Application Note

Interfacing LCD Modules to the Z8 MCU

AN003201-Z8X0500

ZILOG WORLDWIDE HEADQUARTERS • 910 E. HAMILTON AVENUE • CAMPBELL, CA 95008
TELEPHONE: 408.558.8500 • FAX: 408.558.8300 • WWW.ZILOG.COM

This publication is subject to replacement by a later edition. To determine whether a later edition exists, or to request copies of publications, contact:

ZiLOG Worldwide Headquarters
910 E. Hamilton Avenue
Campbell, CA 95008
Telephone: 408.558.8500
Fax: 408.558.8300
www.ZiLOG.com

Information Integrity

The information contained within this document has been verified according to the general principles of electrical and mechanical engineering. Any applicable source code illustrated in the document was either written by an authorized ZiLOG employee or licensed consultant. Permission to use these codes in any form, besides the intended application, must be approved through a license agreement between both parties. ZiLOG will not be responsible for any code(s) used beyond the intended application. Contact the local ZiLOG Sales Office to obtain necessary license agreements.

Document Disclaimer

Table of Contents

Acknowledgements

Project Lead Engineer

John D. Conder

Application and Support Engineer

John D. Conder

System and Code Development

John D. Conder

Interfacing LCD Modules to the Z8 MCU

There is an increasing demand to interface Liquid Crystal Display (LCD) modules to low-end microcontrollers. Unfortunately, little information is offered to address real-world applications and to help the design engineer understand how to make LCD modules work.

General Overview

This Application Note provides a detailed example of creating a simple serial interface to an LCD module, using a Z8 microcontroller. The application allows text messages typed on a computer keyboard to be directly displayed on the LCD module when the circuit is connected to the computer serial port. The messages are up to 16 characters long, and are terminated by the `Enter` key. If more than 16 characters are entered, complete lines of 16 characters are displayed until the `Enter` key terminates the message. The serial interface has the following configuration:

- 4800 baud
- 8 data bits
- 1 start bit, 1 stop bit
- No parity

This Application Note utilizes the Z86E08 microcontroller and the Hyundai Electronics Industries (HEI) HC16102 LCD module. However, the code is applicable to any processor in the Z8 family. Also, because the HC16102 module is based on the Hitachi HD44780 controller, the code is applicable to any other modules which utilize this device to control the LCD.

Discussion

LCD Module Basics

Figure 1 contains a block diagram of the HC16102 module. The HC16102 module contains a 1-line by 16-character display, a Hitachi HD44780 display controller, and an LED backlight. The HD44780 divides the 16 characters into two lines of eight characters each, even though all characters appear physically on the same line. The controller has an on-board character generator in ROM capable of displaying 192 ASCII characters, along with eight user-programmable characters. All characters are displayed in a 5x7 font. The module is also capable of configuring the data bus for either an 8-bit or a 4-bit interface. This Application Note utilizes the 8-bit option. Table 1 indicates the module's pin configuration.

Figure 1. LCD Module Block Diagram

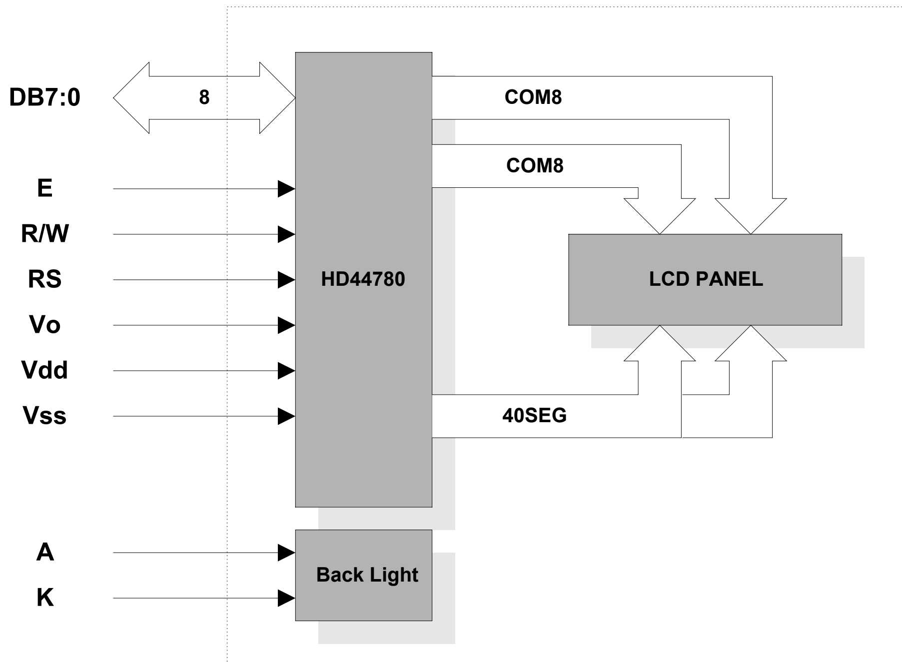


Table 1. HC16102 Pin Configuration

Pin	Symbol	Signal Description
1	V_{SS}	GND
2	V_{DD}	Power Supply
3	V_O	LCD Driver Supply Voltage
4	RS	Register Select: 0 = Instruction, 1 = Data
5	R/W	Read/Write: 0 = MPU to LCM, 1 = LCM to MPU
6	E	Enable: (active high)
7 to 14	DB0 to DB7	Data Bus
15	A	Anode of LED Backlight
16	K	Cathode of LED Backlight

The module is configured and controlled by the microcontroller via the instruction set listed in the HC16102 Instruction Set in Table 2. (Table 2 uses a number of abbreviations that are defined at the bottom of each page of the table.) Each instruction has a maximum execution time. Upon issuing an instruction, the microcontroller waits for at least the maximum execution time before issuing another instruction. Most execution times are at least 40 µsec.

The process of writing an instruction to the module is very straightforward. Essentially, the RS, R/W, and DB7:0 signals are set to the proper levels and then the E signal is pulsed. On the falling edge of the E signal, the instruction is accepted and processed by the HD44780. The minimum pulse width for the E signal is 230 ns with a minimum cycle time of 500 ns.

Table 2. HC16102 Instruction Set

Instruction	**Code**										**Description**	**Execution Time**
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Clear Display	0	0	0	0	0	0	0	0	0	1	Clears entire display and sets DD RAM address 0 in address counter.	1.64ms
Return Home	0	0	0	0	0	0	0	0	1	x	Sets DD RAM address 0 in address counter. Also returns display from being shifted to original position. DD RAM contents remain unchanged.	1.64ms

Notes:

I/D:	1 = Increment, 0 = Decrement
S:	1 = Accompanies display shift
S/C:	1 = Display Shift, 0 = Cursor move
R/L:	1 = Shift to the right, 0 = Shift to the left
DL:	1 = 8-bit interface, 0 = 4-bit interface
N:	1 = 2 lines, 0 = 1 line
F:	1 = 5x10 dot array, 0 = 5x7 dot array
BF:	1 = Busy, 0 = Instructions acceptable
x:	Don’t care
ACG:	CG RAM address
ADD:	DD RAM address (corresponds to cursor address)
AC:	Address counter used for both DD and CG RAM
DD RAM:	Display data RAM
CG RAM:	Character generator RAM

Table 2. HC16102 Instruction Set (Continued)

Instruction	Code										Description	Execution Time
Entry Mode Set	0	0	0	0	0	0	0	1	I/D	S	Sets cursor move direction and specifies shift of display. These operations are performed during data write and read.	40µs
Display On/ Off	0	0	0	0	0	0	1	D	C	B	Sets On/Off of entire display (D), cursor On/ Off (C), and blinking of cursor position character (B).	40µs
Cursor or Display Shift	0	0	0	0	0	1	S/C	R/L	x	x	Moves cursor & shifts display without changing DD RAM contents.	40µs
Function Set	0	0	0	0	1	DL	N	F	x	x	Sets interface data length (DL), number of display lines (N), and character font (F).	40µs
Set CG RAM Address	0	0	0	1	ACG						Sets CG RAM address. CG RAM data is sent and received after this setting.	40µs

