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Driving LCD Displays Using the MC68HC705L16 Microcontroller

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Introduction

This application note describes how to use the MC68HC705L16 microcontroller (MCU) as an LCD (liquid crystal display) controller/driver. By doing so, all LCD control and drive functions are performed by a single chip, which also provides all of the functionality of a microcontroller.

A description of the voltages and waveforms used to drive and control an LCD panel is included as well as an explanation of how the designer can use the MC68HC705L16 to interface directly to a simple LCD display. Also, the source code for controlling a multiplexed display is included at the end of this application note.

MOTOROLA

Liquid Crystal Displays

To understand the types of waveforms that drive LCD displays, it is helpful to understand a few fundamentals about LCDs.

For example, liquid crystal displays are composed of a polarizing liquid crystalline material in between two plates of glass. Typically, one plate is called the common or backplane, and the other is called a segment or frontplane. In a reflective LCD panel (one that has no back light), a voltage difference applied across the two electrodes will result in a polarization which will prevent the light from reflecting back to the observer. This will appear as a dark segment and is, therefore, considered ON. A lack of voltage difference will allow the light to reflect back and is considered OFF.

Contrast

Due to the chemical nature of the liquid crystal material, DC voltages cannot be used to drive the segments or else permanent damage can occur to the LCD. To avoid this problem, voltage levels are applied to the electrodes for a short period and then the levels are reversed to the electrodes for an equal period. This AC waveform will produce an RMS voltage across the LCD, yet it has a net DC value of 0 volts. As a result, LCD material has its contrast specified in terms of an RMS voltage. A typical voltage characteristic for a reflective LCD display is shown in **Figure 1**.

The ON voltage for a segment should be greater than the point where incident light is reduced by 90 percent. The OFF voltage should be less than the point where incident light is reduced by 10 percent. For maximum contrast, the ratio of ON to OFF voltage should be as large as possible. Examples of how to calculate RMS voltages are shown in a later section.

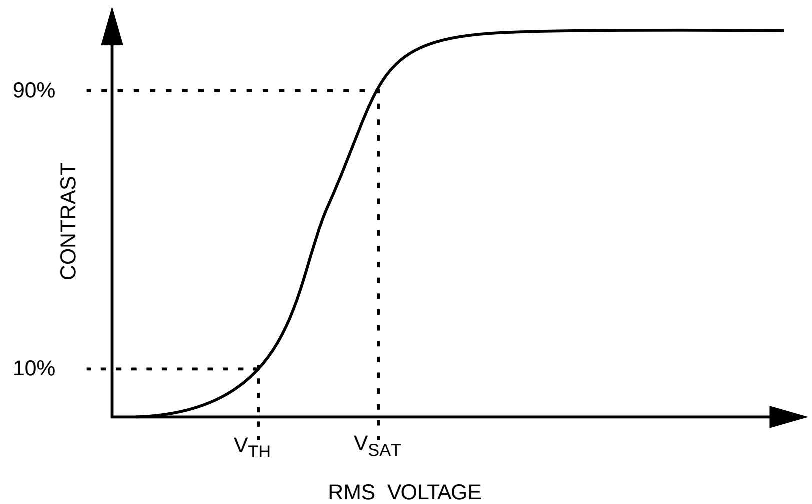


Figure 1. Typical Contrast Characteristic of LCD

Static Mode

Typically, LCD displays are made up of segments or pixels. Segment displays usually have anywhere from 8 to 16 segments for displaying each character, while dot matrix displays typically have arrays of 5 x 7 pixels for each character.

Each of these segments or pixels needs to be driven independently in order for it to be turned on or off independently. The simplest way to do this is to have a separate frontplane driver for each segment or pixel and have a single backplane driver for the entire display. This is known as direct drive or static mode.

Example waveforms of the frontplane and backplane drivers for static mode are shown in **Figure 2**. The voltage across a segment is the difference of the backplane waveform and the frontplane waveform. See **Figure 3**.

For a segment to be OFF, its frontplane waveform and backplane waveform will have the same amplitude and will be completely in phase. This causes the voltage across the segment to be 0 volts.

