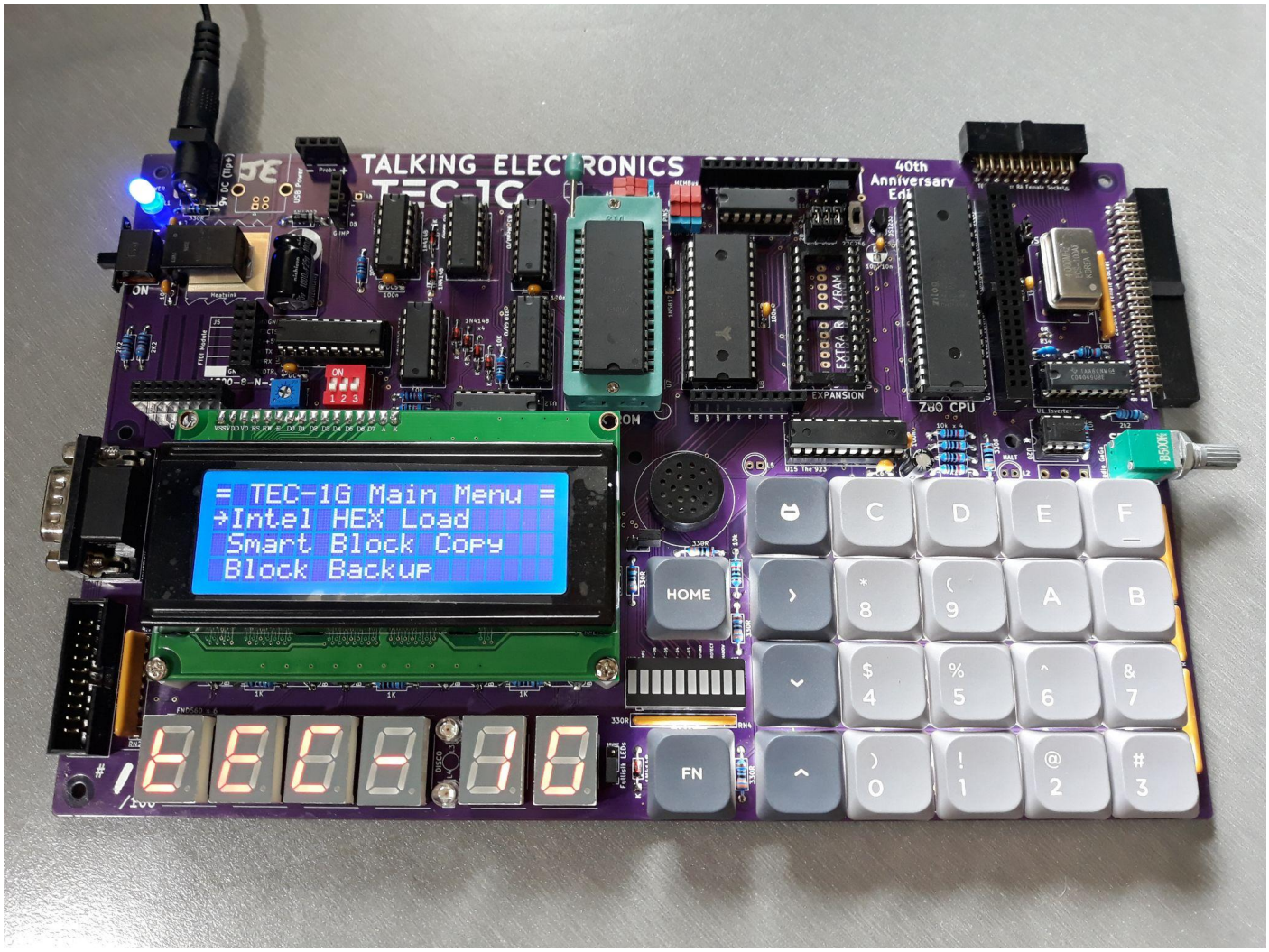
TEC-1G MON3

User guide

By Brian Chiha v1.2

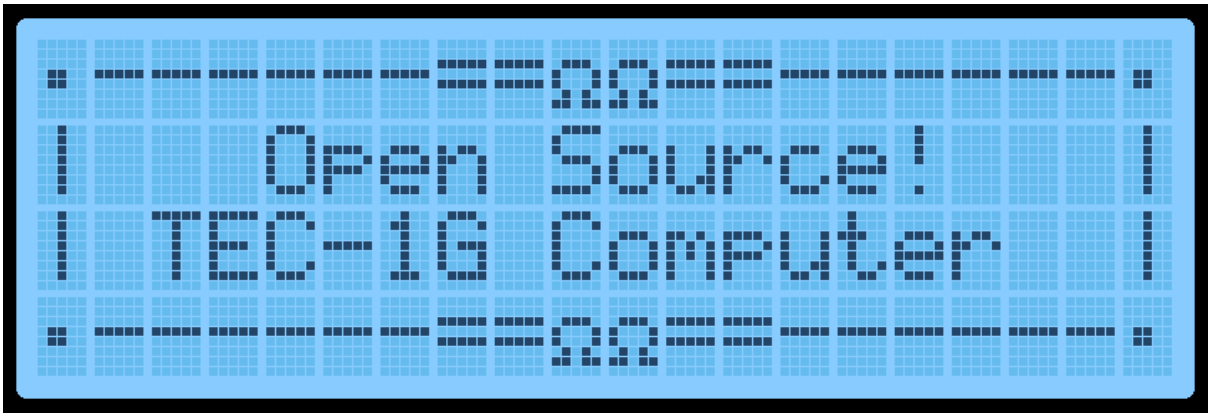


Mon3 (Talking Electronics Computer Monitor version 3) is custom-built for the TEC-1G Single Board Z80 Computer. Mon3 is the heart of the TEC-1G. It brings the hardware to life. Consider it an Operating System that provides the ability to program the TEC. The monitor is jam-packed with features, designed for beginners who are just learning to code Z80 and rich enough for the advanced software developer.

Table of Contents

Basic Operation

With the monitor loaded into the ROM socket and all the jumpers set correctly for the ROM used. Turn the TEC on. If all is working well, a welcome banner will be displayed on the LCD and a short tune will be heard.



Cold Reset

When the TEC turns on after being powered down, a Cold Reset occurs. A Cold Reset signified with the display of the welcome banner and the short tune. A Cold Reset will configure the monitor for first-time use after powering it on. It will default monitor variables and configure the LCD for first use.

If the TEC isn't responding normally or something "weird" is occurring, a manual Cold Reset can be performed. Programs loaded in RAM will be retained when a manual Cold Reset is done. To do a manual Cold Reset, while pressing and releasing the RESET key, hold the Fn key down. The distinctive LCD Banner and music tone will indicate that the Cold Reset was successful. A manual Cold Reset on the HexPad will still work if the Matrix Keyboard is in use.

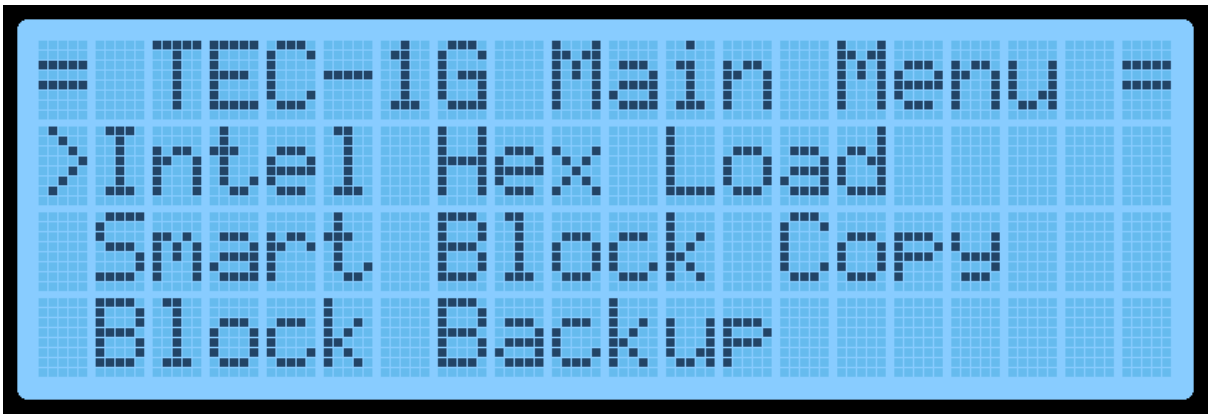
Warm Reset

A Warm Reset occurs when pressing and releasing the RESET key. A warm reset returns the TEC to its initial editing location on a Cold Reset. It's a quick way to get back to the start of a code block.

Main Menu

A menu is provided on the LCD screen to help with navigating the inbuilt routines that the monitor comes with. A menu will appear on Cold Reset.

Navigating the menu should be intuitive. Press the Plus or Minus keys to scroll down and up. Press GO to run the selected routine. A right-facing Arrow indicates which menu item is currently selected. One thing that might not be obvious is how to exit the menu and move into Data Entry mode. This is achieved by pressing the AD key. Once this is known, it's hard to forget it.



The current items on the menu are

Menu Text	**Description**
Intel HEX Load	Receive data in Intel Hex File format via the FTDI connector
Smart Block Copy	Move a block of code AND update all 2-byte addresses that are within the block
Block Backup	Move a block of code
Export Z80 Assembly	Display Z80 Assembly to a Serial terminal via the FTDI connector
Export Raw Data	Send binary data via the FTDI connector
Export Hex Dump	Display a 16-byte per line HEX dump to a Serial terminal via the FTDI connector
Import Binary File	Receive data in binary format via the FTDI connector

Tiny Basic	Run Tiny Basic on a Serial terminal
Terminal Monitor	Serial terminal monitor interface
Music Routine	Play musical notes at a given address
Settings	Update monitor settings
Credit	Display the people who made the TEC-1G

Intel HEX Load

Intel created a text file format that contains information on loading bytes into memory. When this routine is run, the TEC seven segments will go blank and wait for a file to be received. This is done via the FTDI connector and serial terminal. When data is transmitted, the rightmost segment will illuminate in a pattern. This indicates data is being read. Once the file has fully loaded, the letters “PASS” will display on the seven segments. This means that the load was successful. Press any key to exit. If the segments display the word “FAIL”, then there is something wrong with the file or your serial connection.

Smart Block Copy

This very clever routine shifts a program from one spot in memory to another and changes all absolute jumps and calls. Memory pointers are also altered if the memory pointers are within the start and end address of the program being relocated. Any reference to a location outside the start and end range is not altered.

The block copy treats Data bytes as instructions and might change data bytes as well. IE: `.db C3, 23, 01` could be seen as a `JP 0123` instruction.

When this routine is run, it will ask for a START, END and DESTINATION address. Type in the 16-bit address via the HEX PAD and use the Plus or Minus keys to change the selected parameter. Press GO to run the routine.

Here is an example of copying **4000H-4009H** to location **2000H**

Original		After Copy	
4000 11 09 40	LD DE,4009	2000 11 09 20	LD DE,2009
4003 E7	RST 20	2003 E7	RST 20
4004 FE 13	CP 13	2004 FE 13	CP 13
4006 C2 00 40	JP NZ,4000	2006 C2 00 20	JP NZ,2000
4009 C9	RET	2009 C9	RET

Block Backup

This routine simply copies a data block from one address location to another. No bytes are altered when the copy is performed. This routine is also useful to copy data reference tables like music data for the music routine.

When this routine is run, it will ask for a START, END and DESTINATION address. Type in the 16-bit address via the HEX PAD and use the Plus or Minus keys to change the selected parameter. Press GO to run the routine.

Here is an example of copying **4000H-4009H** to location **2000H**

Original		After Copy	
4000 11 09 40	LD DE,4009	2000 11 09 40	LD DE,4009
4003 E7	RST 20	2003 E7	RST 20
4004 FE 13	CP 13	2004 FE 13	CP 13
4006 C2 00 40	JP NZ,4000	2006 C2 00 40	JP NZ,4000
4009 C9	RET	2009 C9	RET

Export Z80 Assembly

If the TEC is connected to a serial terminal via an FTDI to USB adaptor, code that is stored or written on the TEC can be disassembled and sent to the terminal. This is a great way to view the code that is on the TEC in a readable format and could be passed into a Z80 compiler on a PC.

When this routine is run, it will ask for a START and END address. Type in the 16-bit address via the HEX PAD and use the Plus or Minus keys to change the selected parameter. Press GO to run the routine.

Here is an example of its output.

```
4000 3E 3F          LD A,3F
4002 D3 01          OUT (02),A
4004 3E 04          LD A,04
4006 D3 02          OUT (02),A
4008 CF             RST 08
4009 C9             RET
```

Export Raw Data

This routine will send binary data from the TEC to a serial connection. It's a way of saving the code written on the TEC to a PC. As binary data is being sent, the data can only be properly viewed through a HEX file viewer or HEX dump routine.

When this routine is run, it will ask for a START and END address. Type in the 16-bit address via the HEX PAD and use the Plus or Minus keys to change the selected parameter. Press GO to run the routine.

Export Hex Dump

This routine will display binary data in a readable format to a serial terminal connected via an FTDI to USB adaptor. It will display up to 16 bytes per line.

When this routine is run, it will ask for a START and END address. Type in the 16-bit address via the HEX PAD and use the Plus or Minus keys to change the selected parameter. Press GO to run the routine.

Here is an example of its output.

```
C100: 31 80 08 21 00 40 CD FC C5 AF D3 05 D3 06 DB 03
C110: 47 E6 10 C2 00 80 3A 9F 08 E6 04 0E 01 B1 D3 FF
C120: 32 9D 08 78 E6 02 32 9E 08 3A 9D 08 E6 01 28 0B
C130: 21 00 C0 11 00 00 01 00 01 ED B0 21 00 40 22 86
C140: 08 22 A0 08 DB 03 0F 38 06 DB 00 E6 20 18 08 CD
```

Import Binary File

This routine will upload a binary file from a PC onto the TEC via an FTDI to USB adaptor. This is the opposite of the Export Raw Data routine and will load binary data to a given address on the TEC.

When this routine is executed, it will ask for a START and END address. This address range must match the size of the binary file being sent. Type in the 16-bit address via the HEX PAD and use the Plus or Minus keys to change the selected parameter. Press GO to run the routine. The TEC will wait for data to be received and will end when END-START+1 bytes are received.

Tiny Basic

Mon3 comes with Tiny Basic installed. Tiny Basic is an easy-to-use BASIC programming language. At this stage, all interactions with BASIC are done on a serial terminal via an FTDI to USB adaptor.

```
Z80 TINY BASIC 2.2b
TEC-1G VERSION BY B CHIHA, 2023

OK
>LIST
 5 REM ** FIBONACCI SEQUENCE **
10 PRINT "FIBONACCI SEQUENCE"
20 FOR I=1 TO 22
30 GOSUB 70
40 PRINT "F",I,F
50 NEXT I
60 STOP
70 LET A=0; LET B=1
80 FOR J=1 TO I
90 LET T=A+B; LET A=B; LET B=T
100 NEXT J
110 LET F=A
120 RETURN
```

For information on how to use Tiny Basic, go to this link: https://github.com/bchiha/BMon/wiki/tiny_basic.

