SD$ 'Control#'
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;  L43          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L43',L43
                SD$ 'Program#'

;  L44          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L44',L44
                SD$ 'Ch Press'

;  L45          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L45',L45
                SD$ 'Ptch Whl'

;  L4X          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L4X',L4X
                SD$ '********'

;  L50          ( --- a )
;               Packed string. 'a' is addr of count byte.
                $COLON  3,'L50',L50
                SD$ '***'

;  FLDCASE      ( n -- f )
;               Choose an LCD field position.
                $COLON  7,'FLDCASE',FLDCS
                DW      DOLIT,7H,ANDD,CASE
                DW      FLD0,FLD01,FLD2,FLD3,FLD4,FLD5,FLD6,FLD0
                DW      EXIT

;  FLDAT        ( --- )
;               Return LCD cursor to current field.
                $COLON  5,'FLDAT',FLDAT
                DW      EFLD,CAT,FLDCS,LI,EXIT

;  LSTAT        ( n --- )
;               Choose a midi status label.
                $COLON  5,'LSTAT',LSTAT
                DW      CASE,L4X,L40,L41,L42,L43,L44,L45,L4X,EXIT

;

;  SLDISP       ( --- )
;               Slider data update and display.
                $COLON  6,'SLDISP',SLDISP
                DW      ESUPDAT,EFLD,CAT,FLDCS
                DW      EBYT3,CAT,DOLIT,07FH,ANDD
                DW      BDIGS,DIG,DIG,DIG,EDIGS
                DW      DROP,LLI,FLD6,LCD,LLC
                DW      DUPP,CAT,LCD,ONEP,DUPP,CAT,LCD
                DW      ONEP,CAT,LCD,LI,EXIT

;  eDISP        ( --- )
;               Display the Edit buffer on the LCD
                $COLON  5,'eDISP',EDISP
                DW      L0,FLD0,DISP,ESLDN,CAT,FLD01,N2DISP
                DW      EBYT1,CAT,DOLIT,80H,ANDD
                DW      QBRAN,EDISA
                DW      L20,FLD2,DISP
                DW      BRAN,EDISB
   EDISA:       DW      L21,FLD2,DISP
   EDISB:       DW      EBYT1,CAT,DUPP,DOLIT,0FH,ANDD,FLD3,NDISP
                DW      TWOSR,TWOSR,TWOSR,TWOSR,DOLIT,7H,ANDD
                DW      LSTAT,FLD4,DISP
                DW      DOLIT,0CFH,EBYT1,CAT,DOLIT,0F0H,ANDD,LESS
                DW      QBRAN,EDISC
                DW      L50,FLD5,DISP
                DW      BRAN,EDISD
  EDISC:        DW      EBYT2,CAT,FLD5,NDISP
  EDISD:        DW      SLDISP
                DW      FLDAT,EXIT

; SDISP         ( --- )
;               Display the Setup operation on the LCD.
                $COLON  5,'SDISP',SDISP
                DW      DOLIT,01,LI,BDEL
                DW      L1,FLD0,DISP
                DW      ESETN,CAT,FLD01,N2DISP,FLDAT,EXIT

; MNDISP        ( --- )
;               Main display routine for updating LCD display.
                $COLON  6,'MNDISP',MNDISP
                DW      ESET,CAT
                DW      QBRAN,MNDIS1
                DW      SDISP,EXIT
MNDIS1:         DW      EDISP,EXIT

;  BDEL         ( --- )
;               Long delay at end of button routines.
                $COLON  4,'BDEL',BDEL
                DW      DOLIT,08000H,DELAY,EXIT

;  UDCASE      ( n --- )
;              Choose an up/down routine from list.
                $COLON  6,'UDCASE',UDCS
                DW      EFLD,CAT,DOLIT,7H,ANDD,CASE
                DW      UD0,UD1,UD2,UD3,UD4,UD5,UD6,UD7
                DW      EXIT

;  BL/R         ( fld --- pos )
;               Translates LCD field number to a position number.
                $COLON  4,'BL/R',BLR
                DW      DUPP,EFLD,CSTOR,FLDCS
                DW      EXIT