Notes:

I/D:	1 = Increment, 0 = Decrement
S:	1 = Accompanies display shift
S/C:	1 = Display Shift, 0 = Cursor move
R/L:	1 = Shift to the right, 0 = Shift to the left
DL:	1 = 8-bit interface, 0 = 4-bit interface
N:	1 = 2 lines, 0 = 1 line
F:	1 = 5x10 dot array, 0 = 5x7 dot array
BF:	1 = Busy, 0 = Instructions acceptable
x:	Don't care
ACG:	CG RAM address
ADD:	DD RAM address (corresponds to cursor address)
AC:	Address counter used for both DD and CG RAM
DD RAM:	Display data RAM
CG RAM:	Character generator RAM

Table 2. HC16102 Instruction Set (Continued)

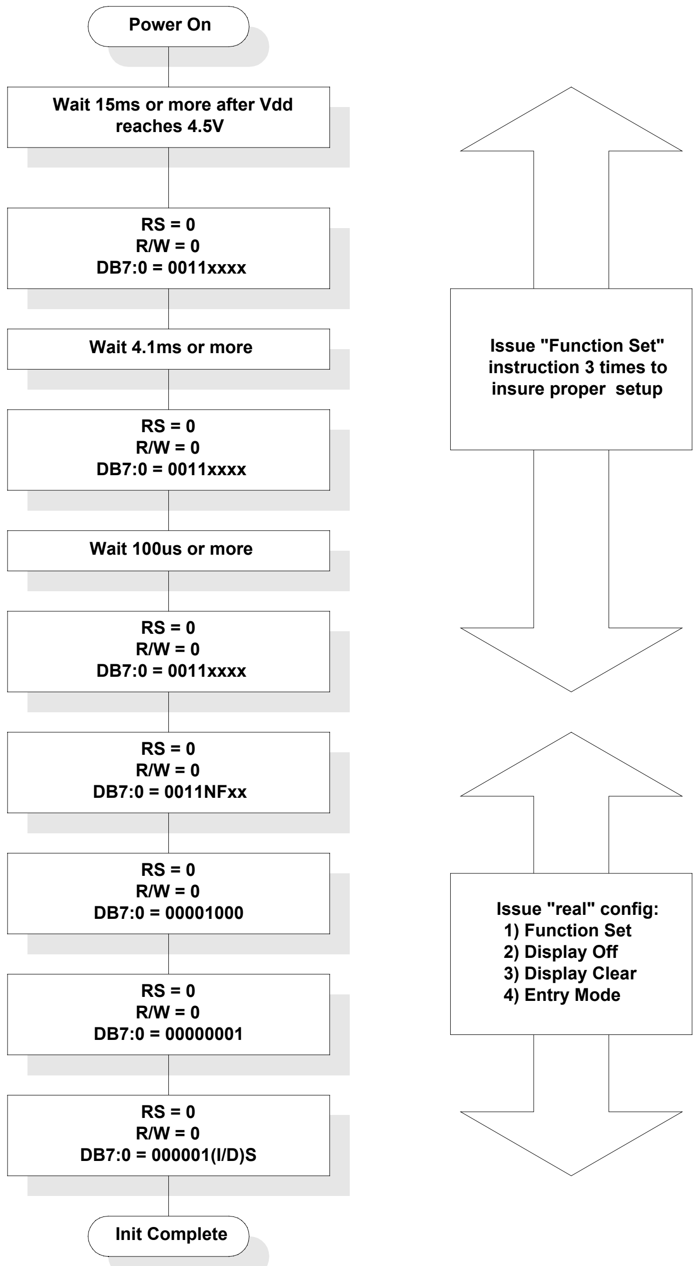
Instruction	Code				Description	Execution Time
Set DD RAM Address	0	0	1	ADD	Sets DD RAM address. DD RAM data is sent and received after this setting.	40µs
Read Busy Flag	0	1	BF	AC	Reads busy flag (BF) indicating internal operation is being performed and reads address counter contents (AC).	0µs
Write Data to CG or DD RAM	1	0		DATA	Writes data into DD RAM or CG RAM.	40µs
Read Data from CG or DD RAM	1	1		DATA	Reads data from DD RAM or CG RAM.	40µs

Notes:

I/D:	1 = Increment, 0 = Decrement
S:	1 = Accompanies display shift
S/C:	1 = Display Shift, 0 = Cursor move
R/L:	1 = Shift to the right, 0 = Shift to the left
DL:	1 = 8-bit interface, 0 = 4-bit interface
N:	1 = 2 lines, 0 = 1 line
F:	1 = 5x10 dot array, 0 = 5x7 dot array
BF:	1 = Busy, 0 = Instructions acceptable
x:	Don't care
ACG:	CG RAM address
ADD:	DD RAM address (corresponds to cursor address)
AC:	Address counter used for both DD and CG RAM
DD RAM:	Display data RAM
CG RAM:	Character generator RAM

Message data must be initialized before it is written to the module. Initialization is done either internally by the module's reset circuit or externally by instructions from the microcontroller. For the module's internal reset circuit to successfully complete initialization, the V_{dd} signal must transition smoothly to 4.5V within 0.1 milliseconds and 10.0 milliseconds. If this condition is not guaranteed, the module must be initialized by the microcontroller. For this Application Note, the initialization is performed externally by the microcontroller. The flowchart in Figure 2 illustrates the initialization sequence. Note that the sequence is for 8-bit mode. A slightly different sequence exists for 4-bit mode. However, the 4-bit mode sequence is beyond the scope of this application and therefore not included in this Application Note.

Figure 2. LCD Module Initialization Sequence



Z8 Microcontroller

The microcontroller selected for this application is the Z86E08. It provides a minimal configuration for the application. As such, there are very few resources remaining for interfacing to other circuitry. For applications that require additional connections, other Z8 microcontrollers, such as the 28-pin Z86E3x series or the 40-pin Z86E4x series may be substituted with minimal impact to the firmware.

The Z86E08 is an 18-pin device with 14 available I/O pins. The I/O pins are arranged into two 3-bit ports (Port 0 and Port 3) and one 8-bit port (Port 2). Port 0 (P02–P00) is a dedicated output port. Por t2 (P27 – P20) is a bidirectional port with each pin independently configurable as input or output. Port 3 (P33 – P31) is a dedicated input port.

The Z86E08 is capable of operating at a crystal frequency of up to 12 MHz. 8 MHz was chosen for this application because it simplifies the system timing. Other frequencies may be selected. However, other frequencies require a reevaluation of the serial interface timing as well as the timing of the firmware delay loops that are used in the LCD Module interface.

Connecting the LCD Module

The Appendix contains the schematic for this application. As illustrated in the schematic, the LCD Module data bus, DB7:0, is connected directly to Port2 of the Z8 microcontroller. Port2 was chosen because it is the only bidirectional port available on the Z86E08. It is also the only 8-bit wide port available. For other Z8 applications, other ports may be used The LCD Module control signals, E, R/W, and RS, are connected to Port0 of the Z8 because they are strictly module inputs. These signals could be connected to any Port0 pin. The required connection is used because the E signal is toggled most frequently. Therefore, it is assigned to the least significant Port0 pin, P00.

The module provides two pins for the LED backlight, pin 15 for the anode (A) and pin 16 for the cathode (K). The anode is connected to V_{CC} by a 10-Ohm resistor, R2, and the cathode is connected to Gnd via a push-button switch, SW1. The LED has a forward voltage of approximately 4.1 V and a forward current of 110 mA. The resistor is provided to limit the current to the 110mA requirement when the button is pressed.