Music Routine

Use this routine to play some notes to the TEC speaker. It is based on John Hardy's Mon1 routine adjusted for a 4Mhz clock speed. The routine uses similar input codes making it suitable for existing tunes to be used.

When this routine is executed, it will ask for a START address of the music data—type in the 16-bit address via the HEX PAD. Press GO to run the routine.

Two octaves are playable. Here is a reference to the note code and its musical note. A Pause is represented by **00** and any other note code that isn't listed will exit the routine.

Note	Code	Note	Code	Note	Code	Note	Code
G	**01**	C#	**07**	G	**0D**	C#	**13**
G#	**02**	D	**08**	G#	**0E**	D	**14**
A	**03**	D#	**09**	A	**0F**	D#	**15**
A#	**04**	E	**0A**	A#	**10**	E	**16**
B	**05**	F	**0B**	B	**11**	F	**17**
C	**06**	F#	**0C**	C	**12**	F#	**18**

Here are some examples tunes that can be typed in a played

Bealach

```
06, 06, 0A, 0D, 06, 0D, 0A, 0D, 12, 16, 14, 12, 0F, 11, 12, 0F
0D, 0D, 0D, 0A, 12, 0F, 0D, 0A, 08, 06, 08, 0A, 0F, 0A, 0D, 0F
06, 06, 0A, 0D, 06, 0D, 0A, 0D, 12, 16, 14, 12, 0F, 11, 12, 0F
0D, 0D, 0D, 0A, 12, 0F, 0D, 0A, 08, 06, 08, 0A, 06, 12, 00, 1F
```

Angels On High

```
0F, 0F, 0F, 0F, 0F, 0F, 12, 12, 12, 12, 12, 10, 0F, 0F, 0F, 0F
0F, 0F, 0D, 0D, 0F, 0F, 12, 12, 0F, 0F, 0F, 0D, 0B, 0B, 0B, 0B
0F, 0F, 0F, 0F, 0F, 0F, 12, 12, 12, 12, 12, 10, 0F, 0F, 0F, 0F
0F, 0F, 0D, 0D, 0F, 0F, 12, 12, 0F, 0F, 0F, 0D, 0B, 0B, 0B, 0B
12, 12, 12, 12, 14, 12, 10, 0F, 10, 10, 10, 10, 12, 10, 0F, 0D
0F, 0F, 0F, 0F, 10, 0F, 0D, 0B, 0D, 0D, 0D, 06, 06, 06, 06, 06
0B, 0B, 0D, 0D, 0F, 0F, 10, 10, 0F, 0F, 0F, 0F, 0D, 0D, 00, 00
00, 12, 12, 12, 12, 14, 12, 10, 0F, 10, 10, 10, 10, 12, 10, 0F
0D, 0F, 0F, 0F, 0F, 10, 0F, 0D, 0B, 0D, 0D, 0D, 06, 06, 06, 06
06, 0B, 0B, 0D, 0D, 0F, 0F, 10, 10, 0F, 0F, 0F, 0F, 0D, 0D, 0D
0D, 0B, 0B, 0B, 0B, 0B, 0B, 0B, 0B, 00, 00, 00, 00, 00, 00, 1F
```

Terminal Monitor

Terminal Monitor or TMON give the user the ability to interface with the TEC-1G via a serial terminal. There is an extensive chapter regarding the use of TMON below.

Settings

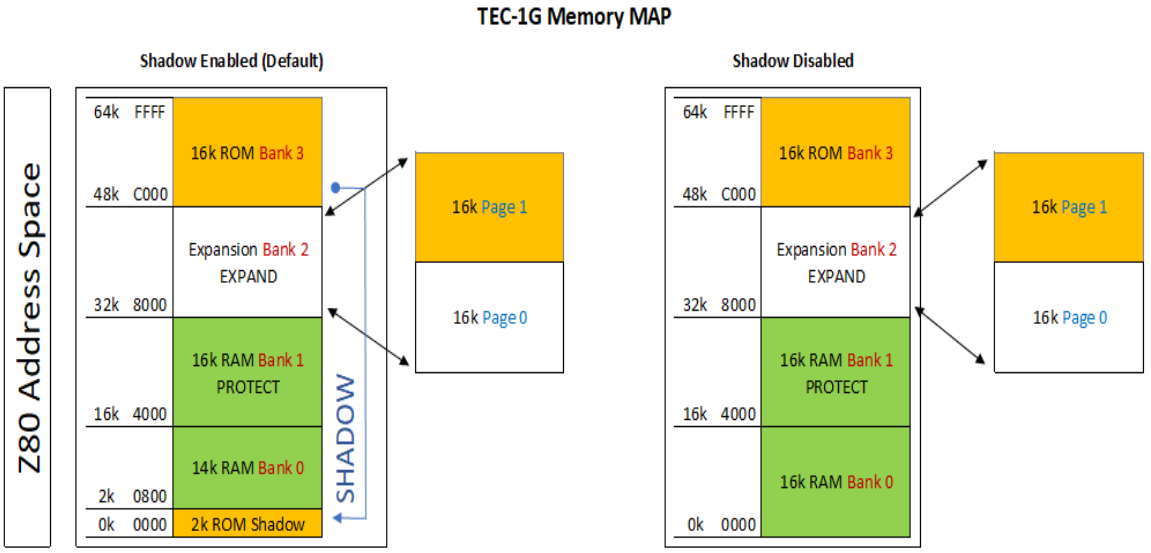
The settings allow the user to configure the monitor. Setting modifications will only remain when the TEC is powered. Turning the power off the TEC will return these settings to their default state

- Toggle Key Beep - Turn the keypress ‘beep’ indication on or off
- Toggle Address Inc - Turn the automatic address increase after a byte has been keyed on or off
- Toggle EXPAND - software controlled the expansion socket to toggle between lower and upper 16Kb memory for a 32Kb ROM/RAM chip.

Credits

Display the people who developed and tested the TEC-1G

- Mark Jelic - Designer of the TEC-1G
- Brian Chiha - Mon3 Programmer
- Craig Hart - TECnical Expert
- Ian McLean - Tester and QA
- James Elphick - Tester and QA
- John Hardy & Ken Stone - The original designers



Memory Map

The table below outlines how the full 64Kb of address space is allocated on the TEC-1G.

Address	Contents	Type
0000H-00FFH	Reserved for Z80 instructions	RAM
0100H-07FFH	Free RAM	RAM
0800H-087FH	Reserved for Hardware Stack	RAM
0880H-0FFFH	Reserved for Monitor RAM	RAM
1000H-3FFFH	Free RAM	RAM
4000H-7FFFH	Free RAM (Protected)	RAM
8000H-BFFFH	Expansion Socket	RAM/ROM
C000H-FFFFH	Monitor ROM	ROM

Some things to be considered are:

- Any RAM location can be updated, but it is highly recommended not to update Monitor Reserved RAM locations. This can/will cause undesirable effects on the running of the TEC. A Cold Reset will restore the TEC to its default running state (hopefully).
- The address range between 4000H-7FFFH is a special area that can be made READ ONLY. This is called a Protected area. Protect mode can be switched on using the configuration 3-DIP switch. If protect is enabled and code is being executed. No RAM update can be done in this range. This feature is designed to protect keyed-in code from being inadvertently erased by a rouge routine.
- The Expansion Socket on the TEC can have a 32Kb ROM or RAM inserted. Only 16kb can be accessed at one time. To switch between high and low memory use the Expand switch on the configuration 3-DIP switch. The switch can also be overridden in software by toggling the Expand flag in the Settings menu or via the API.
- If the monitor ROM is a legacy monitor, IE: Mon1, Mon2, JMon or BMon, The address range 0000H-07FFH will be READ ONLY and will emulate the same addressing that is used for that particular ROM. Shadow mode will be active by default and will be indicated by an illuminated LED segment on the system latch BAR component.

Data Entry Mode

Data Entry Mode allows the user to enter Z80 Op Codes directly into the TEC. To access Data Entry Mode from the Main Menu simply press the AD key. In this mode, the 4 left seven-segment displays will show the current editing address and the 2 right segments will display the byte at that address.

Address **Data**

The decimal place LED on the segments indicates which part, Address or Data is currently enabled for direct updates. In the picture above, the dots are on the Data segments.

The initial starting address is **4000H**. This address was chosen as it's within the Protect RAM area.

Basic Operation

To update a byte at an address, simply use the 0-F keys on the keypad. After the byte has been entered, by default when the next byte is keyed, the current editing address will automatically move to the next address location. This saves the user from pressing the Plus key after each byte is added. This option can be switched off in the Settings menu.

To navigate to another address, press the Plus or Minus key. Or press the AD key. The decimal place dots will move to the address segments indicating that the address field is updateable. Key in a new 2-byte address by using the 0-F keys. Press the AD key to move back to data updating mode.

And finally, to execute code, navigate to the address where the code starts and press the GO key. Protect mode will be honoured if switched on. If the code ends with a **RET** instruction (**C9**), execution will cleanly exit back to the monitor.

One thing to note is that while data is being entered, the decimal place LED on the data segments will change from displaying two lights to one. The one light will indicate which Nibble has been entered. This will assist in knowing if the whole byte has been entered or not.

If a mistake is made during data entry and the byte is to be re-entered. To stop the address from automatically incrementing, press the AD key twice. This will reset the Nibble counter and allow a new byte to be entered.

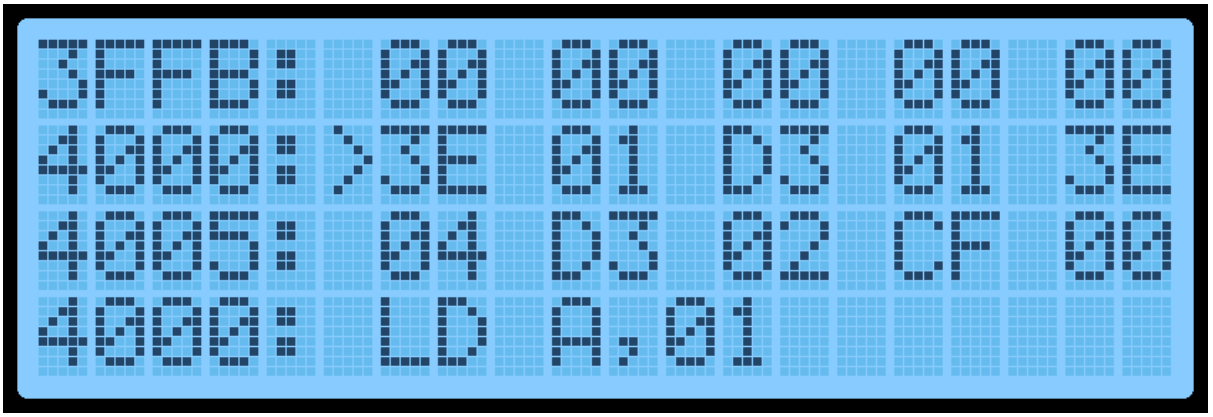
If any key is held down, after a short period, the key will automatically repeat. This is mostly useful while holding down the Plus or Minus key to quickly move to a new address. But can also be used to populate memory with 00 or FF or anything else.

LCD Screen

In Data Entry Mode the LCD Screen will display 15 bytes of data. 5 bytes before the current editing location and 10 bytes after the current editing location. These bytes are displayed in groups of 5 (3 lines). A right arrow indicates the byte at the current editing location.

On the 4th line of the LCD, the Z80 Assembly of the current OP Code is shown. This can be useful to see what instruction is currently being keyed.

By displaying a range of bytes on the LCD, the user can check if the correct bytes have been entered without individually moving to each address.

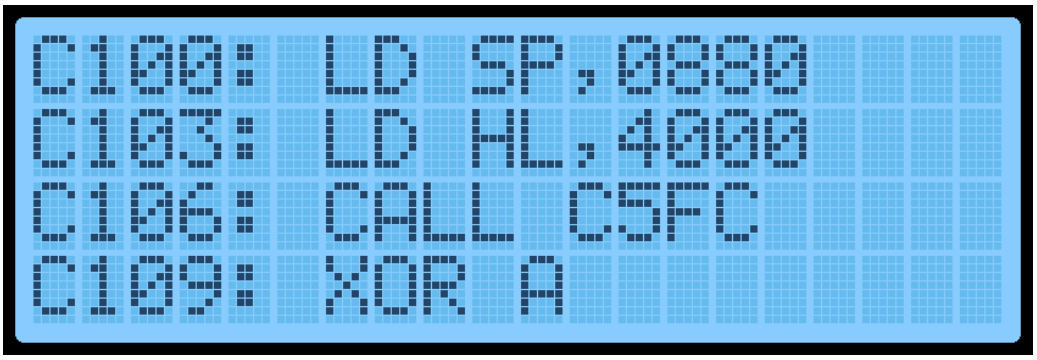


Function Keys

Various extra options can be selected via the Function Key. To use these functions, hold the Fn key down and press one of the 0-F keys.

The routines attached to the Function Key are:

- **Fn-AD** - Display the Main Menu
- **Fn-1** - Intel Hex Load. This is a shortcut to the Main Menu routine.
- **Fn-B** - Block Backup. This is a shortcut to the Main Menu routine.
- **Fn-C** - Smart Block Copy. This is a shortcut to the Main Menu routine.
- **Fn-D** - Switch between Data Entry View and Disassembly View. Disassembly View displays the next 4 Assembly instructions. To move through the instructions press the Plus or Minus keys. Data entry can still be done in this mode if desired.



- **Fn-E** - Toggle the Expansion Socket Expand flag. This will switch between the upper and lower memory of the 32Kb ROM/RAM in the expansion socket.
- **Fn-Plus** - Insert an `NOP` instruction at the current editing location AND move all bytes up to max RAM by one address upwards. It will also do a Smart Block Copy to all moved bytes. This routine can add a Breakpoint (**F7**) or missing opcodes to an existing program.
- **Fn-Minus** - Delete a byte from the current editing location AND move all bytes down by one address. It will also do a Smart Block Copy to all moved bytes.

Matrix Keyboard

Mon3 will work with the TEC Matrix Keyboard Add-on. The Keyboard is connected to the Keyboard Socket on the lower left of the PCB. How your Keyboard PCB is designed might affect which pins can be connected. Please view the TEC-1G Schematic for information on pin configuration.

To activate the Keyboard, The Matrix switch on the 3-DIP switch is to be turned on. This activates the Matrix Keyboard and disables the onboard Hex Keypad (except Reset). Mon3 only maps keys present on the TEC-1G to the Matrix Keyboard.