For a segment to be ON, its frontplane and backplane waveforms will be exactly out of phase. This will produce a difference across the segment equal to the top LCD voltage.

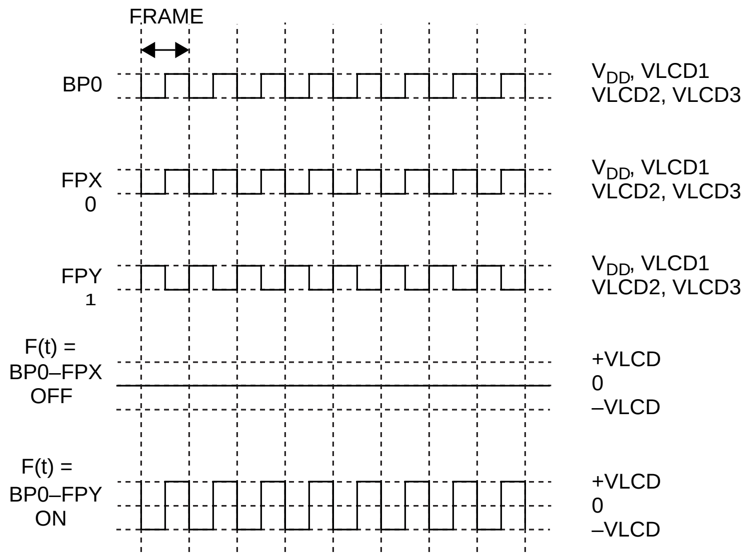


Figure 2. LCD 1/1 Duty and 1/1 Bias Timing Diagram,
$V_{LCD1} = V_{DD}$, $V_{LCD2} = V_{LCD3} = V_{DD}–V_{LCD}$

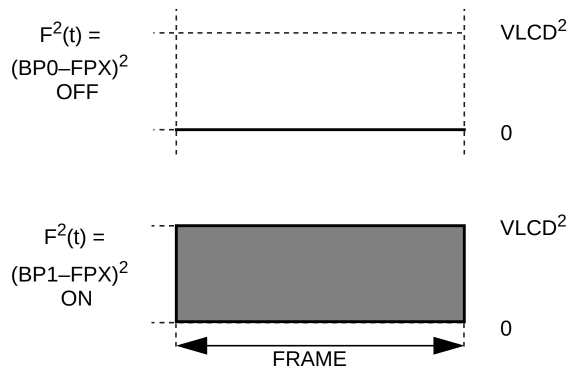


Figure 3. Waveform Components for Calculating ON and OFF RMS Voltages

Since static mode has only two voltage levels, the three LCD pins on the L16 must be connected in a specific manner as shown in **Figure 4**. Here V_{LCD1} is connected to V_{DD}, a resistor is connected between V_{LCD1} and V_{LCD2}, and V_{LCD2} and V_{LCD3} are connected directly. A variable resistor can be connected from V_{LCD3} to ground to allow manual contrast control.