Contrast for the LCD is controlled by the voltage applied at pin 3, V_O, of the LCD Module. The contrast is adjusted by connecting the wiper leg of potentiometer R3 to V_O and connecting the other legs to V_{CC} and Gnd. A 10-kΩ potentiometer is used in this application, but any value from 10K to 20K is acceptable.

Serial Interface

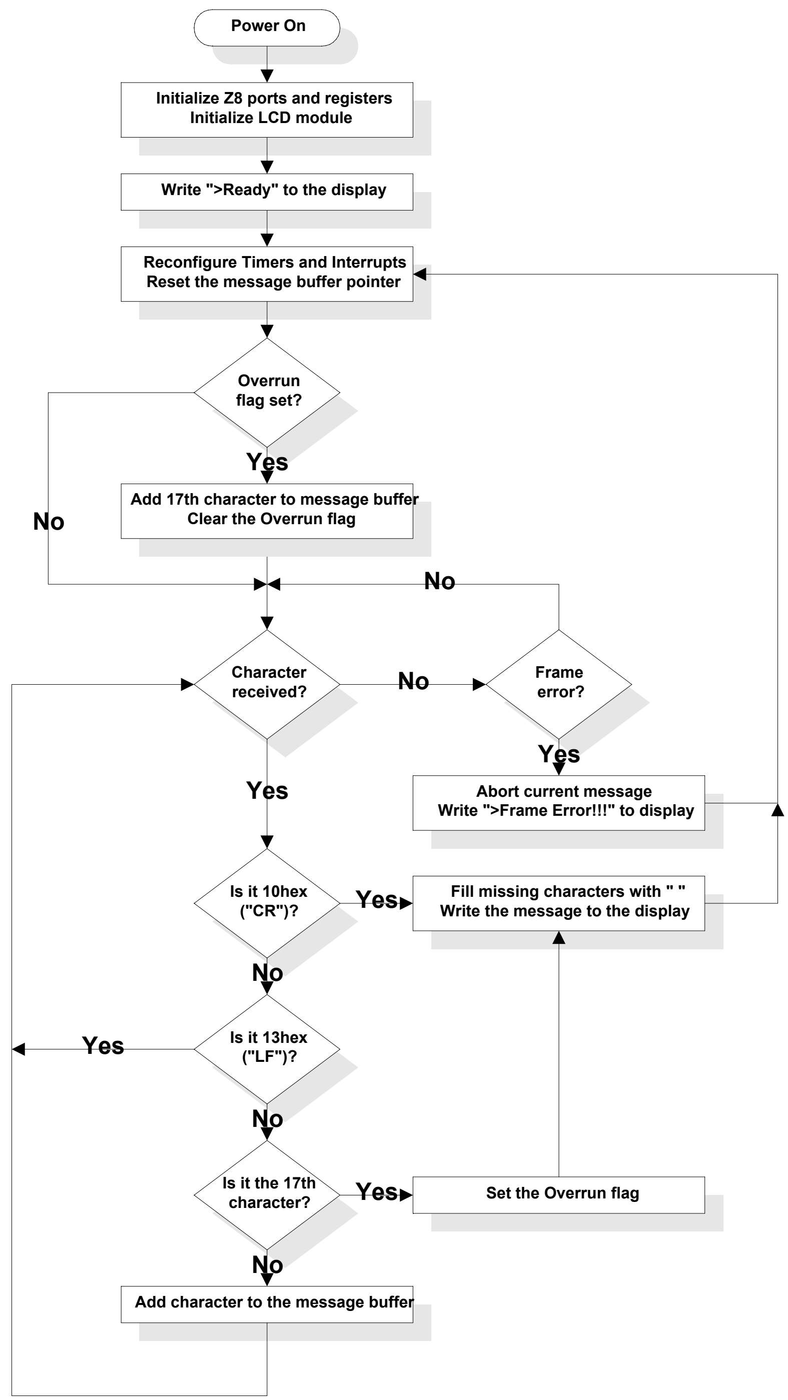
The serial interface for this application functions only to receive data from a host source. Therefore, the serial port connection is limited to the receive data pin (DB9 connector pin 3) and the Gnd pin (DB9 connector pin 5). Traditionally, an RS-232 buffer device is used to isolate the processor from the receive pin of the connector. However, for this application, the buffer device is eliminated and a simple analog circuit replaces it. This circuit consists of two diodes, D1 and D2, and resistor R1. Diode D1 limits the voltage on the processor pin to approximately 0.7V above V_{CC}, while diode D2 limits the voltage to approximately 0.7V below Gnd. This limitation protects the processor pin from the damaging voltages present when connected to an RS-232 driver. Resistor R1 limits the current into or out of the circuit to just a few milliamps, thereby protecting the diodes and processor pin from potential damage due to excessive current.

One of the key differences in this serial interface is that it requires the processor to invert the sense of the serial data transitions. This inversion is traditionally performed by the RS-232 buffer, which has been eliminated. From the processor's point of view, the start bit is logic level 1 instead of the traditional level 0, all the data is inverted, and the stop bit is logic level 0.

Firmware

The majority of the functions for this application reside in the Z8 firmware. This firmware consists of three major routines: a main processing loop, a serial input routine, and a display write routine. Figure 3 contains a high-level flowchart for the main processing loop.

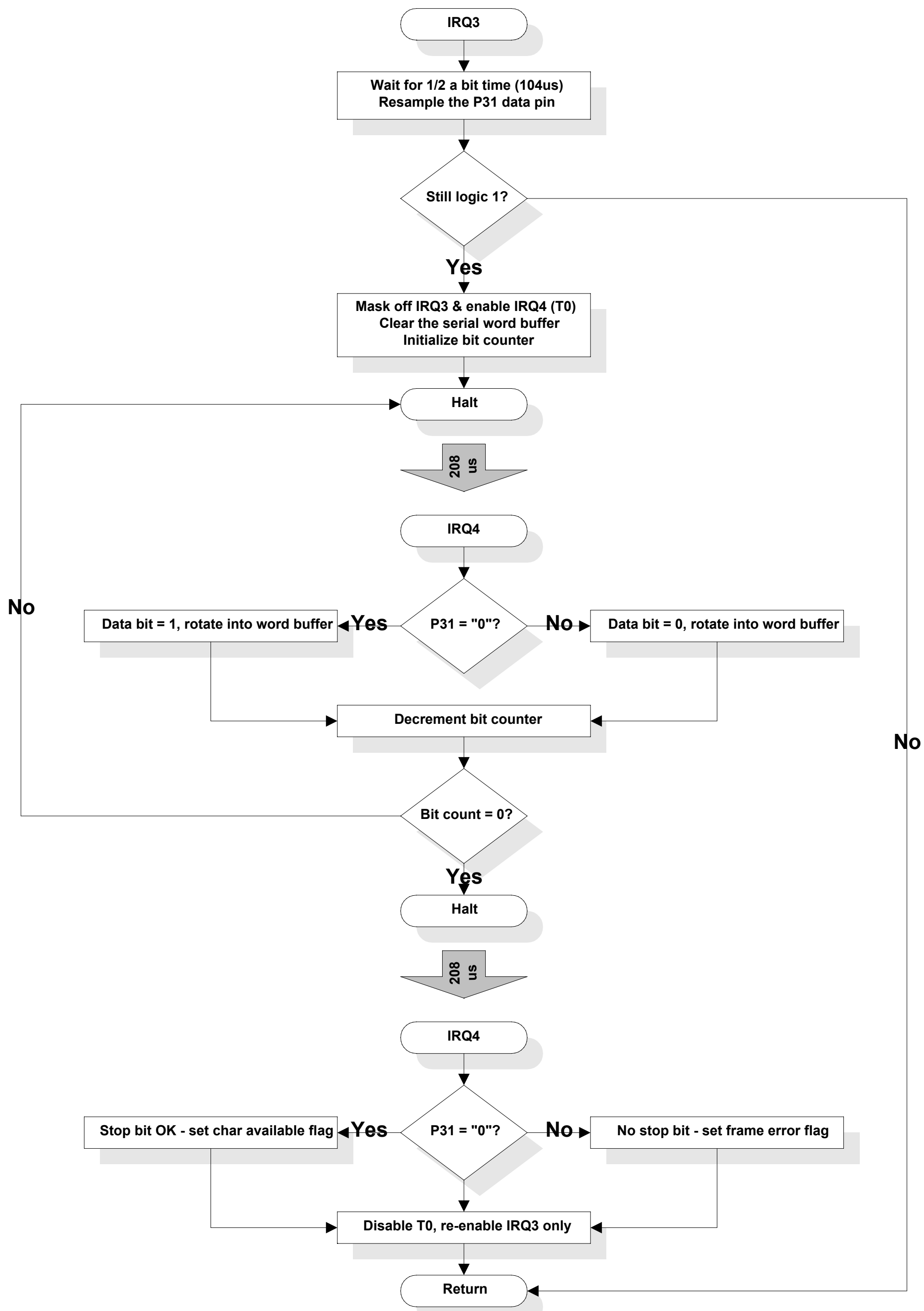
Figure 3. Main Processing Loop Flowchart