; SL/R          ( --- )
;               Limit cursor movement only between fields 0 and 1.
                $COLON  4,'SL/R',SLR
                DW      EFLD,CAT,DOLIT,01,ANDD,DOLIT,01,XORR,DUPP
                DW      EFLD,CSTOR,BLR,LI,BDEL,EXIT

;  BLEFT        ( --- )
;               Moves the LCD cursor to next field. Loads eFLD.
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```
                $COLON  5,'BLEFT',BLEFT
                DW      DOLIT,40H,LEDB
                DW      ESET,CAT
                DW      QBRAN,BLEFT1
                DW      SLR,EXIT
BLEFT1:         DW      EFLD,CAT,DOLIT,5,DECR,BLR,LI,BDEL,EXIT


;  BRIGHT       ( --- )
;               Moves the LCD cursor to next field. Loads eFLD.
                $COLON  6,'BRIGHT',BRIGH
                DW      DOLIT,80H,LEDB
                DW      ESET,CAT
                DW      QBRAN,BRIGH1
                DW      SLR,EXIT
BRIGH1:         DW      EFLD,CAT,DOLIT,5,INCR,BLR,LI,BDEL,EXIT

; SETUP         ( --- )
;               Setup Slider full Ram buffer from ROM, or MIDI in.
                $COLON  5,'SETUP',SETUP
                DW      ESETN,CAT,DOLIT,2000H,PLUS
                DW      DOLIT,0C680H,DOLIT,80H,CMOVE
                DW      EXIT


;  BLOAD        ( --- )
;               Load Buffer data shown on LCD into Slider Memory.
                $COLON  5,'BLOAD',BLOAD
                DW      DOLIT,4,LEDB
                DW      ESET,CAT
                DW      QBRAN,BLOAD1
                DW      SETUP,DOLIT,0,ESET,CSTOR,EUPDAT,EDISP,BDEL,EXIT
 BLOAD1:        DW      ELOAD,EDISP,BDEL,EXIT

;  BMIDI        ( --- )
;               Start the Midi program.
                $COLON  5,'BMIDI',BMIDI
                DW      DOLIT,1,LI,BDEL
                DW      L2,FLD0,DISP
                DW      MIDI,EXIT

;  BUP          ( --- )
;               Increment value in LCD cursor field.
                $COLON  3,'BUP',BUP
                DW      DOLIT,10H,LEDB
                DW      DOLIT,1,UDCS,BDEL,EXIT

;  BDOWN        ( --- )
;               Decrement value in LCD cursor field.
                $COLON  5,'BDOWN',BDOWN
                DW      DOLIT,20H,LEDB
                DW      DOLIT,0,UDCS,BDEL,EXIT

;  U/D0         ( i/d --- )
;               Field increment/decrement routine.
                $COLON  4,'U/D0',UD0
                DW      DROP,ESET,CAT
                DW      QBRAN,UD0A
                DW      DOLIT,0,ESET,CSTOR,EDISP,EXIT
UD0A:           DW      DOLIT,0FFH,ESET,CSTOR,SDISP,EXIT

; U/D7          ( i/d --- )
;               Field increment/decrement routine. (bogus field)
                $COLON  4,'U/D7',UD7
                DW      DROP,EXIT

;  U/D6         ( i/d --- )
;               Field increment/decrement routine.
                $COLON  4,'U/D6',UD6
                DW      DROP,EXIT

;  U/D1         ( i/d --- )
;               Field increment/decrement routine.
                $COLON  4,'U/D1',UD1
                DW      ESET,CAT
                DW      QBRAN,UD1C
                DW      ESETN
                DW      BRAN,UD1D
UD1C:           DW      ESLDN
UD1D:           DW      CAT,DOLIT,3FH,ROT
                DW      QBRAN,UD1A
                DW      INCR
                DW      BRAN,UD1B
   UD1A:        DW      DECR
   UD1B:        DW      CFLD1,EXIT

;  CFLD1        ( sld# --- )
;               Change Slider# in field 1.  Update Edit buffer & LCD.
                $COLON  5,'CFLD1',CFLD1
                DW      ESET,CAT
                DW      QBRAN,CFLA
                DW      ESETN,CSTOR,SDISP
                DW      BRAN,CFLB
CFLA:           DW      ESLDN,CSTOR,EUPDAT,EDISP,FLDAT
CFLB:           DW      FLDAT,EXIT