The Keyboard map to Hex Keypad is as follows:

- **AD** - Esc
- **Plus** - Right Arrow
- **0-F**, **Fn** - 0-F, Fn keys
- **GO** - Enter
- **Minus** - Left Arrow
- **Reset** - Reset key if connected

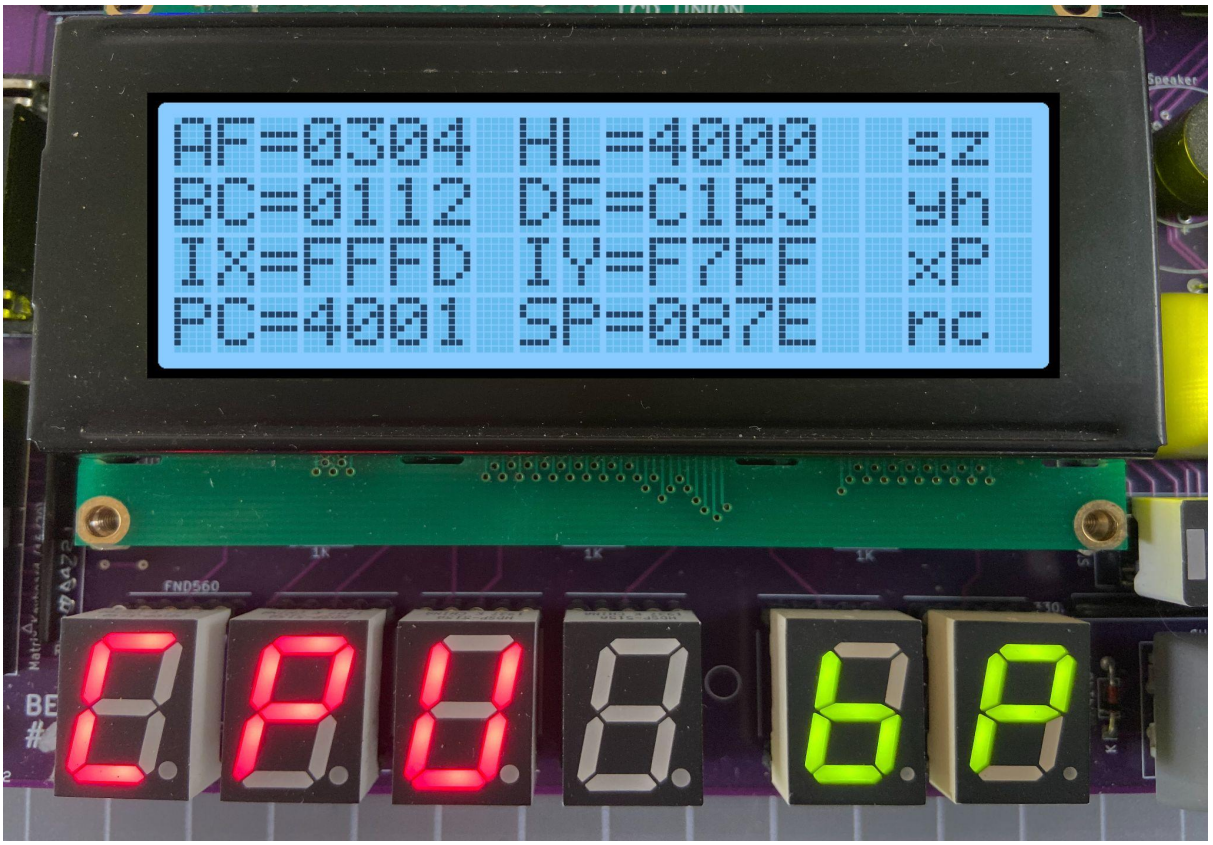
The full range of keys can be accessed and converted when developing programs via the `matrixScan` and `matrixToASCII` API routines.

Debugging Programs

Breakpoints can be inserted within a program which can help with viewing the state of the CPU registers. To break the execution of your code, insert a `RST 30H` or `F7` at the current address where the break should occur.

An easy way to insert a byte into an existing program is to press Fn-Plus. This will insert a `NOP` instruction at the current address. Then change this byte to `F7`.

When the execution of code is interrupted with a breakpoint, the TEC will pause and display register information on the LCD screen.



The contents of the Z80 CPU registers AF, HL, BC, DE, IX, IY, the Program Counter and Stack Pointer are displayed. CPU Flags are also displayed. Flags that are set are in Capitals. To continue code execution press the GO key and to quit execution and return to the Monitor press the AD key. Finally, to remove an inserted Breakpoint press Fn-Minus at the address where the Breakpoint is. This will remove the breakpoint and adjust the code to its original state.

Terminal Monitor

The Terminal Monitor (TMON) is a complete serial port-based monitor for the TEG-1G, designed for users who prefer to interact with the TEC-1G via a terminal. TMON is written by Craig Hart

Starting up TMON

Connect a serial terminal to the TEC-1G via the FTDI to USB connector. Then, select Terminal Monitor from the main menu by pressing GO and look at the serial terminal.

```
TMON for TEC-1G Version 1.0
MON-3 Version: 2023.11
RAM Found between 0000h and 3FFFh - 16384 bytes
1000 >
```

Using TMON

TMON is an interactive tool, that works with a serial terminal e.g. PuTTY or Tera Term on a PC, or a 'real' VT100 serial terminal such as a Wyse WY-60. The TEC-1G keypad and 7-seg displays are not used once the program starts, and do not do anything (except for the testing routines documented below).

Interactions with TMON are via the serial console. The user types commands interactively and the results are displayed on the terminal.

All interactions with TMON use HEX format - so a byte is `00` to FF, etc. The "h" or "0x" is omitted for brevity.

Typically, the ADDR key exits any interactive command, or by entering "Q" from the terminal.

The above text is the default display when TMON first starts. TMON is now awaiting input and commands from the Available Commands list can be entered.

The Command Prompt

```
1000 >
```

The `1000` represents the CURRENT ADDRESS in HEX. Many commands default to their actions interacting with memory at this address. The CURRENT ADDRESS changes as with certain commands. e.g. inputting code and data, and can be set by the ADDR command. By default, TMON points to itself.

The command input editor is very simple. Invalid inputs are typically ignored and result in the user simply being returned to the command prompt. The maximum command length accepted is 40 characters, however, presently the longest valid command possible is 9 characters in length. When the user's input exceeds the maximum command length, the TEC will emit a beep tone to indicate this condition has been reached. Backspace is supported, to correct typos.

All data entered at all times is assumed to be HEX - 4 bytes for addresses, 2 bytes for data. Invalid data input is ignored.

DATA mode

When the DATA command is given, TMON switches to interactive data entry mode. This is signified by the prompt changing as follows:

```
XXXX nn :
```

`XXXX` continues to represent the CURRENT ADDRESS however the `nn` represents the HEX byte stored at that address, which you are presently editing.

- Enter a **HEX byte** and it will be written to memory at CADDR; CURRENT ADDR is then incremented by one.
- **ENTER** increments CURRENT ADDRESS by one and leaves the existing value as-is. In this way, any bytes that don't need altering are skipped over.
- **-** decrements the CURRENT ADDRESS by one. This allows for correcting input errors by going back one address after erroneous input.
- **Q** exits data entry mode.

Invalid entries will be ignored.

The DATA entry system is very simple and will continue to be improved in future versions.

TMON Commands

HELP	**?**	**EXIT**
INTEL	**BEEP**	**BELL**
VER	**STATE**	**CLS**
RAMCHK	**GO [xxxx]**	**DUMP [xxxx]**
ADDR [xxxx]	**DATA [xxxx]**	**INC**
7SEG	**SMON**	**HALT**
DEBUG	**KEYTEST**	**FILL xxxx yyyy nn**
PRINT		

Parameters marked with square brackets e.g. \[xxxx\] are optional.

HELP
Displays help text

?
Display the list of commands

EXIT
Reboots the 1G back to MON3

INTEL
Calls the Intel Hex file transfer routine built into MON-3

BEEP
Beeps the 1G speaker

BELL
Sents the BELL command to the remote console

VER
Displays the version number of TMON and MON-3

STATE
Displays the state of the 1G system - SHADOW, PROTECT, EXPAND, CAPS LOCK

CLS
Sens a clear screen sequence to the remote console

RAMCHK
Runs a simple test to determine how much RAM is installed, and at what momentary address(e)s. Uses whichever bank EXPAND is set to, but does not alter the EXPAND state. Supports multiple discontinuous RAM blocks, if fitted.

GO xxxx
Executes code from the CURRENT ADDRESS, or from xxxx if supplied.

DUMP xxxx
DUMP the contents of 64 bytes of memory; provides HEX and ASCII outputs so memory can be examined.

DUMP pauses at completion - space repeats the command (CADDR continues to increment if auto-increment is on; otherwise the same block repeats). This allows you to quickly run through larger blocks without needing to type commands repeatedly.

Q quits and returns to the command prompt.

ADDR xxxx
Set the CURRENT ADDRESS. If no address is supplied, display the CADDR instead.

DATA xxxx
Interactively Input data into memory. Input one hex byte at a time; the value input is stored in the CADDR memory location.

Enter Q to quit input mode. See full description of DATA mode, above.

INC ON/OFF
Set auto-increment mode of CADDR. No parameter supplied = Display the current auto-increment mode. Sometimes turning auto-increment off is helpful for debugging or monitoring.

7SEG
Displays the CADDR and byte of memory on the TEC 7-seg displays. + and - keys increment/decrement CADDR. Pressing the ADDR key exits to TMON.

SMON
Serial data stream monitor. Accepts serial input from the terminal and displays the HEX bytes received on screen. Great for debugging terminal comms and understanding control codes received from the PC (e.g. VT100 sequences). This is a crude implementation but does display the limitations of the bit-bang serial in not being able to adequately buffer incoming bytes in real time (try pressing an arrow key or a PC function key).

Enter Q (capital) to exit SMON back to TMON.

If a terminal program such as Tera Term is used to add a small delay (e.g 20ms) between bytes transmitted from the PC, SMON can accurately show VT100 control codes such as a PC arrow or function key. Without the delay, the bit-bang serial normally gets the first byte only, or perhaps the first and fourth or fifth byte, hence demonstrating the limitations of the bit-bang interface.

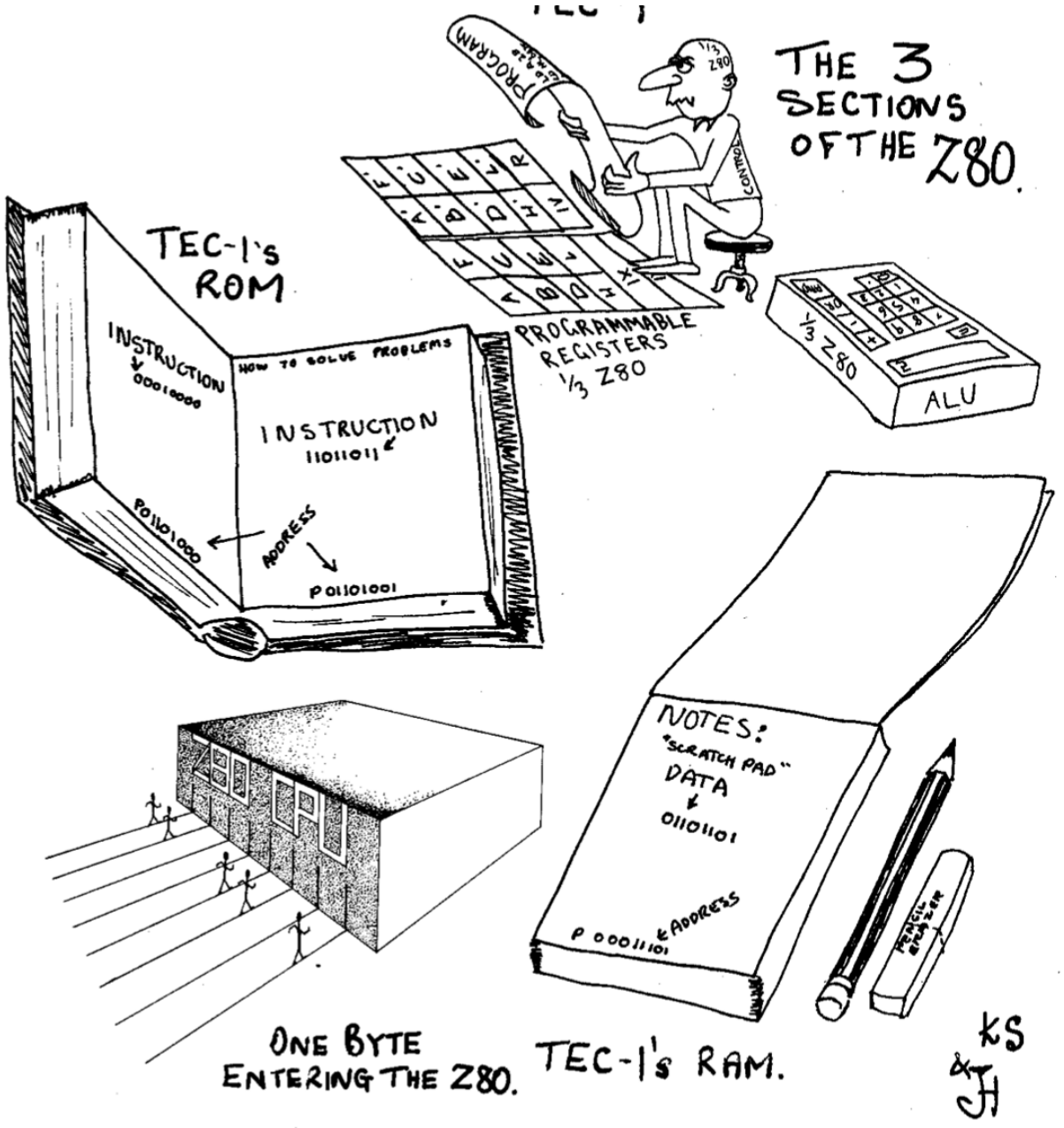
HALT
Executes a CPU HALT instruction - on TEC-1F, press any key to resume.

DEBUG
Calls the MON-3 debugger/breakpoint tool to examine register contents.

KEYTEST
Tests the selected keyboard - the last pressed key's scancode will appear on the 7-segment displays. **Fn** is displayed by bit 5 set. Matrix keypad keys supported by MON3 (*NOT* the full matrix keyset) will be returned if MATRIX mode is enabled. Pressing the ADDR key exits to TMON.

FILL xxxx yyyy nn
Fill memory between address xxxx and yyyy with data nn. note: Fill range must be at least 2 bytes long. Does not do any checks for safety - use with caution, as you can overwrite any area of memory including the stack, program code or data. This does not apply if Protect Mode is on.

PRINT your-text-here
your-text-here is echoed back to the serial terminal.