The basic operation of the main processing loop is as follows. On power-up, the Z8 performs an initialization sequence and then enters into a main loop waiting for an indication that a new character has been received via the serial routine. When a new character is received, the character is examined to determine the next action. If the character is 10h (ASCII carriage return), the message is considered terminated. The message buffer is padded with as many spaces as required to complete the 16-character message and the message is written to the LCD Module. The Z8 reenters the main loop waiting for new characters. The 13h character (ASCII line feed) is ignored completely because it is part of the message termination. If any other character is received, it is written to the message buffer and the buffer pointers are incremented. If the number of characters exceeds 16, without receiving character 10h, the message buffer is automatically written to the LCD Module and message buffering is restarted.

Figure 4 contains the high-level flowchart for the serial input routine. Because the Z86E08 doesn't contain a UART, a firmware routine provides the receive portion of the UART function. Essentially, the firmware routine detects the rising edge of the start bit, samples it again in the middle to validate it, and then repetitively samples at bit-time intervals to obtain the data and stop bits.

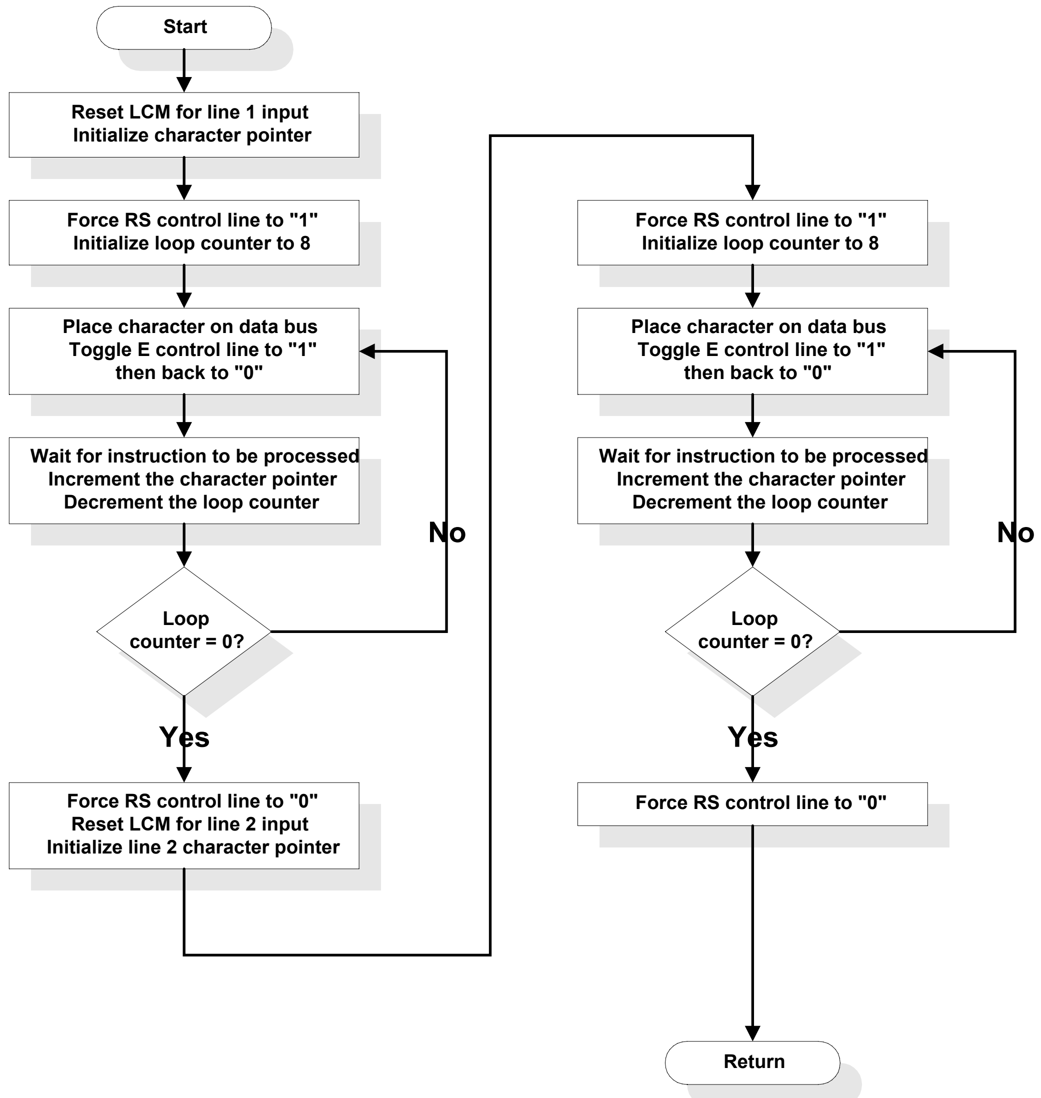
Figure 4. Serial Input Routine Flowchart



By connecting the receive data signal to P31 of the Z86E08, the rising edge of the start bit is used to generate an interrupt, IRQ3, to the processor whenever a start bit occurs. The bit-time delay is created by configuring the internal T0 timer for a time delay of 208 µs. This operation results in an effective baud rate of 4808. When the start bit is detected and validated, the IRQ3 interrupt is masked off and the T0 interrupt, IRQ4, is enabled. The processor is halted between data bits, and resumes processing when the IRQ4 interrupt occurs. If the start bit validation fails, the IRQ3 interrupt is considered to be noise and is ignored. If the stop bit is not present, a frame error is declared by setting the frame error flag. If the word is completed successfully, a flag is set to denote that a new character is available.

Figure 5 contains the high level flowchart for the write display routine. This routine expects a 16-character ASCII message to be in the message buffer. The routine performs 16 consecutive writes to the LCD Module, beginning with the first word in the buffer and writing the next sequential word on each pass. Because the HD44780 LCD controller is configured as two 8-character lines, the 16 character write is broken into two passes of eight characters each. Between the two passes, the display controller must be instructed to switch from line 1 to line 2.

Figure 5. Display Write Routine Flowchart



Operational Results

This application is designed to connect to a regulated +5V power supply. The supply regulation must be within +/- 0.5V, which is the operational limit of the LCD module. Connection to any other power source requires additional circuitry to provide this level of supply voltage and regulation.

When power is applied to the unit, it responds by displaying `>Ready` on the LCD Module. This display is an indication that the unit is ready to receive messages.

The unit displays any message it receives. Note that the LCD module uses the character space greater than 07Fh as Asian characters and other symbols. Messages containing these codes produce interesting results. Consult the data sheet for the HC16102 or the HD44780 for a complete listing of the character map.