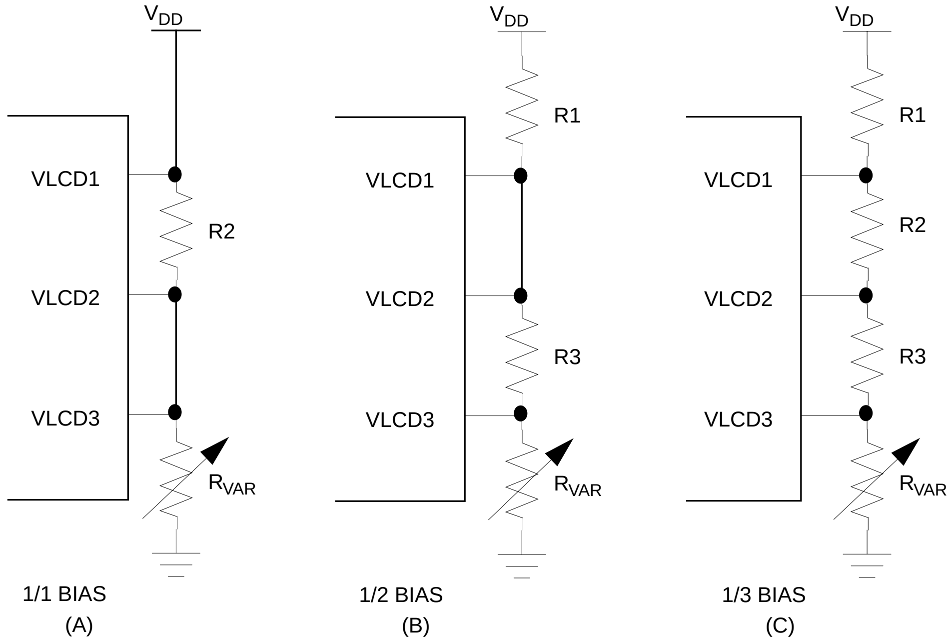


Figure 4. External Connections for 1/1, 1/2, and 1/3 Bias

Now the RMS voltages for the static waveform can be calculated from this formula:

$$V_{RMS} = \sqrt{\frac{1}{T} \cdot \int f^2(t)dt}$$

The function f(t) here is the waveform, BPX–FPY. **Figure 3** shows $f^2(t)$ of the ON and OFF voltage waveforms for one frame. This serves as a graphical aid to illustrate the RMS voltages, which are simply the area under these curves. For the OFF segment, the RMS voltage is obviously 0 volts.

For the ON segment:

$$V_{RMSON} = \sqrt{\frac{1}{2} \cdot \left(V_{LCD}{}^2 + V_{LCD}{}^2\right)} = V_{LCD}$$

where $V_{LCD} = V_{DD} - V_{LCD2}, V_{LCD3}$. This V_{RMSON} voltage, typically, is well above the 90 percent ON threshold, thus producing excellent contrast.

The total number of pins needed for static mode drive is equal to the number of total segments in the display plus one. Unfortunately, as the size of the LCD display increases, the number of required LCD driver pins becomes very large.

As **Table 1** shows, for more than a few 8-segment characters, the number of pins required becomes unreasonable. For small displays, though, this type of LCD drive is commonly used since it produces excellent contrast.

Table 1. LCD Driver Pins Versus Multiplexing

Display Type	Total Segments/ Pixels	Number of Driver Pins				
		Static	1/2 Duty	1/3 Duty	1/4 Duty	1/32 Duty
1 16-segment digit	16	17	10	9	8	N/A
4 7-segment digits	32	33	18	14	12	N/A
8 alphanumeric characters	120	121	62	43	34	36
32 5 x 8 pixel characters	1280	1281	642	430	324	72
General case	S	S +1	S/2 + 2	S/3 + 3	S/4 + 4	S/32 + 32

Multiplex Modes

To reduce the number of drivers required, the data for each frontplane can be multiplexed to control multiple segments by using multiple backplanes. This is done by multiplexing the driving voltages in time.

For instance:

- If each frontplane controls two segments, two backplanes are needed. This is called duplex mode.
- Triplex mode is where each frontplane driver controls three segments and three backplanes are needed.
- Similarly, quadraplex mode has each frontplane driver controlling four segments and has four backplane drivers.

Duplex Mode

The waveforms for duplex mode multiplexing are shown in **Figure 5**. The first thing to notice here is that there are now three voltage levels in each waveform. This is known as 1/2 bias. Connections to the V_{LCD} pins for this configuration should be made as shown in **Figure 4**.

Also obvious from these waveforms is that there are two time cycles in each waveform which make up a frame.

They are:

- When frontplanes connected to segments with backplane 0 are active
- When frontplanes connected to segments with backplane 1 are active

In time cycle one, frontplane X is ON, while in cycle two, it is OFF. Frontplane Y is OFF in both cycles.

Looking at the waveform for BP0–FPX, the ON data produces the maximum voltage swing, V_{LCD}, during its active time, cycle one. The waveform BP1–FPX has OFF data which produces a 0 voltage swing during its active time, cycle two.