TEC Magazine Code on the TEC-1G

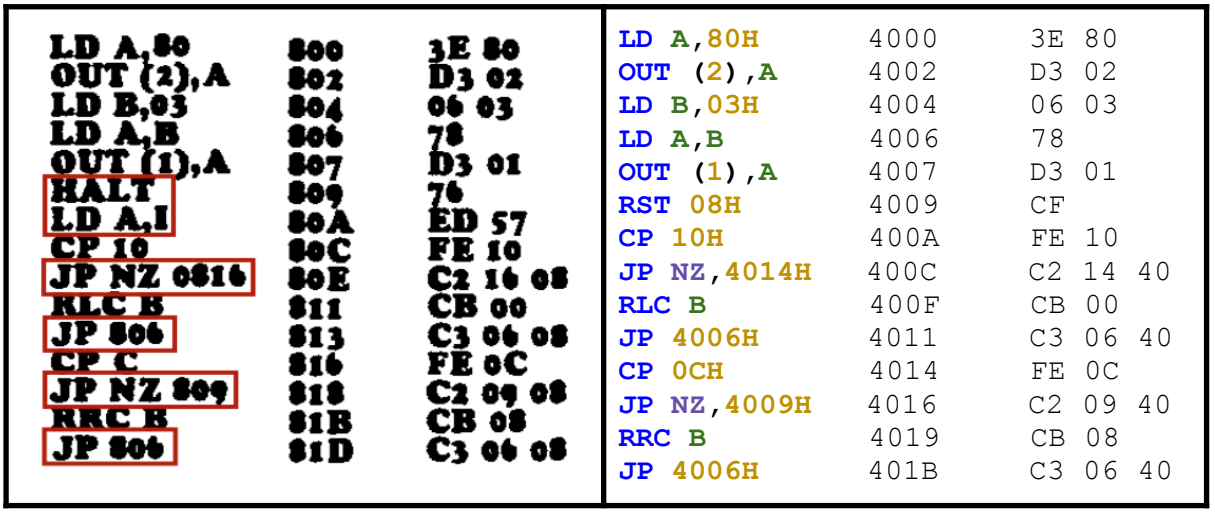
A great way to learn how to use the TEC-1G is to key in programs presented in the TE Magazines Issues 10 to 15. If the programs are keyed in directly, they probably won't work! This is because they usually start at address 0800H or 0900H. These addresses are reserved for Mon3. To get the code working, simply update all 2-byte address references to match the address location of the code on the 1G.

Keypad interactions are a bit more complicated. The old monitors use the register I and the NMI (Non-Maskable Interrupt) to trigger and save a keypad press. Mon3 uses 'Polling' instead and RST/API calls to do keypad reading. See the next chapter for more information on RST and API calls.

Below is a conversion table to help convert older code to work on Mon3 when a keypad press is required.

Old Command	Mon3 Replacement	Reason
HALT	RST 08H	RST 08H simulates a HALT command and sets register A with the key value pressed.
LD A,I	LD C,10H RST 10H	A LD A,I by itself is 'polling' for a key press. Call the scanKey API routine which sets register A with the key value pressed. If LD A,I is immediately after a HALT instruction, then just use RST 08H as described above.

Here is an example of magazine code at 0800H with key input converted to use Mon3 at RAM address 4000H. The code in RED has been modified.



```
LD A,80          $800    3E 80
OUT (2),A        $802    D3 02
LD B,03          $804    06 03
LD A,B           $806    78
OUT (1),A        $807    D3 01
HALT             $809    76
LD A,I           $80A    ED 57
CP 10            $80C    FE 10
JP NZ 0816       $80E    C2 16 08
RLC B            $811    CB 00
JP $806          $813    C3 06 08
CP C             $816    FE 0C
JP NZ $809       $818    C2 09 08
RRC B            $81B    CB 08
JP $806          $81D    C3 06 08
```

```
LD A,80H         4000    3E 80
OUT (2),A        4002    D3 02
LD B,03H         4004    06 03
LD A,B           4006    78
OUT (1),A        4007    D3 01
RST 08H          4009    CF
CP 10H           400A    FE 10
JP NZ,4014H      400C    C2 14 40
RLC B            400F    CB 00
JP 4006H         4011    C3 06 40
CP 0CH           4014    FE 0C
JP NZ,4009H      4016    C2 09 40
RRC B            4019    CB 08
JP 4006H         401B    C3 06 40
```

Advanced Programming

To assist when developing Z80 programs, Mon3 contains inbuilt functionality that makes it easy to interface with the TEC-1G hardware.

RST (Restart) commands

RST commands on the Z80 are one-byte call commands that execute code at certain address locations defined by the Z80. The following table outlines the routines.

Command	Op Code	Description
`RST 00H`	**C7**	Software monitor reset.

`RST 08H`	**CF**	Key wait and press routine. This simulates a HALT command where the TEC will wait for a key to be pressed and continue execution. If a key is currently being held down, the routine will wait first until the key is released and then detect the next key. The key that has been pressed will be stored in register A.
		
		`RST 08H ; Wait for keypress`
		`LD B,A ; Load key to register B`

`RST 10H`	**D7**	API entry call. Executes a monitor routine. See the API calls section below for more details.
`RST 18H`	**DF**	API 2 entry call. Graphical LCD routine entry. See the GLCD section below for more details.
`RST 20H`	**E7**	Scan Seven Segments and Key. Multiplex the seven-segment displays and check for a key press. It can be used to display information on the seven segments and check for a key to be pressed. It must be called in a loop until a key is pressed. Returns Zero flag set when a key is pressed and Register A with the key value. Register DE points to the seven-segment data. See the first program in the Quick Start Programs chapter for an example.

RST 28H	**EF**	LCD Busy Check. To be called prior to sending a command to the LCD if directly communicating with the LCD. The routine will only exit when the LCD Busy flag is not set.
		
		`RST 28H ; Check LCD busy flag`
		`LD A,01H ; Load A with clear screen`
		`OUT (04),A ; Send instruction to LCD`

RST 30H	**F7**	Breakpoint entry. Break execution of the code at the current address location. See the Debugging Programs chapter for more details.
RST 38H	**FF**	Maskable interrupt handler. Jumps here with Interrupts Enabled (**EI**), Interrupt Mode 1 (**IM 1**) and when the INT pin on the CPU goes low. Mon3 will do nothing when this happens. However, a user-defined routine can be used. See the Interrupt section below on how to do this.

Interrupts

The Z80 CPU has the ability to interrupt the execution of code, handle the interrupt and then resume code execution. This is done in software with Interrupts Enabled (**EI**) and Interrupt Mode 1 (**IM 1**) and by hardware when the INT line on the CPU goes low. Mon3 ignores interrupts, but a user-defined routine can be provided to handle the interrupt. To do this, the address of the interrupt routine is to be placed at RAM address **0892H**.

```
      ei              ; Enable interrupts
      im 1            ; Interrupt mode 1
      ld hl,myINT     ; Interrupt routine
      ld (0892H),hl   ; Save address in 0892H
      … continue

myINT:
      ld c,03H    ; Bell routine
      rst 10H     ; Call API
      reti        ; Exit Int routine
```

This code will sound a bell tone in the speaker when an interrupt occurs.

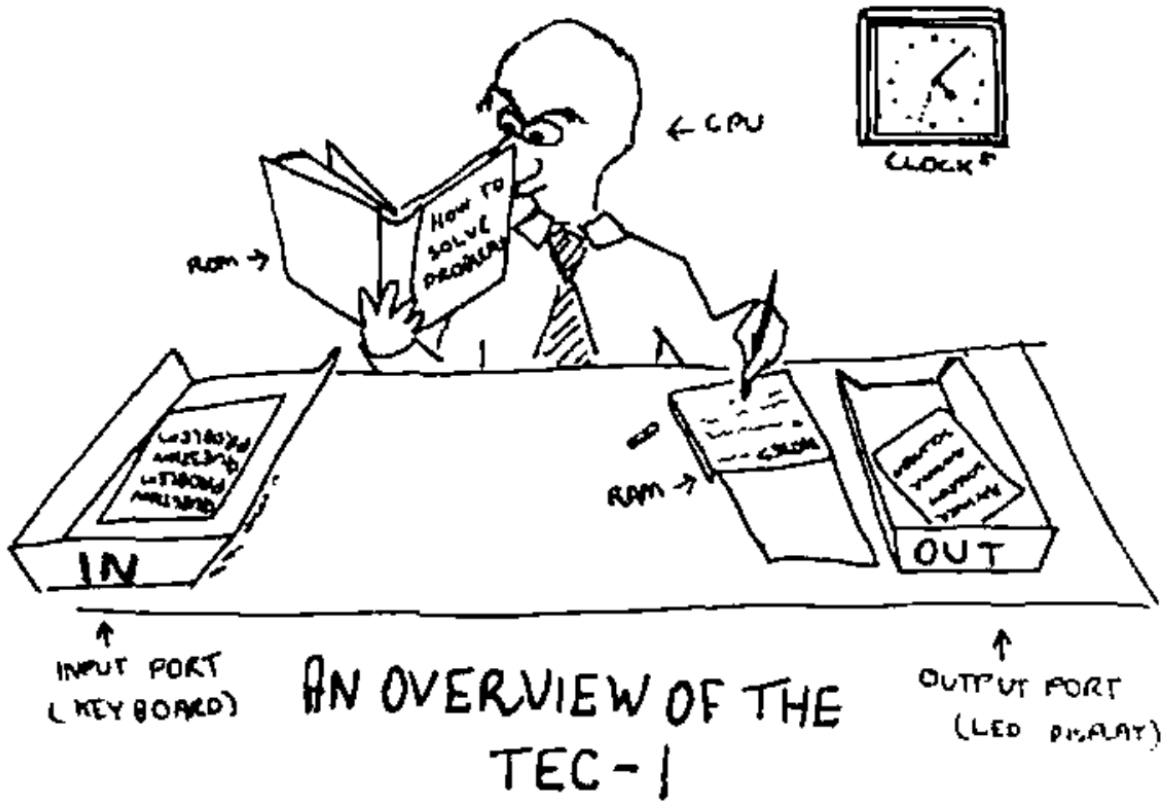
NMI (Non-Maskable Interrupts)

Non-Maskable Interrupts occur when the NMI line on the CPU goes low. These interrupts will always trigger. Mon3 ignores the NMI line, but a user-defined routine can be provided to handle the interrupt. To do this, the address of the interrupt routine is to be placed at RAM address **0894H**.

```
      ld hl,myNMI     ; NMI routine
      ld (0894H),hl   ; Save address in 0894H
      … continue

myNMI:
      ld c,03H    ; Bell routine
      rst 10H     ; Call API
      retn        ; Exit NMI routine
```

This code will sound a bell tone in the speaker when an NMI occurs. The TEC-1G has an NMI jumper that can set NMI to trigger on a Keypad press, a HALT instruction or externally (no jumper).



Credit: Ken Stone

API (Application Programming Interface) commands.

The API on Mon3 exposes routines used by Mon3 which can be used in your own programs. No need to rewrite the world! But more importantly, it makes writing code quicker and easier with most of the complicated stuff removed.

General conventions

The register **C** holds the API Call number. All other registers except the **IX** register can be used as parameters if needed. Executing a **RST 10H** or **D7** calls the API.

General Interface

```
        ld c,[API Call Number]
        rst 10H
```

Some Examples

```
            ;Produce a short Beep from the speaker
0E 03       ld c,3        ;beep call number
D7          rst 10H

            ;Display the letter 'G' on the LCD Screen
0E 0E       ld c,14       ;charToLCD call number
3E 47       ld a,"G"      ;parameter
D7          rst 10H

            ;Wait for a period of time
0E 21       ld c,33       ;timeDelay call number
21 00 30    ld hl,3000H ;parameter
D7          rst 10H
```

To assist with API call number references, the file `api_includes.z80`, in the GitHub repository, contains the API Call Number with its Text equivalent for use with your own code.

See https://github.com/MarkJelic/TEC-1G/tree/main/ROMs/MON3/source

API Calls list

Routine	#	0x
softwareID	0	0
versionID	1	01
preInit	2	02
beep	3	03
convAToSeg	4	04
regAToASCII	5	05
ASCIIToSegment	6	06
stringCompare	7	07
HLToString	8	08
AToString	9	09
scanSegments	10	0A
displayError	11	0B
LCDBusy	12	0C
stringToLCD	13	0D
charToLCD	14	0E
commandToLCD	15	0F
scanKeys	16	10
scanKeysWait	17	11
matrixScan	18	12
joystickScan	19	13
serialEnable	20	14
serialDisable	21	15
txByte	22	16
rxByte	23	17
intelHexLoad	24	18

Routine	#	0x
sendToSerial	25	19
receiveFromSerial	26	1A
sendAssembly	27	1B
sendHex	28	1C
genDataDump	29	1D
checkStartEnd	30	1E
menuDriver	31	1F
paramDriver	32	20
timeDelay	33	21
playNote	34	22
playTune	35	23
playTuneMenu	36	24
getCaps	37	25
getShadow	38	26
getProtect	39	27
getExpand	40	28
setCaps	41	29
setShadow	42	2A
setProtect	43	2B
setExpand	44	2C
toggleCaps	45	2D
toggleShadow	46	2E
toggleProtect	47	2F
toggleExpand	48	30
random	49	31

Routine	#	0x
setDisStart	50	32
getDisNext	51	33
getDisassembly	52	34
matrixScanASCII	53	35

API Utility Calls

softwareID #0
Get Software ID String

- `Input: nothing`
- `Return: HL = Pointer to SOFTWARE ASCII String`
- `Destroy: none`

versionID #1
Get Version Number and Version String

- `Input: nothing`
- `Return: HL = Pointer to Release ASCII String`
  `BC = Release major version number`
  `DE = Release minor version number`
- `Destroys: none`

preInit #2
Performs a cold reset as if the TEC-1G had just been powered on. Returns to MON3 to its default state.

beep #3
Makes a short beep tone to the TEC Speaker

- `Input: nothing`
- `Destroys: A`

convAToSeg #4
Convert register A to Seven Segment display format

- `Inputs: A = byte to convert`
  `DE = address to store segment values (2 bytes)`
- `Destroys: BC`

regAToASCII #5
Convert register A to ASCII. IE: **`2CH`** -> "2C"

- `Input: A = byte to convert`
- `Output: HL = two-byte ASCII string`
- `Destroys: A`

ASCIItoSegment #6
ASCII to Segment. Converts an ASCII character to Seven Segment display format

- `Input: A = ASCII character`
- `Return: A = Segment character or 0 if out of range`
- `Destroys: none`

stringCompare #7
Compare two string

- `Input: HL = source pointer`
  `DE = target pointer`
  `B = #bytes to compare (up to 256)`
- `Output: Zero Flag Set = compare match`
- `Destroys: HL, DE, A, BC`

HLToString #8
Convert HL to ASCII string. IE: **`2CH`** -> "2C"

- `Input: HL = value to convert`
  `DE = address of string destination`
- `Output: DE = address one after last ASCII entry`
- `Destroys: A`

AToString #9
Convert register A to ASCII string

- `Input: A = byte to convert`
  `DE = address of string destination`
- `Output: DE = address one after last ASCII entry`
- `Destroys: A`

scanSegments #10
Multiplex the Seven Segment displays with the contents of DE. Must be called repetitively for segments to stay persistent.