Operating the unit without connection to a serial port can sometimes display the `>Frame Error!!!` message. This message displays because noise is coupled into the unconnected data line. Depending on the amount of noise and its intensity, the display may appear to flash the message. An optional capacitor, C3, is included (see Appendix schematic) to prevent the noise from creating false message starts. C3 has no other purpose and the capacitor can be eliminated from designs that are not required to function while disconnected from the host.

Summary

This application provides an effective and reusable demonstration of applying the basic LCD Module instructions to control an LCD display. A simple serial interface is demonstrated for sending messages to the display. Because the LCD Module utilizes a common Hitachi HD44780 controller, the firmware has wide applicability.

The application code readily fits into the 2-KB program space of the Z86E08, using only 510 bytes. There is a large amount of space available for creating special effects or adding precoded messages. Also, if additional I/O pins are required, the code readily transfers to higher pin-count microcontrollers in the Z8 family.

Technical Support

Assembling the Application Code

Any Z8 assembler may be used, but the ZiLOG Developer Studio (ZDS) is recommended. This integrated suite of software tools allows for program file handling, editing, real-time emulation and debugging when used with the appropriate emulator. Future versions of ZDS incorporate a C-Compiler, simulator and trace buffer. See ZiLOG's web-page at www.zilog.com for news and free downloads of ZDS.

Place the `.ASM` file and `.INC` file in their own sub-directory. Invoke ZDS and select a new project from the file menu. Under `Target Selection`, select `Family`. Under `Master Select`, select `Z8`. Under `Project Target`, select Z86E08. Select the appropriate emulator type to be used. Browse to fill in the project name by clicking on the `...` key. Select the sub-directory containing the `.ASM` and `.INC` files, name the project, (the extension is added for you), click `Save` and the first ZDS screen reappears with the project name, path, and file extension filled in. If everything is acceptable, click `OK`.

Click on the `Project` tab and select `Add to Project`. Then select `Files`. Double click on the `LCM_Interface.asm` file. This file and the `.INC` file are now displayed in the project window. Click on the `Build` tab and select `Build`. The `Output` window displays the assembly results. The standard assembler and linker settings produce listing and hex files, along with the ZDS files, in the same sub-directory. Save the project and files by clicking on the `File` tab and selecting these options. The ZDS Project File is included, and when the ZDS is installed, allows you to skip the above steps for program assembly.

Program the OTP by selecting the OTP option with the hex code installed. Never install the OTP until access to it is required, either for blank checking, verification, or programming. Insert a blank Z86E08 into the OTP socket and click on the program OTP selection. Differences exist between earlier GUIs and the ZDS, so take the time to read and understand the operation of the SW in use. Pad unused memory locations with `FFh` before programming. If padding is not consistently done, differences occur in the check sum.

Source Code

This application uses the following source files:

- `LCM_Interface.asm`
- `RegDef.inc`

Instead of displaying each file separately, they are shown exactly in the order and location they are <.included> in the main source, `LCM_Interface.asm`. This is similar to the way the output listing file (`LCM_Interface.lst`) is generated.

```
*************************************************************************
*       Module Name:    Z8 based Serial Interface to a LCD Module
*       Copyright:      ZiLOG Inc.
*       Date:           09/24/99
*       Created by:     John D. Conder
*       Modified by:
*
*       Description:    This module contains the code for using the
*                       Z86E08 microcontroller to create a 4800 baud RS232
*                       serial interface to a Hyundai HC16102 LCD module.
*
*                       The module has a 16-character by 1-line display
*                       format. The controller will display a 0 to 16
*                       character message received via the serial port.
*                       Messages are terminated by the "Enter" key (ASCII
*                       code sequence 13hex, 10hex). The display is not
*                       updated until either the "Enter" is received or
*                       16 characters are received.  The serial interface
*                       is fixed at 8 data bits, no parity, 1 start bit
*                       and 1 stop bit.
*
*
```

```
***************************************************************************
*///////////////////////////////////////////////////////////////////////////*
*///////////////////////////////////////////////////////////////////////////*
***************************************************************************
*       Include section
***************************************************************************

;     Include the register and constant definitions
      include     "RegDef.inc"

;=========================================================================
;=      TITLE:          RegDef.inc
=
;=      DATE:           September 24 1999
=
;=      PURPOSE:        Register and constant definitions for the=
;=                      LCD Module interface app note
=
;=
=
;=      FILE TYPE:      .included header file
=
;=
=
;=      ASSEMBLER:      ZiLOG ZDS/ZMASM
=
;=      PROGRAMMER:     John Conder
=
;=========================================================================


;     BIT DEFINITIONS

;     Port 0
; pins  na----------na 13 12 11  Function                   Polarity    I/O
; bits  [7  6  5  4  3  2  1  0]
;                       |  |  |_ LCM Enable            hi-true     O
;                       |  |____ LCM R/W               bipolar     O
;                       |_______ LCM Reg Sel           bipolar     O

P0_E_Hi     .equ  00000001b   ; LCM E control bit = 1
PO_RW_Hi    .equ  00000010b   ; LCM RW control bit = 1
P0_RS_Hi    .equ  00000100b   ; LCM RS control bit = 1

P0_Init     .equ  00000000b   ; Reg 000 - Port0 Data Init


;     Port 1
; pins  na-------------------na          (Port 1 nonexistant on Z86E08)
; bits  [7  6  5  4  3  2  1  0]
;
P01M_Init   .equ  00000100b   ; Reg 0F8 - Port0&1 Mode Init
;                 xxxxxx00b   ; P00-P03 Mode=Outputs
;                 xxxxx1xxb   ;  1=Reserved
;                 00000xxxb   ;  0=Reserved
```

```
;      Port 2
; pins   4  3  2  1 18 17 16 15  Function                     Polarity    I/O
; bits  [7  6  5  4  3  2  1  0]
;        |  |  |  |  |  |  |  |_ DB0           bipolar     I/O
;        |  |  |  |  |  |  |____ DB1           bipolar     I/O
;        |  |  |  |  |  |_______ DB2           bipolar     I/O
;        |  |  |  |  |__________ DB3           bipolar     I/O
;        |  |  |  |_____________ DB4           bipolar     I/O
;        |  |  |________________ DB5           bipolar     I/O
;        |  |___________________ DB6           bipolar     I/O
;        |______________________ DB7           bipolar     I/O

P2_Init     .equ  00000000b         ; Reg 002 - Port2 Data Init
P2_LCM8bits       .equ  00111000b   ;  LCM 8bit function set
P2_DOnNoC   .equ  00001100b         ;  LCM display on, no cursor
P2_AIncNoS  .equ  00000110b         ;  LCM addr incr, no shift
P2_DspClr   .equ  00000001b         ;  LCM display clear
P2_CurHome  .equ  00000010b         ;  LCM cursor home
P2_CGRam    .equ  01000000b         ;  LCM set CG Ram
P2_DDRam1   .equ  10000000b         ;  LCM DD Ram line 1
P2_DDRam2   .equ  11000000b         ;  LCM DD Ram line 2

P2M_Init    .equ  11111111b   ; Reg 0F6 - Port2 Mode Init
P2M_Read    .equ  11111111b   ; Input data from LCM
P2M_Write   .equ  00000000b   ; Output data to LCM

;      Port 3
; pins  na-------na 10  9  8 na  Function                  Polarity    I/O
; bits  [7  6  5  4  3  2  1  0]
;                    |  |  |____ Unusedq
;             |  |________ Serial Input                     bipolar     I
;                    |__________ Unused

P3_RxBit    .equ  00000100b   ; Serial Input data bit

P3_Init     .equ  00000000b   ; Reg 003 - Port3 Data Init
P3M_Init    .equ  00000001b   ; Reg 0F7 - Port3 Mode
;                 xxxxxxx1b   ; 1=Port2 as Push-Pull
;                 xxxxxx0xb   ; 0=P33-P31 as Digital Mode
;                 000000xxb   ; 0=Reserved

;      Timer definitions
;
TMR_Init    .equ  00000000b   ; Reg 0F1 - Timer Mode
;                 xxxxxxx0    ; 1=Load T0
;                 xxxxxx0x    ; 1=Enable T0 Count
;                 xxxxx0xx    ; 1=Load T1
;                 xxxx0xxx    ; 1=Enable T1 Count
;                 xx00xxxx    ; 00=Tin Mode: external clock
;                 00xxxxxx    ; 00=Reserved
TMR_RxEnab  .equ  00000011b   ; Enable Serial Receive

;      Timer0 (serial input)
;
T0_Init     .equ  208         ; Reg 0F4 - 208uS (4808bps)
```

```
PRE0_Init    .equ  00000101b   ; Reg 0F5 - T0 Prescaler
;                  xxxxxxx1    ; 1=Modulo n
;                  xxxxxx0x    ; 0=Reserved
;                  000001xx    ; Modulo value (1us @ 8MHz)

;      Timer1 (unused)
T1_Init      .equ  208         ; Reg 0F2 - 208uS (4808bps)
PRE1_Init    .equ  00000111b   ; Reg 0F3 - T1 Prescaler
;                  xxxxxxx1    ; 1=Modulo-n
;                  xxxxxx1x    ; 1=Internal Clock Source
;                  000001xx    ; Modulo value (1us @ 8MHz)


;      Interrupt definitions
;
IPR_Init     .equ  00100011b   ; Reg 0F9 - Interrupt Priority
;                  xxx00xx1    ;  Group priority C>A>B
;                  xxxxxx1x    ;  Group C 1=IRQ4>IRQ1
;                  xxxxx0xx    ;  Group B 0=IRQ2>IRQ0
;                  xx1xxxxx    ;  Group A 1=IRQ3>IRQ5
;                  00xxxxxx    ;  Reserved-Must be 0

IMR_Init     .equ  00000000b   ; Reg 0FB - Interrupt Mask
;                  xx000000    ; 0=IRQ5-IRQ0 disabled
;                  x0xxxxxx    ; 0=Reserved-Must be 0
;                  0xxxxxxx    ; 0=Global Interrupt disable
IMR_RxEnab   .equ  00001000b   ; Enable IRQ3(P32) for serial detect
IMR_RxLoop   .equ  00010000b   ; Enable IRQ4(T0) for serial loop

IRQ_Init     .equ  00000000b   ; Reg 0FA - Interrupt Request
;                  xx000000    ; 0=Clear request bits 5-0
;                  00xxxxxx    ; Reserved - Must be 0
IRQ_T0bit    .equ  00010000b   ; TO interrupt bit



;      System Definitions
;
RegBot       .equ  004h        ; Bottom register
RegTop       .equ  07Fh        ; Top register
StackTop     .equ  RegTop+1    ; Top of Stack

AppRP        .equ  010h        ; System Register Pointer
MsgBufRP     .equ  020h        ; Message Buffer Pointer

Wt1MCnst     .equ  01Fh        ; WaitLoop1 msbyte count constant
Wt1LCnst     .equ  0FFh        ; WaitLoop1 lsbyte count constant
Wt2Const     .equ  01Fh        ; WaitLoop2 count constant

;      System Flags
;
RxWrdAvail   .equ  00000001b   ; Serial input word available
RxFrameErr   .equ  00000010b   ; Serial input frame error
RxOverrun    .equ  00000100b   ; Display line greater than 16
```

```
*************************************************************************
*       Global variables
*************************************************************************
      DEFINE      REGDATA, SPACE=RFILE

;     RAM MAP
      SEGMENT     REGDATA
;
;     Register Bank0
            DS    16          ; Bank0 Space

;     Register Bank1 - AppRP (010-01Fhex)
FlagReg     DS    1           ; R0 - System Flag register
RxBitNum    DS    1           ; R1 - Current bit
RxChrNum    DS    1           ; R2 - Current character
RxWrdBuf    DS    1           ; R3 - Serial Word Buffer

Unused            DS    7           ; R4-R10

IRQ3Gnrl    DS    1           ; R11 - Interrupt general reg
General0    DS    1           ; R12 - Main general reg0
General1    DS    1           ; R13 - Main general reg1
General2    DS    1           ; R14 - Main general reg2
General3    DS    1           ; R15 - Main general reg3

;     Register Bank2 - SerialRP (020-02F hex)
            DS    16          ; Message Buffer space

;     END RAM MAP

*************************************************************************
*       Global function declarations
*************************************************************************

; none

*************************************************************************
*       Interrupt Vectors
*************************************************************************

      SEGMENT code

      vector  reset = Main
      vector  irq0  = IRQ0
      vector  irq1  = IRQ1
      vector  irq2  = IRQ2
      vector  irq3  = IRQ3
      vector  irq4  = TMR0
      vector  irq5  = TMR1

*************************************************************************
*       Z8 based Serial Interface to a LCD Module
*
```

```
*       This is the main section of the program.  It is essentially a
*       loop that cycles each time a complete message is received.  The
*       message is considered complete when the "CR" + "LF" characters are
*       received.  If the message exceeds 16 characters, the characters
*       are displayed in lines of 16 characters with each new line over-
*       writing the previous one.  The receipt of individual characters is
*       denoted by activation of the character available flag.
*
*************************************************************************

Main:
      di                        ; Disable interrupts
; Init Ports
      ld     P2M,#P2M_Init      ; Init Port2 Mode
      ld     P2,#P2_Init        ; Init Port2 Data
      ld     P3M,#P3M_Init      ; Init Port3 Mode
      ld     P3,#P3_Init        ; Init Port3 Data
      ld     P01M,#P01M_Init    ; Init Port0&1 Mode
      ld     P0,#P0_Init        ; Init Port0 Data

; Init Timer subsystem
      ld     T0,#T0_Init        ; Init T0
      ld     PRE0,#PRE0_Init    ; Init PRE0
      ld     T1,#T1_Init        ; Init T1
      ld     PRE1,#PRE1_Init    ; Init PRE1
      ld     TMR,#TMR_Init      ; Init TMR

; Init Interrupt subsystem
      ld     IPR,#IPR_Init      ; Init Interrupt Priority
      ld     IMR,#IMR_Init      ; Init Interrupt Mask