;  U/D2         ( i/d --- )
;               Ch/Off Field increment/decrement routine.
                $COLON  4,'U/D2',UD2
                DW      QBRAN,UD2A
                DW      EBYT1,CAT,DOLIT,80H,ORR
                DW      EBYT1,CSTOR,L20,FLD2,DISP
                DW      BRAN,UD2B
   UD2A:        DW      EBYT1,CAT,DOLIT,7FH,ANDD
                DW      EBYT1,CSTOR,L21,FLD2,DISP
   UD2B:        DW      FLDAT,EXIT

;  U/D3         ( i/d --- )
;               Field increment/decrement routine.
                $COLON  4,'U/D3',UD3
                DW      EBYT1,CAT,DOLIT,0FH,ANDD,DOLIT,0FH,ROT
                DW      QBRAN,UD3A
                DW      INCR
                DW      BRAN,UD3B
   UD3A:        DW      DECR
   UD3B:        DW      CFLD3,EXIT
```

```
;  CFLD3        ( chnl --- )
;               Change midi channel in field 3.
                $COLON  5,'CFLD3',CFLD3
                DW      DUPP,EBYT1,CAT,DOLIT,0F0H
                DW      ANDD,ORR,EBYT1,CSTOR,FLD3,NDISP,EXIT

;  U/D4         ( i/d --- )
;               Field increment/decrement routine.
                $COLON  4,'U/D4',UD4
                DW      EBYT1,CAT,DOLIT,70H,ANDD
                DW      TWOSR,TWOSR,TWOSR,TWOSR,DOLIT,7,ROT
                DW      QBRAN,UD4A
                DW      INCR
                DW      BRAN,UD4B
   UD4A:        DW      DECR
   UD4B:        DW      DUPP,DOLIT,0,EQUAL,OVER,DOLIT,7H,EQUAL,ORR
                DW      QBRAN,UD4C
                DW      DROP,DOLIT,1
   UD4C:        DW      CFLD4,EXIT

;  CFLD4        ( status --- )
;               Change Midi operation label in field 4.
                $COLON  5,'CFLD4',CFLD4
                DW      DUPP,TWOSL,TWOSL,TWOSL,TWOSL
                DW      DOLIT,80H,ORR,EBYT1,CAT
                DW      DOLIT,0FH,ANDD,ORR,EBYT1,CSTOR
                DW      LSTAT,FLD4,DISP,FLDAT,EXIT

;  U/D5         ( i/d --- )
;               Field increment/decrement routine.
                $COLON  4,'U/D5',UD5
                DW      EBYT2,CAT,DOLIT,07FH,ROT
                DW      QBRAN,UD5A
                DW      INCR
                DW      BRAN,UD5B
   UD5A:        DW      DECR
   UD5B:        DW      CFLD5,EXIT

;  CFLD5        ( data --- )
;               Change Midi data byte in field 5.
                $COLON  5,'CFLD5',CFLD5
                DW      DOLIT,0CFH,EBYT1,CAT,DOLIT,0F0H,ANDD,LESS
                DW      QBRAN,UD5AA
                DW      L50,FLD5,DISP,FLD5,LI,DROP
                DW      BRAN,UD5BB
   UD5AA:       DW      DUPP,EBYT2,CSTOR,FLD5,NDISP
   UD5BB:       DW      EXIT

;  BSUP         ( --- )
;               Button 1.  Increments Slider number.
                $COLON  4,'BSUP',BSUP
                DW      DOLIT,1,UD1,BDEL,EXIT

;  BSDWN        ( --- )
;               Button 2.  Decrements Slider Number.
                $COLON  5,'BSDWN',BSDWN
                DW      DOLIT,0,UD1,BDEL,EXIT
```

```
;   MNCASE        ( --- )
;                 Button case for Main.
                  $COLON  6,'MNCASE',MNCASE
                  DW      SAT,CASE
                  DW      DUMMY,BSDWN,BSUP,BLOAD,BMIDI,BUP,BDOWN,BLEFT,BRIGH
                  DW      EXIT


;   MLOOP         ( --- stat)
;                 Loop thru ADC values until an enabled one is found.
                  $CODE   5,'MLOOP',MLOOP
                  DB 68H,0FFH             ;V<FF
                  DB 6AH,0C6H             ;B<C6
                  DB 1,0E0H               ;A<(V/E0), LOOPBACK
                  DB 41H                  ;A<A+1 skip if carry
                  DB 07H,3FH              ;A<A AND 3F
                  DB 63H,0E0H             ;(V/E0)<A