- `Inputs: DE = pointer to 6-byte location of segment data`
- `Destroys: A, B, DE = DE + 6`

displayError #11
Display ERROR on the Seven Segments and wait for keypress

- `Input: none`
- `Destroys: all`

API LCD Calls

LCDBusy #12
LCD busy check. Checks the LCD busy flag and loops until LCD isn't busy

- `Input: nothing`
- `Destorys: none`

stringToLCD #13
ASCII string to LCD. Writes a string (text) to the current cursor location on the LCD

- `Input: HL = ASCII string terminated with a zero byte`
- `Destroy: A, HL (moves to end of the list)`

```
TEXT: .db “HELLO TEC!”,0

      ld hl,TEXT
      ld c,13
      rst 10h
```

charToLCD #14
ASCII character to LCD. Writes one character to the LCD at the current cursor location

- `Input: A = ASCII character`
- `Destroy: none`

```
      ld a,”G”
      ld c,14
      rst 10h
```

commandToLCD #15
Command to LCD. Sends an LCD instruction to the LCD

- `Input: B = Instruction byte`
- `Destroy: none`

```
      ld b,01  ;clear LCD
      ld c,15
      rst 10h
```

API Input Calls

scanKeys #16

Universal Key input detection routine. Supports HexPad and Matrix. The routine does not wait for a key press the returns immediately. Only Hexpad keys are detected if using the Matrix Keyboard.

- Return: A = key value (if the following is met)
  zero flag set if a key is pressed
  carry flag set if press detected of a new key
  carry flag not set for a key pressed and held or if no key has been pressed
- Destroys: DE if using Matrix Keyboard

Key mapping returned in register A

0-F = 00-0F	Fn-0-F = 20-2F (Bit 5 set)
Plus = 10	Fn-Plus = 30
Minus = 11	Fn-Minus = 31
GO = 12	Fn-GO = 32
AD = 13	Fn-AD = 33

scanKeysWait #17

Generic Key input detection routine. Supports HexPad and Matrix. Waits until a key is pressed. The routine will only detect a key if all keys are released first. Only Hexpad keys are detected if using the Matrix Keyboard.

- Return: A = key value (if following are met)
- zero flag set if a key is pressed
- Destroys: DE if using Matrix Keyboard

See table above for return values in register A

joystickScan #19

Joystick port scan routines. This routine will return a value based on the movement/button of the joystick or any combination: IE: UP+DOWN = 03H, Routine must be called repetitively.

- Input: None
- Output: A = Joystick return value between 00H-5FH (0-95)
  01H = Up 10H = Fire 2
  02H = Down 20H = Comm2 (Pin 9)
  04H = Left 40H = Fire 1
  08H = Right 80H = Fire 3
  zero flag set if no joystick value returned
- Destroy: none

matrixScan #18

Key scan routine for the Matrix Keyboard. This routine detects up to two key presses at the same time. Key values stored in DE. The routine must be called repetitively.

- `Input: None`
- `Output: E = Key pressed between 00H-3FH (0-63)`
  `D = Second key, FF=no key,00=shift,01=Ctrl,02=Fn`
  `zero flag set if a key is pressed or combination valid`

Key mapping returned in register E (note: some gaps are present)

Shift = 00	Esc = 0C	4 = 17	D = 27	O = 32	Z = 3D
Ctrl = 01	Space = 0D	5 = 18	E = 28	P = 33	\ = 3F
Fn = 02	Single Qt = 0E	6 = 19	F = 29	Q = 34	
Up = 03	Comma = 0F	7 = 1A	G = 2A	R = 35	
Down = 04	Minus = 10	8 = 1B	H = 2B	S = 36	
Left = 05	F.Stop = 11	9 = 1C	I = 2C	T = 37	
Right = 06	/ = 12	; = 1E	J = 2D	U = 38	
Caps = 07	0 = 13	= = 20	K = 2E	V = 39	
Del = 08	1 = 14	A = 24	L = 2F	W = 3A	
Tab = 09	2 = 15	B = 25	M = 30	X = 3B	
Enter = 0A	3 = 16	C = 26	N = 31	Y = 3C	

matrixScanASCII #53

Convert the output of the matrixScan routine to ASCII. matrixScan returns values between `0` and `64`, these represent key presses on the keyboard. This routine will convert the output of matrixScan `DE`, to the actual key pressed in ASCII. If key doesn't map to an ASCII character then the matrix key value is returned.

- `Input: DE = value return from matrixScan.`
  `E = key, D = Secondary key`
- `Output: A = key pressed in ASCII`
- `Destroy: BC, HL`

Example code on using matrixScanASCII can be found in the Quick Start Programs chapter below.

API Serial Data Transfer Calls

serialEnable #20
Activates the BitBang serial port for serial transmit. Disco LED's glow blue to indicate ready status.

- `Input: none`
- `Destroy: A`

serialDisable #21
Deactivates the BitBang serial port for serial transmit. Disco LEDs turn off.

- `Input: none`
- `Destroy: A`

txByte #22
Bit Bang FTDI USB transmit routine. Send one byte via the FTDI USB serial connection. It assumes a UART connection of `4800-8-N-2`.

- `Input: A = byte to transmit`
- `Output: nothing`
- `Destroy: none`

rxByte #23
Bit Bang FTDI USB receive routine. Receive one byte via the FTDI USB serial connection. It assumes a UART connection of `4800-8-N-2`. Note routine will wait until a bit is detected.

- `Input: nothing`
- `Return: A = byte received`
- `Destroy: none`

intelHexLoad #24
Load an Intel Hex file via the FTDI USB serial connection. Displays file progress on the segments and PASS or FAIL at the end of the load. Intel Hex file format is a string of ASCII with the following parts:

MARK | LENGTH | ADDRESS | RECORD TYPE | DATA | CHECKSUM
`:10200000210621CD7D20CD98203A00213C320021AF` <- EXAMPLE LINE

MARK is a colon character, LENGTH is the number of bytes per line, ADDRESS is the 2-byte address of where the data is to be stored. RECORD TYPE is 00 for Data and 01 for EOF. DATA is the bytes to be stored. CHECKSUM is the addition of all bytes in one line.

- Input: nothing
- Output: nothing
- Destroy: HL,DE,BC,A

sendToSerial #25
SIO Binary Dump. Transfer data on the TEC to a serial terminal. From and To address data is needed and input.

- Input: 2 byte from address = Stored in RAM at address 08C0H
- 2 byte to address = Stored in RAM at address 08C2H
- Destroys: A,HL,DE,BC

receiveFromSerial #26
SIO receive binary data. Receive binary data from FTDI. From and To address data is needed and input.

- Input: 2 byte from address = Stored in RAM at address 08C0H
- 2 byte to address = Stored in RAM at address 08C2H
- Destroys: A,HL,DE,BC

sendAssembly #27
Send Assembly instructions to the serial port. Print out the disassembled code that is on the TEC in readable assembly language on the serial terminal. From and To address data is needed and input.

- Input: 2 byte from address = Stored in RAM at address 08C0H
  2 byte to address = Stored in RAM at address 08C2H
- Destroys: A,HL,DE,BC

sendHex #28
Send a traditional HEX dump as text to the serial terminal. Upto 16 bytes are displayed per line. From and To address data is needed and input.

- Input: 2 byte from address = Stored in RAM at address 08C0H
  2 byte to address = Stored in RAM at address 08C2H
- Destroys: A,HL,DE,BC

genDataDump #29
Generate data dump in ASCII. Print the Address and then B number of bytes. This routine is a subroutine in the _sendHex routine.

- `Input: B = number of bytes to display`
- `HL = start address of data dump`
- `DE = address of string destination`
- `Output: DE = zero terminated address one after last ASCII entry`
  `IE: "4000: 23 34 45 56 78 9A BC DE",0`
- `Destroys: A, HL (moves to next address after last byte)`

API Menu & Parameter Calls

checkStartEnd #30
Check start and end address difference.

- `Input: HL = address location of START value`
  `HL+2 = address location of END value`
- `Output: HL = start address`
  `BC = length of end-start`
  `Carry = set if end is less than start`
- `Destroys: DE`

menuDriver #31
Menu driver for user programs. Creates a selectable custom menu. Keys: Go = Select menu item, AD = Exit Menu, Plus/Minus = Navigate menu

- `Input: HL = Pointer to Menu configuration.`
- `Destroys: A, HL`

Menu configuration is as follows. All strings are ZERO terminated!

```
<Menu Entries>, <Menu Text Title>, [<Menu Text Label>,
<Menu Routine Address>]+
  EG: .db 2                  ; Two menu items
      .db "Games",0          ; Menu title
      .db "TEC Invaders",0   ; Text and Routine
      .dw invaders
      .db "TEC Maze",0       ; Text and routine
      .dw maze
```

paramDriver #32

Parameter data entry driver. Creates a list of editable two-byte parameters. Keys: Go = Continue, AD = Exit, Plus/Minus = Navigate, 0-F = enter values

- `Input: HL = Pointer to Parameter configuration.`

Parameter text can be no longer than 14 characters. All strings are ZERO terminated! Parameters entered will be stored in the Param RAM Address locations. Parameter configuration is as follows.

```
<No. of Entries>, <Parameter Title Text>, [<Param Text
Label>, <Param RAM Address>]+
  EG: .db 3                          ; Three parameters
      .db "= Enter Parameters =",0   ; Parameter title
      .db "Start Address:",0         ; Text and Address
      .dw COPY_START
      .db "End Address:",0           ; Text and Address
      .dw COPY_END
      .db "Dest. Address:",0         ; Text and Address
      .dw COPY_DEST
```

Menu and Parameter Driver Example

Create a Menu with 3 items. The first two items will jump to routines and the last item will create a parameter entry list of four 2-byte items.

```
MENUDRIVER   .EQU 1FH   ;Menu API
PARAMDRIVER  .EQU 20H   ;Param API

PROGRAM1     .EQU 1000H ;Program 1
PROGRAM2     .EQU 1800H ;Program 2

PARAM1       .EQU 2000H ;two bytes
PARAM2       .EQU 2002H ;per param
PARAM3       .EQU 2004H
PARAM4       .EQU 2006H

;Create Menu
0E 1F     ld c,MENUDRIVER
21 00 30  ld hl,menuCFG ;config
D7        rst 10H ;API call
C9        ret

;Create Parameter Entry
createParam:
0E 20     ld c,PARAMDRIVER
21 80 30  ld hl,paramCFG ;config
D7        rst 10H ;API call
...       ;Handle parameters here
```

```
;Menu Configuration
            .ORG 3000H
menuCFG:
    .db 3    ;three entries
    .db "= MENU TITLE =",0
    .db "Program 1",0
    .dw PROGRAM1
    .db "Program 2",0
    .dw PROGRAM2
    .db "Parameters",0
    .dw createParam

;Parameter Entry Configuration
            .ORG 3080H
paramCFG:
    .db 4    ;four entries
    .db "= PARAM TITLE =",0
    .db "Start Address",0
    .dw PARAM1
    .db "End Address",0
    .dw PARAM2
    .db "Copy Address",0
    .dw PARAM3
    .db "Backup Address",0
    .dw PARAM4
```

API Sound Calls

playNote #34

Play a note. Play a note with a given frequency and wavelength

- `Input: HL = frequency (01-7F)`
  `B = wavelength (00-FF)`
- `Destroys: HL, BC, A`

playTune #35

Play a series of notes. To play a note use a reference between `01H` and `18H`. Where `01H` is the lowest frequency and `18H` is the highest frequency. Use `00H` for a pause and any value greater than `18H` to exit. A single pause can be used to separate notes.

Note reference table is as follows:

G	01H	C#	07H	G	0DH	C#	13H
G#	02H	D	08H	G#	0EH	D	14H
A	03H	D#	09H	A	0FH	D#	15H
A#	04H	E	0AH	A#	10H	E	16H
B	05H	F	0BH	B	11H	F	17H
C	06H	F#	0CH	C	12H	F#	18H

- `Input: DE = Address of first note`
- `Destroy: A,B,DE,HL`

playTuneMenu #36

Play a series of notes with the _playTune routine, but address of first note is selected via a parameter menu.

- `Input: none`
- `Destroy: A,B,DE,HL`

API System Latch Calls

getCaps #37
Get Caps lock state

- `Input: none`
- `Output: A = caps lock state; 0 = off, 80H = on`

getShadow #38
Get SHADOW state

- `Input: none`
- `Output: A = shadow state; 0 = off, 01H = on`

getProtect #39
Get PROTECT state

- `Input: none`
- `Output: A = protect state; 0 = off, 02H = on`

getExpand #40
Get EXPAND state

- `Input: none`
- `Output: A = expand state; 0 = off, 04H = on`

setCaps #41
Set Caps lock state

- `Input: A = Desired caps lock state; 0 = off, 80H = on`
- `Destroy: A`

setShadow #42
Set Shadow state

- `Input: A = Desired shadow state; 0 = off, 01H = on`
- `Destroy: A`

setProtect #43
Set Protect state

- `Input: A = Desired protect state; 0 = off, 02H = on`
- `Destroy: A`

setExpand #44
Set Expand state

- `Input: A = Desired expand state; 0 = off, 04H = on`
- `Destroy: A`

toggleCaps #45
Toggle Caps Lock state

- `Input: none`
- `Destroy: A`

toggleShadow #46
Toggle Shadow state

- `Input: none`
- `Destroy: A`

toggleProtect #47
Toggle Protect state

- `Input: none`
- `Destroy: A`

toggleExpand #48
Toggle Expand state

- `Input: none`
- `Destroy: A`

Miscellaneous Calls

timeDelay #33
A 16-bit delay routine. An input delay of `2000H` is approximately 50ms.

- `Input: HL = delay amount`
- `Destroys: none`

random #49
Random number generator. Return a random number between `00H-FFH`

- `Input: none`
- `Output: A = pseudo-random number`
- `Destroy: B`

setDisStart #50
Set Disassembly start address. Set the first address for disassembly output

- `Input: HL = start address`
- `Output: none`
- `Destroy: none`

getDisNext #51
Get Disassembly next address. The new start address for the next output.