      ld     IRQ,#IRQ_Init      ; Clear any IRQ prior to ei
      ld     RP,#AppRP          ; Initialize the register pointer

; Clear Register Banks for debug clarity
      ld     RegBot,#RegBot+1   ;
ClrRam:                         ;
      clr    @RegBot            ;
      inc    RegBot             ;
      cp     RegBot,#RegTop+1   ;
      jr     ule,ClrRam         ;

      ld     SPL,#StackTop      ; Initialize the stack pointer
      ld     P2M,#P2M_Write     ; Port2 Mode = output
      call   LCM_Wait1          ; Wait for LCM to stabilize
      call   LCM_Init           ; Initialize the LCD Module
      ld     R12,#>MsgInit      ; Create a message pointer
      ld     R13,#<MsgInit      ;
      call   MsgBufLoad         ; Load the message buffer
      call   DisplayMsg         ; Write message to the LCD module
Msg_Loop:
; Reconfigure to recieve new input string and wait for characters
      di
      ld     TMR,#TMR_Init      ; Disable Timers
      ld     IMR,#IMR_RxEnab    ; Enable IRQ3 start bit detect
      ld     IRQ,#IRQ_Init      ; Clear all pending interrupts
      ld     R2,#MsgBufRP       ; Initialize buffer location
```

```
      tm    R0,#RxOverrun     ; Check for overrun situation
      jr    z,ClrBuffer       ; If no overrun, clear the buffer
      ld    @R2,R3            ; Save the overrun character
      inc   R2                ; Move character pointer
      and   R0,#~RxOverrun    ; Clear the Over-run flag
ClrBuffer:
      clr   R3                ; Clear the word buffer
      ei
Chr_Wait:
      tm    R0,#RxWrdAvail    ; Valid character received?
      jr    nz,Rcvd_Char      ; If so, jump
      tm    R0,#RxFrameErr    ; Frame error received?
      jr    z,Chr_Wait        ; If not, jump & continue waiting

; Frame error detected - abort the input string - display error message
      di
      ld    TMR,#TMR_Init     ; Disable Timers
      ld    IMR,#IMR_Init     ; Mask off all interrupts
      ld    IRQ,#IRQ_Init     ; Clear any pending interrupts
      ld    R12,#>MsgFrErr    ; Create a message pointer
      ld    R13,#<MsgFrErr    ;
      call  MsgBufLoad        ; Load the message buffer
      call  DisplayMsg        ; Write message to the LCD module
      and   R0,#~RxFrameErr   ; Clear the frame error flag
      jr    Msg_Loop          ; Return to main message loop

Rcvd_Char:
; Complete character's been recieved - check for end message or
; buffer overflow - otherwise, save char & continue looking for more.
      cp    R3,#'\r'          ; End of message: "CR"?
      jr    eq,EndOfMsg       ; If so, jump to display it
      cp    R3,#'\n'          ;   else, "LF" character?
      jr    eq,IgnoreLF       ; If so, jump to ignore it
      cp    R2,#MsgBufRP+10h  ;   else, check for overrun
      jr    uge,MsgOvrRun     ; If overrun, jump to display
      ld    @R2,R3            ;   else, save the character
      inc   R2                ; Move character pointer
      and   R0,#~RxWrdAvail   ; Clear the char available flag
      jr    Chr_Wait          ; Return to wait for more


IgnoreLF:
; End of input message - ignore the line feed character
      and   R0,#~RxWrdAvail   ; Clear char available flag
      jr    Chr_Wait          ; Return to wait for more


MsgOvrRun:
; More than 16 characters have been recieved - display partial message
      or    R0,#RxOverrun     ; Set the Over-run flag

EndOfMsg:
; End of input message - blank fill empty buffer space, if any, and
; write the message to the LCD module.
      di
      and   R0,#~RxWrdAvail   ; Clear char available flag
```

```
      ld     TMR,#TMR_Init      ; Disable Timers
      ld     IMR,#IMR_Init      ; Mask all interrupts
      ld     IRQ,#IRQ_Init      ; Clear any pending interrupts
BlankFill:
      cp     R2,#MsgBufRP+10h   ; Check for end of buffer
      jr     uge,MsgBufFull     ; If at end, jump
      ld     @R2,#' '           ;   else, save a ' ' character
      inc    R2                 ; Move character pointer
      jr     BlankFill          ; jump to continue filling
MsgBufFull:
      call   DisplayMsg         ; Write message to the LCD module
      jr     Msg_Loop           ; Return to wait for more


*************************************************************************
*   Function Name:      LCM_Init
*
*   Returns:            Nothing
*   Entry values:       Register Pointer set to AppRP
*   Description:     This routine prepares the LCD Module for message
*                    display.
*   Notes:           This routine has 2 entry points.  The first one
*                    (LCM_Init) perform intialization and reset, the
*                    second one (LCM_Reset) performs reset only.
*************************************************************************
LCM_Init:
      and    P0,#~P0_RS_Hi      ; Force RS control line low
      ld     P2,#P2_Init        ; Zero the data bus
      or     P0,#P0_E_Hi        ; Force E control line hi
      and    P0,#~P0_E_Hi       ; Force E control line low
      call   LCM_Wait1          ; Wait for approx 20ms
      ld     P2,#P2_LCM8bits    ; Function set instruction - 8bits
      or     P0,#P0_E_Hi        ; Force E control line hi
      and    P0,#~P0_E_Hi       ; Force E control line low
      call   LCM_Wait1          ; Wait for approx 20ms
      or     P0,#P0_E_Hi        ; Force E control line hi
      and    P0,#~P0_E_Hi       ; Force E control line low
      call   LCM_Wait1          ; Wait for approx 20ms
      or     P0,#P0_E_Hi        ; Force E control line hi
      and    P0,#~P0_E_Hi       ; Force E control line low
      call   LCM_Wait1          ; Wait for approx 20ms
      ld     P2,#P2_DOnNoC      ; Turn on display - no cursor
      or     P0,#P0_E_Hi        ; Force E control line hi
      and    P0,#~P0_E_Hi       ; Force E control line low
      call   LCM_Wait1          ; Wait for approx 20ms
      ld     P2,#P2_AIncNoS     ; Address increment, no shift
      or     P0,#P0_E_Hi        ; Force E control line hi
      and    P0,#~P0_E_Hi       ; Force E control line low
      call   LCM_Wait1          ; Wait for approx 20ms
LCM_Reset:
      ld     P2,#P2_DspClr      ; Clear the display
      or     P0,#P0_E_Hi        ; Force E control line hi
      and    P0,#~P0_E_Hi       ; Force E control line low
      call   LCM_Wait1          ; Wait for approx 20ms
      ld     P2,#P2_CurHome     ; Send the cursor home
      or     P0,#P0_E_Hi        ; Force E control line hi
      and    P0,#~P0_E_Hi       ; Force E control line low
```

```
      call  LCM_Wait1          ; Wait for approx 20ms
      ld    P2,#P2_CGRam       ; Set the CG Ram
      or    P0,#P0_E_Hi        ; Force E control line hi
      and   P0,#~P0_E_Hi       ; Force E control line low
      call  LCM_Wait2          ; Wait for approx 80us
      ld    P2,#P2_DDRam1      ; Set the DD Ram
      or    P0,#P0_E_Hi        ; Force E control line hi
      and   P0,#~P0_E_Hi       ; Force E control line low
      call  LCM_Wait2          ; Wait for approx 80us
      ret


************************************************************************
*  Function Name:      DisplayMsg
*
*  Returns:            Nothing
*  Entry values:       Register Pointer set to AppRP
*  Description:   This routine writes the contents of the message
*                 buffer into the LCD module for display.
*  Notes:
************************************************************************
DisplayMsg:
      call  LCM_Reset          ; Reset LCM for line1
      ld    R13,#MsgBufRP      ; Initialize line1 char pointer
      call  LCM_Write          ; Write line1 data to the LCM
      and   P0,#~P0_RS_Hi      ; Force RS control line to 0
      ld    P2,#P2_DDRam2      ; Load line2 starting address
      or    P0,#P0_E_Hi        ; Force E control line to 1
      and   P0,#~P0_E_Hi       ; Force E control line to 0
      call  LCM_Wait2          ; Wait for approx 80us
      ld    R13,#MsgBufRP+8    ; Initialize line2 char pointer
      call  LCM_Write          ; Write line2 data to the LCM
      ret


************************************************************************
*  Function Name:      LCM_Write
*
*  Returns:       Nothing
*  Entry values:  Register Pointer set to AppRP
*                 R13 loaded with addr of 1st character of the line
*  Description:   This routine loads the 8 characters of the display
*                 line into the module.
*  Notes:
************************************************************************
LCM_Write:
      or    P0,#P0_RS_Hi       ; Force RS control line to 1
      ld    R12,#008h          ; Initialize loop counter
LCM_WrLoop:
      ld    P2,@R13            ; Place character on data bus
      or    P0,#P0_E_Hi        ; Force E control line to 1
      and   P0,#~P0_E_Hi       ; Force E control line to 0
      call  LCM_Wait2          ; Wait for LCM processing
      inc   R13                ; Move the character pointer
      djnz  R12,LCM_WrLoop     ; Check for end of loop
      and   P0,#~P0_RS_Hi      ; Force RS control line to 0
      ret
```

```
*************************************************************************
*   Function Name:      LCM_Wait1
*
*   Returns:        Nothing
*   Entry values:   None
*   Description:    This routine creates a delay of approximately 20ms
*   Notes:
*************************************************************************
LCM_Wait1:
      ld    R14,#Wt1MCnst     ; Initialize upper byte of count
Wait1_Lp2:
      ld    R15,#Wt1LCnst     ; Initialize lower byte of count
Wait1_Lp1:
      djnz  R15,Wait1_Lp1     ; Decrement ls byte count till 0
      djnz  R14,Wait1_Lp2     ; Decrement ms byte count till 0
      ret


*************************************************************************
*   Function Name: LCM_Wait2
*
*   Returns:        Nothing
*   Entry values:   None
*   Description:    This routine creates a delay of approximately 80us
*   Notes:
*************************************************************************
LCM_Wait2:
      ld    R14,#Wt2Const     ; Initialize count value
Wait2_Lp:
      djnz  R14,Wait2_Lp      ; Decrement count till 0
      ret


*************************************************************************
*   Function Name: MsgBufLoad
*
*   Returns:        Message buffer loaded with 16 character message
*   Entry values:   Register Pointer set to AppRP
*                   R12 contains msbyte of message start addr
*                   R13 contains lsbyte of message start addr
*   Description:    This routine loads the message buffer with an
*                   internally generated 16 byte message.
*   Notes:
*************************************************************************
MsgBufLoad:
      ld    R2,#MsgBufRP      ; Initialize Comm Buffer Location
      ld    R14,#010h         ; Initialize loop counter
MsgBufLoop:
      ldci  @R2,@RR12         ; Load Character into buffer
      djnz  R14,MsgBufLoop    ; Test for end of message
      dec   R2
      ret


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