                  DB 46H,0C0H             ;A<A+C0
                  DB 1BH                  ;C<A
                  DB 29H                  ;A<(BC), midi byte1
                  DB 47H,80H              ;A AND 80, skip if no zero
                  DB 0F2H                 ;JMP LOOPBACK, if disabled

                  DB 7H,7FH               ;A<A AND 7F
                  DB 48H,21H              ;A shift right
                  DB 48H,21H              ;A shift right
                  DB 48H,21H              ;A shift right
                  DB 48H,21H              ;A shift right
                  DB 1BH                  ;C<A
                  DB 6AH,0                ;B<0
                  DB 0B1H                 ;PUSH BC, push status# on stack
                  $NEXT

;   ADCV          ( --- adc value)
;                 Push stack with current adc value for MIDI operation.
                  $CODE   4,'ADCV',ADCV
                  DB 1,0E0H               ;A<(V/E0), Midi loop count.
                  DB 1BH                  ;C<A
                  DB 6AH,0C6H             ;B<C6
                  DB 29H                  ;A<(BC)
                  DB 1BH                  ;C<A
                  DB 6AH,0                ;B<0
                  DB 0B1H                 ;PUSH BC
                  $NEXT

;   SLAST         ( --- diff value)
;                 Push stack with current diff value for MIDI operation.
                  $CODE   5,'SLAST',SLAST
                  DB 1,0E0H               ;A<(V/E0), Midi loop count.
                  DB 46H,40H              ;A<A+40
                  DB 1BH                  ;C<A
                  DB 6AH,0C6H             ;B<C6
                  DB 29H                  ;A<(BC)
                  DB 1BH                  ;C<A
                  DB 6AH,0                ;B<0
                  DB 0B1H                 ;PUSH BC
```

```
                $NEXT

;  BYT2         ( --- byt2 value)
;               Push stack with current BYTE2 value for MIDI operation.
                $CODE   4,'BYT2',BYT2
                DB 1,0E0H               ;A<(V/E0), Midi loop count.
                DB 46H,80H              ;A<A+80
                DB 1BH                  ;C<A
                DB 6AH,0C6H             ;B<C6
                DB 29H                  ;A<(BC)
                DB 1BH                  ;C<A
                DB 6AH,0                ;B<0
                DB 0B1H                 ;PUSH BC
                $NEXT

;  BYT1         ( --- byt1 value)
;               Push stack with current BYTE1 value for MIDI operation.
                $CODE   4,'BYT1',BYT1
                DB 1,0E0H               ;A<(V/E0), Midi loop count.
                DB 46H,0C0H             ;A<A+C0
                DB 1BH                  ;C<A
                DB 6AH,0C6H             ;B<C6
                DB 29H                  ;A<(BC)
                DB 1BH                  ;C<A
                DB 6AH,0                ;B<0
                DB 0B1H                 ;PUSH BC
                $NEXT

;  FLAG         ( --- flag value)
;               Push stack with current FLAG value for MIDI operation.
                $CODE   4,'FLAG',FLAG
                DB 1,0E0H               ;A<(V/E0), Midi loop count.
                DB 1BH                  ;C<A
                DB 6AH,0C7H             ;B<C7
                DB 29H                  ;A<(BC)
                DB 1BH                  ;C<A
                DB 6AH,0                ;B<0
                DB 0B1H                 ;PUSH BC
                $NEXT

; FLGON         ( --- )
;               Store FF in FLAG of current slider.
                $CODE   5,'FLGON',FLGON
                DB 1,0E0H               ;A<(V/E0)
                DB 1BH                  ;C<A
                DB 6AH,0C7H             ;B<C7
                DB 69H,0FFH             ;A<FF
                DB 39H                  ;(BC)<A
                $NEXT

; FLGOFF        ( --- )
;               Store 0 in FLAG of current slider.
                $CODE   6,'FLGOFF',FLGOFF
                DB 1,0E0H               ;A<(V/E0)
                DB 1BH                  ;C<A
                DB 6AH,0C7H             ;B<C7
                DB 69H,0                ;A<0
                DB 39H                  ;(BC)<A
                $NEXT