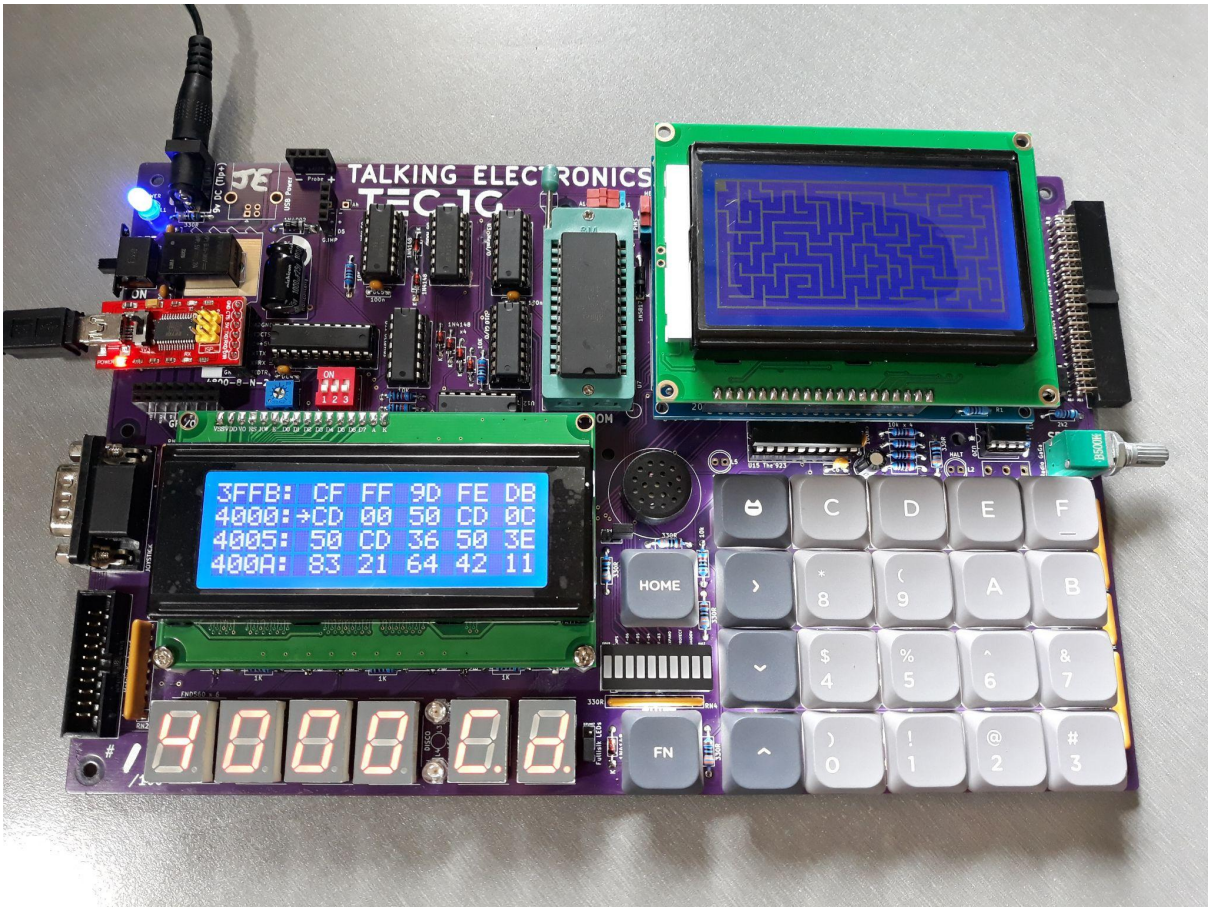
- `Input: none`
- `Output: HL = start address`
- `Destroy: none`

getDisassembly #52
Generate Disassembly line. Must call **setDisStart** prior. Only need to call **setDisStart** once as the next address is automatically increased.

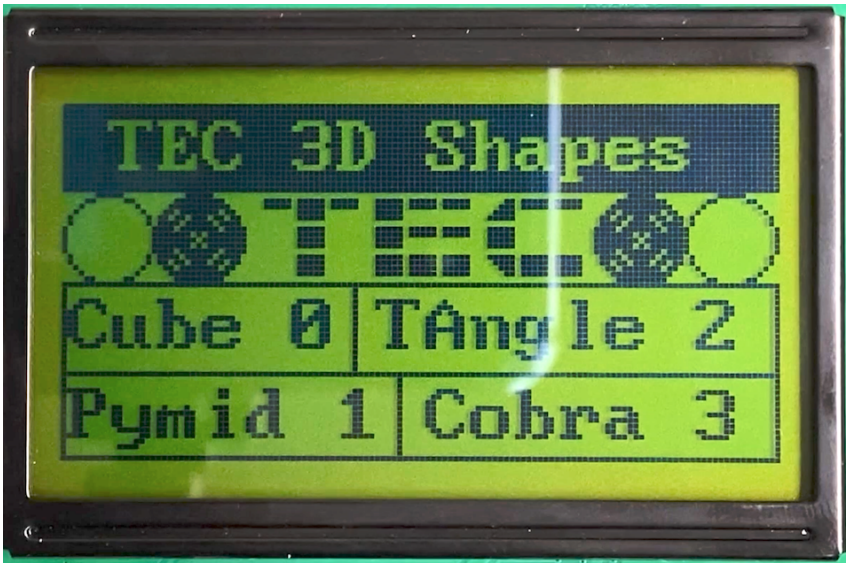
- `Input: none`
- `Output: HL = pointer to disassembly ASCII, zero terminated`
- `Destroy: none`

Graphical LCD Add-On Interface

Mon3 includes a Graphical LCD (GLCD) library that will work with the TEC-DECK Graphical LCD PCB Add-On. If the Graphical LCD is installed on the TEC-1G via the TEC-DECK headers, special GLCD API calls can be used to interface with the GLCD. The library is for GLCDs with the **ST7920** chip.



The GLCD library contains a variety of routines that can produce simple shapes and lines, these include text, lines, rectangles, circles and pixels.



General Conventions

The register **A** holds the API Call number. All other registers except the **IX** register can be used as parameters if needed. Executing a **RST 18H** or **DF** calls the GLCD API.

General Interface

```
        ld a,[API Call Number]
        rst 18H
```

The following code will draw a box and write text to the GLCD

```
          ; Initialise and set to Graphics Mode
3E 00     ld a,0            ; Initialise GLCD
DF        rst 18H
3E 04     ld a,4            ; Graphics Mode
DF        rst 18H

          ; Draw Box - Box Outline Example
01 20 00  ld bc,0020H       ; X0, Y0
11 3F 7F  ld de,7F3FH       ; X1, Y1
3E 06     ld a,6 ; Draw a outline box from X0,Y0 to X1,Y1
DF        rst 18H

          ; Plot Graphics to LCD Screen (must do)
3E 0C     ld a,12           ; Plot To LCD
DF        rst 18H

          ;Write Text to the Screen
3E 05     ld a,5            ; Text Mode
DF        rst 18H
0E 01     ld c,01H          ; Row 1
3E 0D     ld a,13           ; Print String
DF        rst 18H
54 45 43 2D 31 47 00 .db "TEC-1G",0
```

initLCD must be called at the start of every program. The GLCD has two modes, Text and Graphics. Both Text and Graphics can be displayed at the same time. These modes must be selected prior to the drawing or text routine. Also, **plotToLCD** must be called to display any graphics drawn to the screen. The above example displays these to principals.

GLCD API Calls list

Routine	#	0x
initLCD	0	0
clearGBUF	1	01
clearGrLCD	2	02
clearTxtLCD	3	03
setGrMode	4	04
setTxtMode	5	05
drawBox	6	06
drawLine	7	07
drawCircle	8	08
drawPixel	9	09
fillBox	10	0A

Routine	#	0x
fillCircle	11	0B
plotToLCD	12	0C
printString	13	0D
printChars	14	0E
delayUS	15	0F
delayMS	16	10
setBufClear	17	11
setBufNoClear	18	12
clearPixel	19	13
flipPixel	20	14

GLCD API Configure Calls

initLCD #0

Initalise the LCD Screen. This routine is to be called before any other routine.

- `Input: nothing`
- `Destroy: All`

clearGBUF #1

Clear the Graphics Buffer. The Graphics Buffer or GBUF is the internal memory area that contains pixel data for the LCD. The drawing routines write data to the GBUF. Once all pixels are set, this buffer is then plotted to the LCD with the **plotToLCD** Routine. Clearing the GBUF is a good way to ensure the pixel area is empty.

- `Input: nothing`
- `Destroy: All`

clearGrLCD #2
Clear the Graphics LCD Screen. This routine clears the GDRAM or Graphics screen on the LCD.

- `Input: nothing`
- `Destroy: All`

clearTxtLCD #3
Clear the Text LCD Screen. This routine clears the DDRAM or Text screen on the LCD.

- `Input: nothing`
- `Destroy: All`

setGrMode #4
Set the LCD to Graphics Mode. This routine puts the LCD in Graphics mode (Extended Instructions) and any further instructions to the LCD will be for the graphics screen. It only needs to be called once if multiple graphics routines are used.

- `Input: nothing`
- `Destroy: AF,DE`

setTxtMode #5
Set the LCD to Text Mode. This routine puts the LCD in Text mode (Basic Instructions) and any further instructions to the LCD will be for the text screen. It only needs to be called once if multiple text routines are used.

- `Input: nothing`
- `Destroy: AF,DE`

drawBox #6

Draws a single-line rectangle between two points X1, Y1 and X2, Y2.

- Input: B = X1-coordinate (0-127)
  C = Y1-coordinate (0-63)
  D = X2-coordinate (0-127)
  E = Y2-coordinate (0-63)
- Destroy: AF,HL

```
ld bc,0020H     ;X0, Y0
ld de,7F3FH     ;X1, Y1
ld a,6          ;drawBox
rst 18H
```

drawLine #7

Draws a straight line between X1, Y1 and X2, Y2. Uses the Bresenham Line drawing algorithm. http://members.chello.at/~easyfilter/bresenham.html

- Input: B = X1-coordinate (0-127)
  C = Y1-coordinate (0-63)
  D = X2-coordinate (0-127)
  E = Y2-coordinate (0-63)
- Destroy: All

```
ld bc,0010H     ;X0, Y0
ld de,7F30H     ;X1, Y1
ld a,7          ;drawLine
rst 18H
```

drawCircle #8

Draws a circle from a midpoint to a radius.

- Input: B = Mid-X-coordinate (0-127)
  C = Mid-Y-coordinate (0-63)
  E = Radius (1-63)
- Destroy: All

```
ld bc,0818H     ;Mid X, Mid Y
ld e,08H        ;Radius
ld a,8          ;drawCircle
rst 18H
```

drawPixel #9
Draws a single Pixel.

- Input: B = X-coordinate (0-127)
  C = Y-coordinate (0-63)
- Destroy: AF,HL

```
ld bc,4020H    ;X,Y
ld a,9         ;drawPixel
rst 18H
```

fillBox #10
Draws a filled rectangle between X1, Y1 and X2, Y2.

- Input: B = X1-coordinate (0-127)
  C = Y1-coordinate (0-63)
  D = X2-coordinate (0-127)
  E = Y2-coordinate (0-63)
- Destroy: AF,HL

```
ld bc,0020H    ;X0, Y0
ld de,7F3FH    ;X1, Y1
ld a,10        ;fillBox
rst 18H
```

fillCircle #11
Draws a filled circle from a midpoint to a radius. This routine iteratively calls the **drawCircle** routine increasing the radius until it equals the register E. There might be gaps in the filled circle, but hey it looks just like what you get on a BASIC program.

- Input: B = Mid-X-coordinate (0-127)
  C = Mid-Y-coordinate (0-63)
  E = Radius (1-63)
- Destroy: All

```
ld bc,1018H    ;Mid X, Mid Y
ld e,08H       ;Radius
ld a,11        ;fillCircle
rst 18H
```

plotToLCD #12
This routine draws the Graphics Buffer or GBUF to the Graphics LDC screen. It is usually called after one of the drawing routines is called. This routine must be called for any graphics to appear on the GLCD

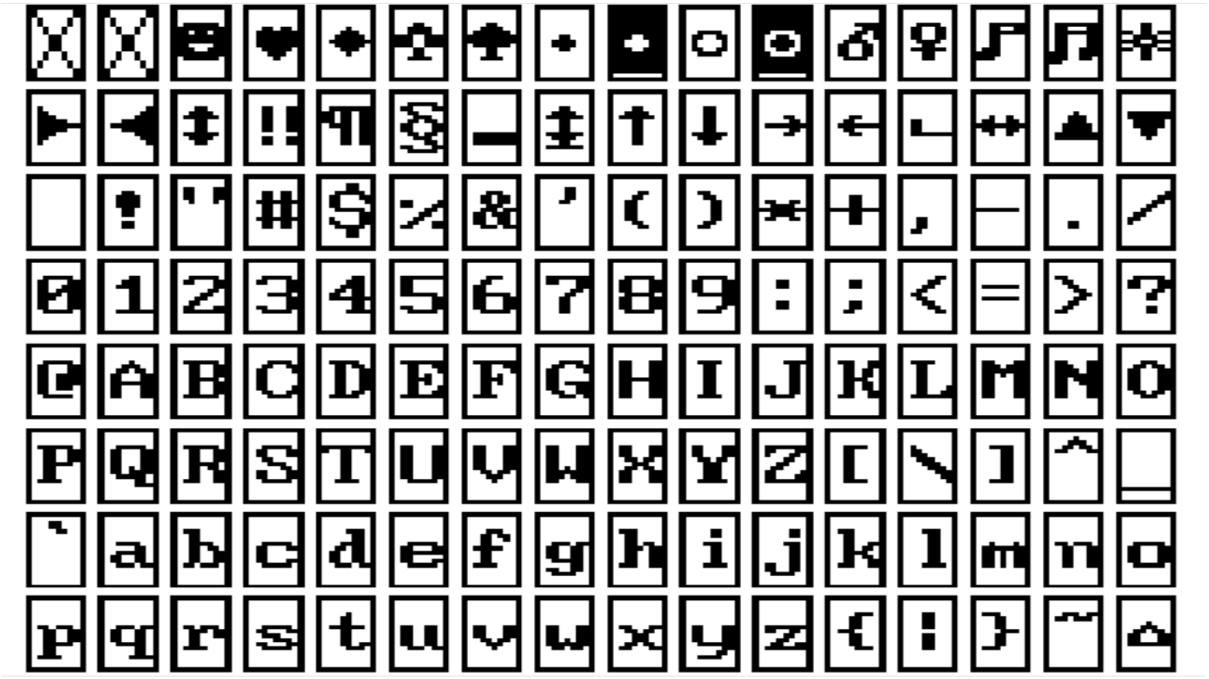
- `Input: nothing`
- `Destroy: All`

GLCD API Text Calls

printString #13
Prints ASCII text on a given row. There are 4 text rows on the LCD screen. The text is to be defined directly **after** the `RST 18H` routine and is to be terminated with a zero.

- `Input: C = row number (0-3)`
  `Text = "String" on the next line, terminate with 0`
- `Destory: All`

```
ld c,02H        ;Row 2
ld a,13         ;printString
rst 18H
.db 02H, " This Text ", 1BH ,00H
```



There are 128 characters that are available from `00H-7FH`. Conveniently, Alphanumeric characters align with the ASCII table.

printChars #14
Print Characters on the screen in a given row and column. This routine is similar to the one above but character row *and* column placement can be made. Characters to be printed are to be terminated with a zero.

Even though there are 16 columns, only every second column can be written to and two characters are to be printed. IE: if one character is to be printed in column 2, then set B=0 and print " x", putting a space before the character.

- Input: B = column (0-7)
  C = row (0-3)
  HL = start address of text data
- Destroy: All. (HL will be at the end of the text data)

```
ld hl,TEXT_DATA
ld bc,0102H     ;Column 1, Row 2
ld a,14         ;printChars
rst 18H
...
TEXT_DATA:
.db "Hello!",0
```

GLCD API Utility Calls

delayUS #15
Delay loop for LCD to complete its instruction. Every time a command is sent to the LDC, it requires a small amount of time to complete that operation. IE: setting extended instruction mode. The time needed for most operations is defined in the LDC specification. It is usually around 72us. This routine is used internally, but can also be used directly. The delay time depends on how fast the CPU is running.

- Input: nothing
- Destroy: AF,DE

```
ld a,02H    ;Home instruction
out (07),a  ;send instruction to GLCD
ld a,15     ;delayUS
rst 18H
```

delayMS #16
This is the same as the above routine, but the delay can be software controlled.