```
*       IRQ3 Interrupt Service
*
*       This routine performs the RS232 input function @4800 baud
*       Format: 8 bits data - LSB first,no parity, 1 start, 1 stop
*       Note: All bits inverted since there's no inverting input buffer
*
*       Procedure: Rising Start bit edge causes IRQ3 service.
*       After a half bittime input is sampled again to validate
*       the Start bit. Then IRQ5 is enabled and T0 is setup for bittime
*       delay in continous mode.
*
**************************************************************************
IRQ3:
; Setup half bit-time and wait to validate start bit
        ld      R11,#024h           ; Half bit-time =~ 104us
StrtBitWait:
        djnz    R11,StrtBitWait     ; Wait for center of start bit
        tm      P3,#P3_RxBit        ; Take Sample on P32: RX=0?
        Jr      nz,StrtValid        ; If nonzero, Start bit is valid!
        Iret                        ;   else, ignore it

StrtValid:
        ld      TMR,#TMR_RxEnab     ; Load & enable T0
        ld      IMR,#IMR_RxLoop     ; Enable IRQ4 (T0) only
        ei                          ; Reenable interrupts

        clr     R3                  ; Clear the word buffer
        ld      R1,#008h            ; Load the number of data bits
Rcv_Loop:
        nop                         ; Clear pipeline
        halt                        ; Wait to sample data
        tm      P3,#P3_RxBit        ; RX=0?
        jr      z,Rcvd0             ; If zero, then jump
        rcf                         ;   else, reset carry (data=0)
        jr      Rcvd1               ;
Rcvd0:
        scf                         ; Set carry (data=1)
Rcvd1:
        rrc     R3                  ; Carry into MSB, LSB into carry
        dec     R1                  ; Decrement bit counter
        jr      nz,Rcv_Loop         ; If not 0, jump to continue loop
        nop                         ;   else, wait for stop bit
        halt                        ;

        tm      P3,#P3_RxBit        ; Test Stop Bit
        jr      z,FrameOK           ; If stop bit=0 - OK, jump
        or      R0,#RxFrameErr      ;    else, set frame error flag
        jr      RxExit              ;
FrameOK:
        Or      R0,#RxWrdAvail      ; Set data available flag
RxExit:
        di
        ld      IRQ,#IRQ_Init       ; Clear interrupts
        ld      TMR,#TMR_Init       ; Disable timers
        ld      IMR,#IMR_RxEnab     ; Reenable IRQ3 only
        iret
```

```
*************************************************************************
*     Timer 0 Interrupt Service
*
*     This timer is used to create the bit time for the 4800 baud xfer.
*     There is no processing involved.
*
*************************************************************************
TMR0:
      iret

*************************************************************************
*     Unused Interrupt Service
*************************************************************************

; Empty IRQ's defined earlier so that the processor will have a 16 bit
;   address in memory to jump to and return from in the case of a stray
;   or glich interrupt.

IRQ0:
IRQ1:
IRQ2:
TMR1:
        iret

*************************************************************************
*     System messages
*************************************************************************

MsgBlank:   .ASCII      "                "      ; Blank display message
MsgInit:    .ASCII      ">Ready          "      ; Initialization message
MsgFrErr:   .ASCII      ">Frame Error!!! "      ; Frame error message


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

; End of main program.

        End
```

Test Procedure

Equipment Used

Testing the application requires the following items:

- Target application board built according to the schematic in the Appendix
- 5V, 1A bench supply (for application power)

- Windows 95/98/NT-based PC with ZDS 2.11 or higher installed
- Z86CCP01ZEM (CCP Emulator)
- Z86CCP00ZAC (Emulator Accessory Pack)
- 8V @ 0.8 A power supply (for emulator power)

A DOS or Windows terminal program, such as HyperTerminal, running on the COM port of your choice, is also required to exercise the applications's RS-232 interface.

General Test Setup and Execution

Exercise the application by either burning an OTP (stand-alone) or running the application from the emulator.

If using an emulator, at least two free serial ports are required on your PC. One is for the emulator and the other for the application's RS-232 interface. Follow the instructions for Assembling the Application Code as described in the previous section.

To send messages to the application, configure the terminal program as follows:

- Direct connection to the com port where the application is connected
- 4800 baud, no parity, 8 data bits, 1 stop bit, and 1start bit
- No flow control
- Echo locally typed characters to the computer screen.

Test Results

When power is applied to the application, the application immediately responds with the >Ready message. To read the display, it may be necessary to adjust the LCD contrast by changing the setting of potentiometer R3. Also, press switch SW1 to demonstrate the module backlight.

Using the terminal program, demonstrate the display of messages entered from the keyboard. Note that the standard ASCII character set (7-bit) is supported. Messages containing ASCII characters greater than 07Fh result in the display of Asian or symbol characters. A message may contain from 0 to 16 characters and is terminated by the Enter key. If more than 16 characters are entered as a message, they display in sets of 16 characters until the Enter terminates the message.

Note: If the HyperTerminal program is used as the terminal software, be aware that some versions contain a bug. If any character is pressed repeatedly, the third occurrence and then every other occurrence of the character is corrupted. The corruption is manifested as having the most significant bit of the character set to 1 (for example, `031h` is corrupted into `0B1h`). This value includes the `Enter` key.

References

1. Z8 Microcontroller User's Manual, UM97Z8X0104, ZiLOG, Inc., 1997.
2. The Z8 Application Note HandbookDB97Z8X01, ZiLOG Corporation, 1996.
3. Serial Communications Using the Z8 CCP Software UART, AP96Z8X1300, ZiLOG, Inc., 1997.
4. Interfacing LCDs to the Z8,AP96Z8X1400, ZiLOG, Inc., 1997.
5. The ZiLOG Macro Cross Assembler User Manual, UM003601, ZiLOG, Inc., 1997.
6. Liquid Crystal Display, HC16102 Datasheet, Hyundai Electronic Industries Co, Ltd.

Appendix

Figure 6. LCM Interface Schematic