; ?DIFF         (old,new --- /shifted new,0F/  OR /00/)
;               Flag=0F if /old-new/>1, else Flag=0.
                $CODE   5,'?DIFF',QDIFF
                DB 0A4H                 ;POP EA, new
                DB 0A1H                 ;POP BC, old
                DB 09H                  ;A<EAL
                DB 60H,0E3H             ;A<A-C

                DB 6BH,0FFH             ;C<FF
                DB 60H,0EBH             ;A-C, skip if no zero
                DB 69H,0                ;A<0
                DB 6BH,0                ;C<0
                DB 47H,0FEH             ;A AND FE, skip if no zero
                DB 0C7H                 ;JMP AHEAD
                DB 9H                   ;A<EAL
                DB 48H,21H              ;A SHIFT RIGHT
                DB 19H                  ;EAL<A
                DB 0B4H                 ;PUSH EA
                DB 6BH,0FFH             ;C<FF

                DB 6AH,0                ;B<0, AHEAD
                DB 0B1H                 ;PUSH BC
                $NEXT

; LDLAST        ( --- )
;               Moves ADC value to SLAST value in current MLOOP slider buffer.
                $CODE   6,'LDLAST',LDLAST
                DB 1,0E0H               ;A<(V/E0)
                DB 1BH                  ;C<A
                DB 6AH,0C6H             ;B<C6
                DB 29H                  ;A<(BC)
                DB 19H                  ;EAL<A
                DB 0BH                  ;A<C
                DB 46H,40H              ;A<A+40
                DB 1BH                  ;C<A
                DB 09H                  ;A<EAL
                DB 39H                  ;(BC)<A
                $NEXT

;  DUMMY        ( --- )
;               Do nothing dummy.
                $COLON  5,'DUMMY',DUMMY
                DW      EXIT

;  LDSTAT       ( --- )
;               Load current Byte1 to FFE1, last Midi status sent.
                $COLON  6,'LDSTAT',LDSTAT
                DW      BYT1,DOLIT,0FFE1H,CSTOR,EXIT

;  KEYN         ( --- )
;               Midi routine for Key On and Key Off.
                $COLON  4,'KEYN',KEYN
                DW      ADCV,DOLIT,0,EQUAL
                DW      QBRAN,KEYN1
                DW      LDLAST,FLAG
                DW      QBRAN,KEYN4
                DW      BYT1,TM,LDSTAT,BYT2,TM,FLGOFF,DOLIT,0,TM,EXIT
KEYN1:          DW      FLAG
                DW      QBRAN,KEYN2
                DW      EXIT
KEYN2:          DW      ADCV,SLAST,SUBB,ZLESS
                DW      QBRAN,KEYN3
                DW      BYT1,TM,LDSTAT,BYT2,TM,FLGON,ADCV,TWOSR,TM
KEYN3:          DW      LDLAST
KEYN4:          DW      EXIT

;  TSTAT        ( --- )
;               Test status byte, send midi status if not last sent.
                $COLON  5,'TSTAT',TSTAT
                DW      BYT1,DUPP,DOLIT,0FFE1H,CAT,EQUAL
                DW      QBRAN,TSTAT1
                DW      DROP,BRAN,TSTAT2
TSTAT1:         DW      TM,LDSTAT
TSTAT2:         DW      EXIT

;  KEYAT        ( --- )
;               Midi routine for Key On and Key Off with Poly After Touch.
                $COLON  5,'KEYAT',KEYAT
                DW      ADCV,DOLIT,0,EQUAL
                DW      QBRAN,KEYAT1
                DW      LDLAST,FLAG
                DW      QBRAN,KEYAT4
                DW      BYT1,DOLIT,0FH,ANDD,DOLIT,90H,ORR,TM
                DW      DOLIT,90H,DOLIT,0FFE1H,CSTOR
                DW      BYT2,TM,FLGOFF,DOLIT,0,TM,EXIT
KEYAT1:         DW      FLAG
                DW      QBRAN,KEYAT2
                DW      SLAST,ADCV
                DW      QDIFF
                DW      QBRAN,KEYAT4
                DW      TSTAT,BYT2,TM,LDLAST,TM,EXIT
KEYAT2:         DW      ADCV,SLAST,SUBB,ZLESS
                DW      QBRAN,KEYAT3
                DW      BYT1,DOLIT,0FH,ANDD,DOLIT,90H,ORR,TM
                DW      DOLIT,90H,DOLIT,0FFE1H,CSTOR
                DW      BYT2,TM,FLGON,ADCV,TWOSR,TM
KEYAT3:         DW      LDLAST
KEYAT4:         DW      EXIT