- Input: DE = delay value
- Destroy: AF,DE

```
ld a,01H    ;Clear instruction
out (07),a  ;send instruction to GLCD
ld de,0050H ;longer delay
ld a,16     ;delayMS
rst 18H
```

setBufClear #17
On every **_plotToLCD** call, clear the graphics buffer GBUF. Calling this routine will clear the graphics buffer on every draw to LCD. This is useful if doing animation that requires a new drawing to be displayed on every plot or frame.

- Input: none
- Destroy: AF

setBufNoClear #18
Do not clear the graphics buffer on every **plotToLCD**. Calling this routine will not clear the graphics buffer on every draw to LCD. This is useful for adding graphics data to an existing drawing.

- Input: none
- Destroy: AF

clearPixel #19
Removes or clears a single Pixel from the LCD.

- Input: B = X-coordinate (0-127)
  C = Y-coordinate (0-63)
- Destroy: AF,HL

```
ld bc,4020H     ;X,Y
ld a,19         ;clearPixel
rst 18H
```

flipPixel #20
Inverts a single Pixel. If the Pixel is on, it will turn off and if the Pixel is off, it will turn on.

- `Input: B = X-coordinate (0-127)`
  `C = Y-coordinate (0-63)`
- `Destroy: AF,HL`

```
ld bc,4020H     ;X,Y
ld a,20         ;flipPixel
rst 18H
```

GLCD Examples

Provided in the TEC-1G GitHub repository are three GLCD programs. The programs have already been converted to Intel Hex files and are ready to load onto the TEC. All programs start at address **2000H**. Source code for all programs are provided and can be changed and studied.

The TEC-1G GitHub account is here: https://github.com/MarkJelic/TEC-1G and the GLCD examples are in the TEC-Deck/Graphical_LCD directory.

lcd_3d_demo
Draw 3D wireframe graphics and rotate them. This program requires keypad input to rotate the objects. Buttons 4,8 and C rotate the object in the 3-axis. Plus and Minus will zoom the object in and out. 0 will return to the main menu. Pressing GO will exit the program

lcd_mad_program
Draw the face of Alfred E. Neuman. This program draws lines between two points and creates the face of the Mad Magazine mascot. It generates similar to how it would using the BASIC language. But if the program is run at **2022H** it will generate instantly. https://meatfighter.com/mad/

lcd_maze_gen
Create a maze. This program generates a maze using a recursive backtracking algorithm. Watch the maze slowly generate before your eyes.

Some easy-to-type examples have also been provided in the Quick Start Programs chapter below.

Quick Start Programs

Who wants the TEC-1G to say Hello? Here are three different ways the TEC can do this. Only a summary of the programs has been provided, making the examples a good exercise for learning how they work. The programs utilise Mon3 API routines as discussed in the Advanced Programming chapter.

This routine is the shortest. It will display the data at **4009** using **RST 20** to multiplex and key scan. If the AD key is pressed the routine will exit. Data at **4009** is hardcoded to display HELLO on the seven segments

```
4000 11 09 40    LD DE,4009
4003 E7          RST 20
4004 FE 13       CP 13
4006 20 F8       JR NZ,4000
4008 C9          RET
4009 6E C7 C2    .db 6E C7 C2
400B C2 EB 18    .db C2 EB 18
```

This routine will display HELLO on the LCD Screen. It firstly clears the LCD by calling **commandToLCD** and then calling **stringToLCD** to display a zero-terminated ASCII string. Press the AD key to exit.

```
4000 06 01       LD B,01
4002 0E 0F       LD C,0F
4004 D7          RST 10
4005 21 11 40    LD HL,4011
4008 0E 0D       LD C,0D
400A D7          RST 10
400B CF          RST 08
400C FE 13       CP 13
400E 20 FB       JR NZ,400B
4010 C9          RET
4011 48 45 4C    .db "HEL"
4014 4C 4F 21 00 .db "LO!",0
```

This routine will convert the ASCII "HELLO!" to seven segment code using the **ASCIItoSegment** routine. Then it will use **RST 20** to multiplex and key scan. Change the ASCII at **401A** to display something different.

```
4000 21 1A 40    LD HL,401A
4003 11 20 20    LD DE,2020
4006 06 06       LD B,06
4008 0E 06       LD C,06
400A 7E          LD A,(HL)
400B D7          RST 10
400C 12          LD (DE),A
400D 23          INC HL

400E 13          INC DE
400F 10 F9       DJNZ 400A
4011 11 20 20    LD DE,2020
4014 E7          RST 20
4015 FE 13       CP 13
4017 20 F8       JR NZ,4011

4019 C9          RET
401A 48 45 4C    .db "HEL"
401D 4C 4F 21    .db "LO!"
```

Matrix Keyboard echo to the Serial Terminal

This program demonstrates how to read in key presses from the Matrix Keyboard, convert the keys to ASCII, handle key bounce and send the ASCII to a serial terminal. *Fun Task*: Modify the program to display on the LCD.

```
MATRIXSCAN        .EQU 12H
SERIALENABLE      .EQU 14H
TXBYTE            .EQU 16H
TOGGLECAPS        .EQU 2DH
MATRIXSCANASCII   .EQU 35H
KEY_VALUE         .EQU 2000H        ;RAM location of key value

4000 0E 14        LD C,SERIALENABLE ;set serial to send bytes
4002 D7           RST 10H           ;API call
4003 0E 12        LD C,MATRIXSCAN   ;Scan the keyboard
4005 D7           RST 10H           ;API call
4006 28 06        JR Z,400E         ;valid key has been pressed
4008 AF           XOR A             ;reset last key pressed
4009 32 00 20     LD (KEY_VALUE),A
400C 18 F5        JR 4003           ;get next key
400E 3E 07        LD A,07H          ;is the key CAPS LOCK?
4010 BB           CP E
4011 20 09        JR NZ,401C        ;no, then skip caps toggle
4013 3A 00 20     LD A,(KEY_VALUE)  ;was the previous key CAPS?
4016 BB           CP E
4017 28 03        JR Z,401C         ;yes, then skip caps toggle
4019 0E 2D        LD C,TOGGLECAPS   ;toggle caps lock flag
401B D7           RST 10H           ;API call
401C 0E 35        LD C,MATRIXSCANASCII ;convert to ASCII
401E D7           RST 10H           ;API call
401F FE 03        CP 03H            ;ignore Shift,Ctrl or Fn if
4021 38 E0        JR C,4003         ;first key pressed
4023 4F           LD C,A
4024 3A 00 20     LD A,(KEY_VALUE)  ;ignore key if its the same
4027 B9           CP C              ;as the previous key
4028 28 D9        JR Z,4003
402A 79           LD A,C
402B 32 00 20     LD (KEY_VALUE),A  ;store new key pressed
402E 0E 16        LD C,TXBYTE       ;send key pressed to serial
4030 D7           RST 10H           ;API call
4031 18 D0        JR 4003           ;loop back to matrixScan
```

Seven Segment Scroller via the Serial Terminal

This program reads in text from the serial terminal and scrolls the text on the Seven Segment Displays. Pressing Enter (Carriage Return) will start the scroll. It uses **ASCIITOSEGMENT** to convert ASCII to Seven Segment Display format. *Fun Task*: Modify the program to display text on the LCD.

```
ASCIITOSEGMENT    .EQU 06H
SERIALENABLE      .EQU 14H
TXBYTE            .EQU 16H
RXBYTE            .EQU 17H
START_STR         .EQU 2000H          ;Start of string address
ASCII_STR         .EQU 2002H          ;RAM location of ASCII text

4000 0E 14        LD C,SERIALENABLE ;set serial to send bytes
4002 D7           RST 10H           ;API call
4003 11 02 20     LD DE,ASCII_STR   ;set DE to store ASCII
4006 0E 17        LD C,RXBYTE       ;get a byte from terminal
4008 D7           RST 10H           ;API call
4009 FE 0D        CP 0DH            ;is the byte a CR?
400B 28 0A        JR Z,4017         ;yes jump to scroll routine
400D 0E 16        LD C,TXBYTE       ;echo byte back to terminal
400F D7           RST 10H           ;API call
4010 0E 06        LD C,ASCIITOSEGMENT ;convert ASCII to 7-Seg
4012 D7           RST 10H           ;API call
4013 12           LD (DE),A         ;save modified ASCII
4014 13           INC DE            ;move to next RAM location
4015 18 EF        JR 4006           ;loop for more input
4017 3E FF        LD A,0FFH         ;place FF at end of string
4019 12           LD (DE),A
401A 21 02 20     LD HL,ASCII_STR   ;scroll loop starts here
401D 22 00 20     LD (START_STR),HL ;reset to start of string
4020 26 00        LD H,00H          ;set timer to zero
4022 ED 5B 00 20  LD DE,(START_STR) ;point to start of string
4026 E7           RST 20H           ;scan segments & scan keys
4027 C8           RET Z             ;if key is pressed, exit
4028 25           DEC H             ;delay for full 256 bytes
4029 20 F7        JR NZ,4022        ;repeat multiplex
402B 1A           LD A,(DE)         ;check to see if FF is
402C 3C           INC A             ;the next char to display
402D 28 EB        JR Z,401A         ;it is, go back to begining
402F 21 00 20     LD HL,START_STR   ;shift start by one address
4032 34           INC (HL)          ;(max 254 characters!)
4033 18 EB        JR 4020           ;display scroll again
```

Two GLCD demos are provided to demonstrate how to use the GLCD API calls. The first example is a circle animation that uses graphics mode and the second displays all known fonts on the GLCD which uses text mode.

Making Bubbles

This program first sets up the LCD to use Graphics and ensures that on every plotToLCD the internal graphics buffer is cleared. This makes the circle animate. Then a circle is expanded until it reaches the end of the screen. A beep is played and the code is repeated.

```
INITLCD         .EQU 0
SETGRMODE       .EQU 4
DRAWCIRCLE      .EQU 8
PLOTTOLCD       .EQU 12
SETBUFCLEAR     .EQU 17
BEEP            .EQU 3
TIMEDELAY       .EQU 33

4000 3E 00      LD A,INITLCD        ;Initialise the GLCD
4002 DF         RST 18H
4003 3E 04      LD A,SETGRMODE      ;Set Grahpics Mode
4005 DF         RST 18H
4006 3E 11      LD A,SETBUFCLEAR    ;Set Gr Buffer to Clear
4008 DF         RST 18H
4009 0E 03      LD C,BEEP           ;Play a Beep
400B D7         RST 10H
400C 1E 01      LD E,1              ;Set initial radius to 1
400E 01 20 40   LD BC,4020H         ;Set X,Y to mid screen
4011 C5         PUSH BC             ;Save BC/DE
4012 D5         PUSH DE
4013 3E 08      LD A,DRAWCIRCLE     ;Draw Circle
4015 DF         RST 18H
4016 3E 0C      LD A,PLOTTOLCD      ;Output to LCD
4018 DF         RST 18H
4019 0E 21      LD C,TIMEDELAY      ;Wait a bit
401B 21 00 40   LD HL,4000H
401E D7         RST 10H
401F D1         POP DE              ;Restore BC/DE
4020 C1         POP BC
4021 1C         INC E               ;Increase radius by 1
4022 CB 6B      BIT 5,E             ;Check if bubble hits edge
4024 20 E3      JR NZ,4009          ;Yes, reset radius
4026 18 E9      JR 4011             ;No, redraw circle
```

GLCD Font Display

This program cycles through all stored fonts on the GLCD. Characters on the GLCD are stored in the Character Generator ROM (CGROM). The program sets up the LCD for text mode and displays characters on the screen. Press any key to continue. The code also uses the GLCD ports directly, skipping the API. This is perfectly fine to do. See the ST7920 manual on how to send instructions directly to the GLCD.

```
INITLCD         .EQU 0
SETTXTMODE      .EQU 5
PRINTSTRING     .EQU 13
DELAYUS         .EQU 15

4000 3E 00      LD A,INITLCD      ;Initialise the GLCD
4002 DF         RST 18H
4003 3E 05      LD A,SETTXTMODE   ;Set Text Mode
4005 DF         RST 18H
4006 3E 0D      LD A,PRINTSTRING ;Display Text
4008 DF         RST 18H
4009 20 50 72 65 .DB " Press Any Key",0
400D 73 73 20 41
4011 6E 79 20 4B
4015 65 79 00
4018 0E 00      LD C,0            ;Character Counter
401A CF         RST 08H           ;Wait for key press
401B 06 40      LD B,40H          ;64 Characters per screen
401D 3E 80      LD A,80H          ;row 1 on LCD
401F CD 47 40   CALL 4047         ;Set Row on LCD
4022 79         LD A,C            ;Get Character
4023 CD 4B 40   CALL 404B         ;Display Character on LCD
4026 0C         INC C             ;Next Character
4027 CB 79      BIT 7,C           ;Is C=80H
4029 20 04      JR NZ,402F        ;Yes, display chinese chars
402B 10 F5      DJNZ 4022         ;No, display next character
402D 18 EB      JR 401A           ;Page done, next page
402F 21 40 A1   LD HL,A140H       ;Point to Chinese ROM
4032 CF         RST 08H           ;Wait for key press
4033 06 20      LD B,20H          ;32 Characters per screen
4035 3E 80      LD A,80H          ;row 1 on LCD
4037 CD 47 40   CALL 4047         ;Set Row on LCD
403A 7C         LD A,H            ;Get Character High Byte
403B CD 4B 40   CALL 404B         ;Display Character on LCD
403E 7D         LD A,L            ;Get Character Low Byte
403F CD 4B 40   CALL 404B         ;Display Character on LCD
4042 23         INC HL            ;Next Character
4043 10 F5      DJNZ 403A         ;Display next character
4045 18 EB      JR 4032           ;New Page
4047 D3 07      OUT (07H),A       ;Send instruction to LCD
4049 18 02      JR 404D           ;Do Delay
404B D3 87      OUT (87H),A       ;Send data to LCD
404D 3E 0F      LD A,DELAYUS      ;Set Delay
404F DF         RST 18H
4050 C9         RET
```

Appendix

Ports

Port	Direction	Description
00H	In	Keypad press encoder ➔ Bit 0-4 HexPad ➔ Bit 5 Function Key (Active Low) ➔ Bit 6-7 N/A
01H	Out	Seven segment digits switch ➔ Bit 0-1 Data Segments ➔ Bit 2-5 Address Segments ➔ Bit 6 FTDI Rx (Out), Disco LED's ➔ Bit 7 Speaker
02H	Out	Seven segment LED switch ➔ Bit 0 G segment ➔ Bit 1 F segment ➔ Bit 2 C segment ➔ Bit 3 D segment ➔ Bit 4 E segment ➔ Bit 5 DP segment ➔ Bit 6 B segment ➔ Bit 7 A segment
03H	In	System Input ➔ Bit 0 Matrix Keyboard (DIP-3) ➔ Bit 1 Protect Mode (DIP-3) ➔ Bit 2 Expand Mode (DIP-3) ➔ Bit 3 Expand Status ➔ Bit 4 Cartridge Flag ➔ Bit 5 General Input ➔ Bit 6 Keypress Flag ➔ Bit 7 FTDI Tx (In)
04H	In/Out	LCD Instruction
05H	Out	LED 8x8 Matrix Horizontal (TEC Expander)
06H	Out	LED 8x8 Matrix Vertical (TEC Expander)
07H	Out	Graphical LCD Instruction

Port	Direction	Description
84H	In/Out	LCD Data
87H	Out	Graphical LCD Data
F8H	In/Out	Spare (TEC Expander & I/O Bus)
F9H	In/Out	Spare (TEC Expander & I/O Bus)
FAH	In/Out	Spare (I/O Bus)
FBH	In/Out	Spare (General I/O & I/O Bus)
FCH	In/Out	Spare (General I/O & I/O Bus)
FDH	In/Out	SD (Secure Digital) Flash Card (General I/O)
FEH	In	Matrix Keyboard
FFH	Out	System Latch ➔ Bit 0 Shadow (Active Low) ➔ Bit 1 Protect ➔ Bit 2 Expand ➔ Bit 3 FF-D3 (Mem Bus) ➔ Bit 4 FF-D4 (Mem Bus) ➔ Bit 5 FF-D5 (Mem Bus) ➔ Bit 6 FF-D6 (Mem Bus) ➔ Caps Lock (Matrix Keyboard)

Serial Connection

Constant	Value
FTDI to USB Serial Transmission	4800-8-N-2 ➔ Baud 4800 ➔ 8 Packet Bits ➔ No Parity ➔ 2 Stop bits

LCD Cheatsheet

Z80 instructions to communicate with the LCD screen are given as direct commands. IE: OUT (04),A. Mon3 also provides API routines that do the same but also check for the LCD busy state. If using direct port instructions, the LCD busy flag is to be checked prior to the instruction call. The example code provided uses the API routines.