;  CNTRL        ( --- )
;               Midi Routine for controller data.
                $COLON  5,'CNTRL',CNTRL
                DW      SLAST,ADCV
                DW      QDIFF
                DW      QBRAN,CNTRL1
                DW      TSTAT,BYT2,TM,LDLAST,TM,EXIT
CNTRL1          DW      EXIT

;  PRG          ( --- )
;               Midi Routine for program changes.
                $COLON  3,'PRG',PRG
                DW      DOLIT,40H,ADCV,LESS
                DW      QBRAN,PRG2
                DW      FLAG
                DW      QBRAN,PRG1
                DW      EXIT
PRG1:           DW      BYT1,TM,LDSTAT,FLGON,BYT2,TM,EXIT
PRG2:           DW      FLGOFF,EXIT

;  CHAT         ( --- )
;               Midi Routine for Channel Pressure.
                $COLON  4,'CHAT',CHAT
                DW      SLAST,ADCV
                DW      QDIFF
                DW      QBRAN,CHAT1
                DW      TSTAT,LDLAST,TM,EXIT
CHAT1:          DW      EXIT

;  PWHL         ( --- )
;               Midi Routine for Pitch Wheel.
                $COLON  4,'PWHL',PWHL
                DW      SLAST,ADCV
                DW      QDIFF
                DW      QBRAN,PWHL1
                DW      TSTAT,DOLIT,0,TM,LDLAST,TM,EXIT
PWHL1:          DW      EXIT

;  MCASE        ( --- )
;               Midi Routines Case Statement.
                $COLON  5,'MCASE',MCASE
                DW      CASE,DUMMY
                DW      KEYN,KEYAT,CNTRL,PRG,CHAT,PWHL,DUMMY
                DW      EXIT

;  MIDI         ( --- )
;               Main Midi Loop.
                $COLON  4,'MIDI',MIDI
                DW      DOLIT,0C700H,DOLIT,40H,DOLIT,0,FILL
                DW      DOLIT,0C640H,DOLIT,40H,DOLIT,0,FILL
MIDI1:          DW      ADCIN,MLOOP,MCASE,SWAT,INVER,DOLIT,07H,ANDD
                DW      QBRAN,MIDI1
                DW      EXIT
;

;  EDIT         ( --- )
;               MAIN SLIDER EDIT PROGRAM.
                $COLON  4,'EDIT',EDIT

                DW      CR,DECIM,DOLIT,1,LI,BDEL
                DW      EUPDAT,EDISP
EDIT1:          DW      ADCIN,SLDISP,DOLIT,0,LEDB,MNCASE,NUFQ
                DW      QBRAN,EDIT1
                DW      HEX,EXIT

; ENBRM         ( --- )
;               Enable Midi Receive.
                $CODE   5,'ENBRM',ENBRM
                DB      64H,81H,0EH     ;SMH<E
                $NEXT

; RM            ( --- b,f)
;                Receive Midi.  If midi received, returns the data plus true,
;                else returns false flag.
                $CODE   2,'RM',RM
                DB      6AH,0           ;B<0
                DB      6BH,0           ;C<0
                DB      48H,49H         ;SKIT FSR, skip if interrupt flg
                DB      0C6H            ;JMP AHEAD
                DB      4CH,0D9H        ;A<RXB
                DB      1BH             ;C<A
                DB      0B1H            ;PUSH BC, received byte
                DB      6BH,0FFH        ;C<FF
                DB      0B1H            ;PUSH BC, the flag, AHEAD
                $NEXT
;===============================================================

LASTN           EQU     _NAME+4                 ;last name address

NTOPP           EQU     _NAME-0      ;next available memory in ROM name
dictionary
CTOPP           EQU     $+0          ;next available memory in ROM code
dictionary

MAIN    ENDS
END     ORIG

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