Instruction Register

One Byte commands to configure the LCD Screen

OUT (04), A

When LCD turns on or resets, screen defaults with 0x01, 0x06, 0x08 and 0x30

Hex	Description	Hex	Description	Hex	Description
0x01	Clear Screen, Cursor reset	0x0F	Display On, Cursor On and Blink	0x40	Set CGRAM Address Pos 1
0x02	Return Cursor to top left	0x10	Move Cursor one to the left		(Address from 40-7F)
0x04	Decrement Cursor on write	0x14	Move Cursor one to the right		
0x06	Increment Cursor on write	0x18	Shift Display to the left	0x80	Set Row 1, Col 1 DDRAM Address
0x05	Display to Shift Right	0x1C	Shift Display to the right	0xC0	Set Row 2, Col 1 DDRAM Address
0x07	Display to Shift Left	0x30	8-Bit, 1 Line, 5x8 dots	0x94	Set Row 3, Col 1 DDRAM Address (20x4)
0x08	Display Off, Cursor Off	0x34	8-Bit, 1 Line, 5x11 dots	0xD4	Set Row 4, Col 1 DDRAM Address (20x4)
0x0C	Display On, Cursor Off	0x38	8-Bit, 2 Line, 5x8 dots		(Address from 80-A7, C0-E7)
0x0E	Display On, Cursor On	0x3C	8-Bit, 2 Line, 5x11 dots		See Screen Layout Below

OUT (84), A
to write a character to DDRAM

Only write while LCD is not busy

IN A, (84)
to read a character from DDRAM

Screen Layout

DDRAM Address Counter with Bit 7 set

Pos	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Row 1	80	81	82	83	84	85	86	87	88	89	8A	8B	8C	8D	8E	8F	90	91	92	93
Row 2	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	CA	CB	CC	CD	CE	CF	D0	D1	D2	D3
Row 3	94	95	96	97	98	99	9A	9B	9C	9D	9E	9F	A0	A1	A2	A3	A4	A5	A6	A7
Row 4	D4	D5	D6	D7	D8	D9	DA	DB	DC	DD	DE	DF	E0	E1	E2	E3	E4	E5	E6	E7

20x4

IN A, (04)
read busy flag (bit 7)

BF	AC	AC	AC	AC	AC	AC	AC

Pos	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Off Screen
Row 1	80	81	82	83	84	85	86	89	88	89	8A	8B	8C	8D	8E	8F	90-A7
Row 2	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	CA	CB	CC	CD	CE	CF	D0-E7

16x2

Writing a character to the screen will increase/decrease the Address Counter automatically

To move the cursor to Row 2, Column 10 do `LD A,0xC9 / OUT (04),A`
For `IN A,(04)`, If Bit 7 is set, then LCD is Busy. Other bits are the current Address Counter

Character Table

Lower 4 Bits \ Upper 4 Bits	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
xxxx0000	CG RAM (1)			0	@	P	`	p				ー	タ	ミ	α	p
xxxx0001	(2)		!	1	A	Q	a	q			。	ア	チ	ム	ä	q
xxxx0010	(3)		"	2	B	R	b	r			「	イ	ツ	メ	ß	θ
xxxx0011	(4)		#	3	C	S	c	s			」	ウ	テ	モ	ε	∞
xxxx0100	(5)		$	4	D	T	d	t			、	エ	ト	ヤ	μ	Ω
xxxx0101	(6)		%	5	E	U	e	u			・	オ	ナ	ユ	σ	ü
xxxx0110	(7)		&	6	F	V	f	v			ヲ	カ	ニ	ヨ	ρ	Σ
xxxx0111	(8)		'	7	G	W	g	w			ァ	キ	ヌ	ラ	g	π
xxxx1000	(1)		(	8	H	X	h	x			ィ	ク	ネ	リ	√	x̄
xxxx1001	(2)		)	9	I	Y	i	y			ゥ	ケ	ノ	ル	⁻¹	y
xxxx1010	(3)		*	:	J	Z	j	z			ェ	コ	ハ	レ	j	千
xxxx1011	(4)		+	;	K	[	k	{			ォ	サ	ヒ	ロ	ˣ	万
xxxx1100	(5)		,	<	L	¥	l	|			ャ	シ	フ	ワ	¢	円
xxxx1101	(6)		-	=	M	]	m	}			ュ	ス	ヘ	ン	£	÷
xxxx1110	(7)		.	>	N	^	n	→			ョ	セ	ホ	゛	ñ	
xxxx1111	(8)		/	?	O	_	o	←			ッ	ソ	マ	°	ö	

Note: The user can specify any pattern for character-generator RAM.

Creating Custom Characters

CGRAM Address	Character In DDRAM
40	0
48	1
50	2
58	3
60	4
68	5
70	6
78	7

0	0	0	0	0	0	0	1	0x01
0	0	0	0	0	0	1	1	0x03
0	0	0	0	0	1	0	1	0x05
0	0	0	0	1	0	0	1	0x09
0	0	0	0	1	0	0	1	0x09
0	0	0	0	1	0	1	1	0x0B
0	0	0	1	1	0	1	1	0x1B
0	0	0	1	1	0	0	0	0x18

Up to 8 Custom Characters can be programmed

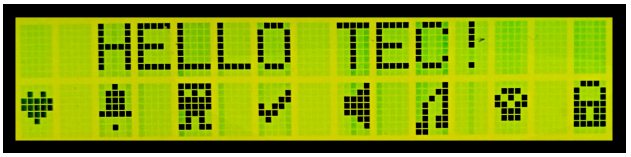
Use Bits 0 to 4 only

After each byte is written CGRAM Address increases

To display character use 0-7 in DDRAM

Use OUT (04), A to set the CGRAM address, where A is between 40h-7Fh
Then OUT (84), A to write one 5 pixel row

Example Using CGRAM and DDRAM




```
_stringToLCD    .equ  13
_charToLCD      .equ  14
_commandToLCD   .equ  15
        ; LCD Setup
        ld c,_commandToLCD    4000  0E 0F    ;LCD Instruction API routine
        ld b,01H              4002  06 01    ;Clear display
        rst 10H               4004  D7       ;call API routine
        ld b,38H              4005  06 38    ;8-Bit, 2 Lines, 5x8 Characters
        rst 10H               4007  D7       ;call API routine
        ; Tell the LCD that next data will be to CGRAM
        ld b,40H              4008  06 40    ;CGRAM entry
        rst 10H               400A  D7       ;call API routine
        ; Save multiple characters to CGRAM using lookup table
        ld b,40H              400B  06 40    ;8 Characters (8 bytes each)
        ld c,_charToLCD       400D  0E 0E    ;LCD Data API routine
        ld hl,403FH           400F  21 3F 40 ;LCD custom character table
loop1:
        ld a,(hl)             4012  7E       ;get custom character byte
        inc hl                4013  23       ;move to next item in table
        rst 10H               4014  D7       ;call API routine
        djnz loop1            4015  10 FB    ;continue for all 64 char bytes
        ; Display first line of text
        ld c,_commandToLCD    4017  0E 0F    ;LCD Instruction API routine
        ld b,82H              4019  06 82    ;Move Cursor to Row 1, Col 3
        rst 10H               401B  D7       ;call API routine
        ld hl,4034H           401C  21 34 40 ;ASCII text
        ld c,_stringToLCD     401F  0E 0D    ;LCD String API routine
        rst 10H               4021  D7       ;call API routine
        ; Display customer characters
        ld c,_commandToLCD    4022  0E 0F    ;LCD Instruction API routine
        ld b,0C0H             4024  06 C0    ;Move Cursor to Row 2, Col 1
        rst 10H               4026  D7       ;call API routine
        ld b,08H              4027  06 08    ;8 Characters
        ld c,_charToLCD       4029  0E 0E    ;LCD Data API routine
loop2:
        ld a,b                402B  78       ;set A to current character
        rst 10H               402C  D7       ;call API routine
        ld a,20H              402D  3E 20    ;space character
        rst 10H               402F  D7       ;call API routine
        djnz loop2            4030  10 F9    ;continue for all 8 characters
        ; All Done, what for key press and exit
        rst 08H               4032  CF       ;key wait and press (HALT)
        ret                   4033  C9       ;exit

  TEXT TABLE:   4034  48 45 4C 4C 4F 20 54 45 43 21 00  ; "HELLO TEC!"
  CHAR TABLE:   403F  00 0A 1F 1F 0E 04 00 00    ; Heart
                4047  04 0E 0E 0E 1F 00 04 00    ; Bell
                404F  1F 15 1F 1F 0E 0A 1B 00    ; Alien
                4057  00 01 03 16 1C 08 00 00    ; Tick
                405F  01 03 0F 0F 0F 03 01 00    ; Speaker
                4067  01 03 05 09 09 0B 1B 18    ; Note
                406F  00 0E 15 1B 0E 0E 00 00    ; Skull
                4077  0E 11 11 1F 1B 1B 1F 00    ; Lock
```

Useful Links

TEC-1G GitHub Repository
https://github.com/MarkJelic/TEC-1G

TEC-1 Facebook Page
https://www.facebook.com/groups/tec1z80

Z80 Instruction Set Reference
https://clrhome.org/table/

Online Z80 Compiler and Debugger
https://www.asm80.com/

Rodney Zaks Programming the Z80
https://archive.org/details/ptz80

TEC Seven Segment Value Calculator
https://slartibartfastbb.itch.io/seven-segment-calculator

Ready? Z80 YouTube Channel (TEC related content)
https://www.youtube.com/@ReadyZ80

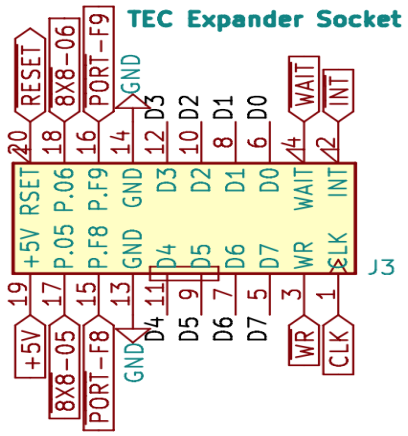
Mon3 video demonstration
https://youtu.be/0peIG2HKX3Q

TEC-1 GitHub Group
https://github.com/tec1group/

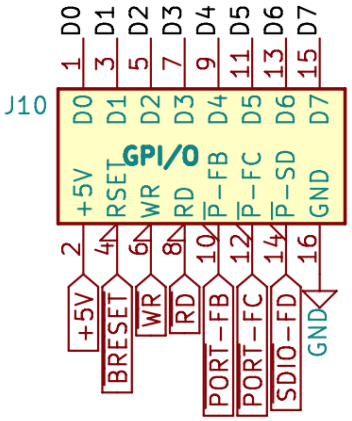
Talking Electronics Website including original TEC related magazines
https://www.talkingelectronics.com/te_interactive_index.html

I/O Connectors

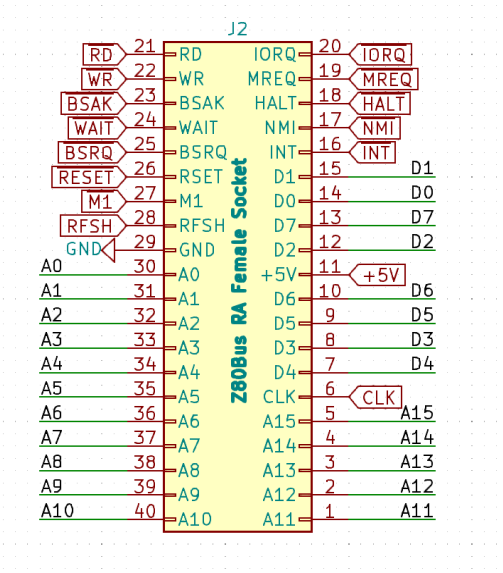
Expander Socket



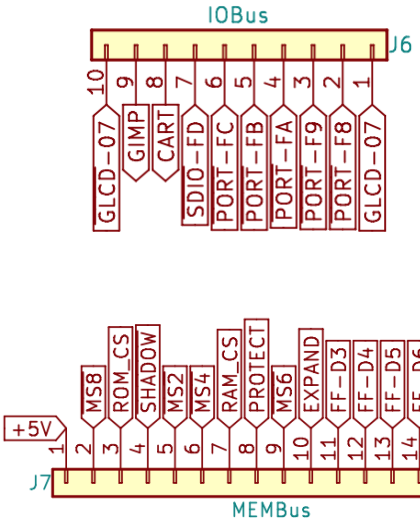
General Purpose I/O

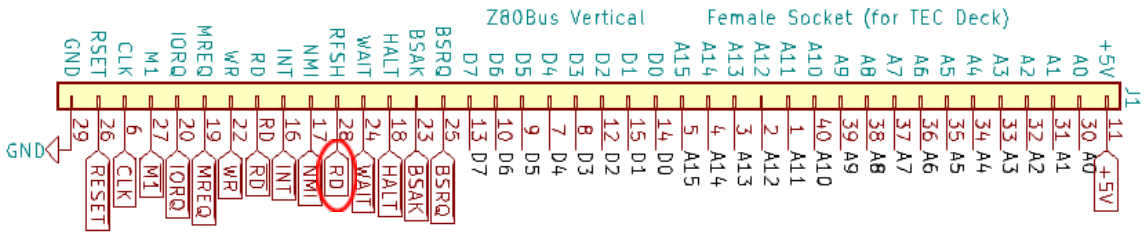


Z80 Bus Connector



TEC Deck Connectors





Note: pin 28 is RD