NOTE: *Notice that when both of these segments are not active, they have the same voltage swing, $V_{LCD}/2$, even though one has OFF data when non-active and the other has ON data when non-active. This is important because the RMS voltages for ON and OFF waveforms should be independent of the data during non-active cycles. Otherwise, there would be multiple ON RMS voltages as well as OFF RMS voltages.*

Figure 6 shows the components for calculating the RMS waveforms for duplex mode ON and OFF cases. The ON and OFF RMS voltages are calculated as:

$$V_{RMSON} = \sqrt{\frac{1}{2} \cdot \left[V_{LCD}^{2} + \left(\frac{V_{LCD}}{2}\right)^{2}\right]} = 0.79 \cdot V_{LCD}$$

$$V_{RMSOFF} = \sqrt{\frac{1}{2} \cdot \left(\frac{V_{LCD}}{2}\right)^{2}} = 0.353 \cdot V_{LCD}$$

For V_{LCD} = 5 volts, V_{RMSON} = 3.95 volts, and V_{RMSOFF} = 1.75 volts

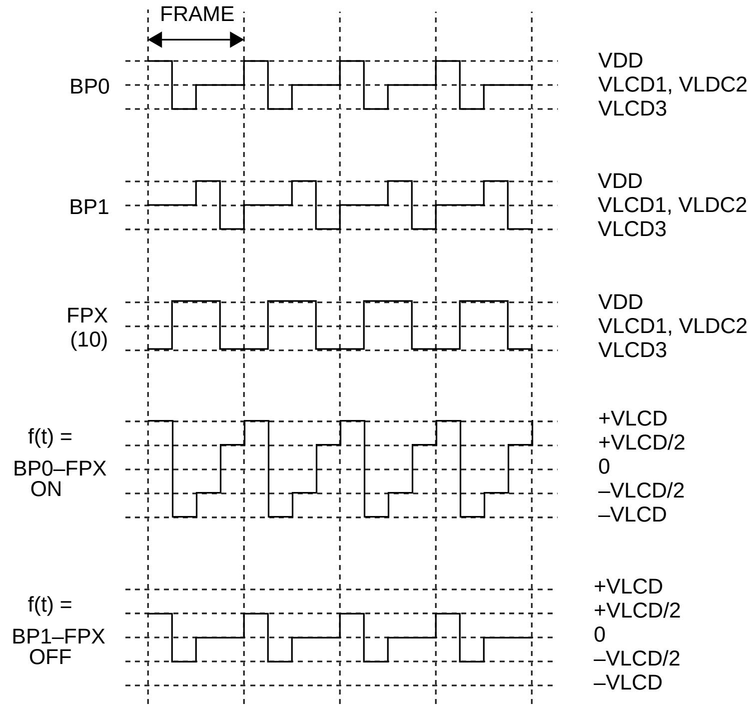


Figure 5. LCD 1/2 Duty and 1/2 Bias Timing Diagram, $V_{LCD1} = V_{LCD2} = V_{DD}–V_{LCD}/2$, $V_{LCD3} = V_{DD}–V_{LCD}$

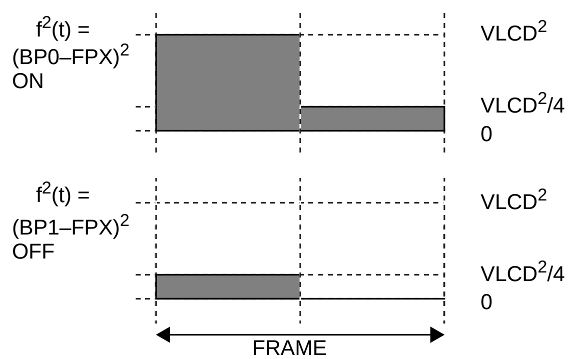


Figure 6. Waveform Components for Calculating ON and OFF RMS Voltages

Triplex Mode

Triplex multiplexing uses four voltage levels (1/3 bias) and utilizes three time cycles per frame. See **Figure 4** for V_{LCD} pin connections. Waveforms for triplex (1/3 duty) are shown in **Figure 7**. Again, notice that during the active cycle, an ON voltage swing across a segment is $\pm V_{LCD}$. The OFF voltage swing is only $\pm V_{LCD}/3$.

The components for calculating the RMS voltages are shown in **Figure 8** and are calculated as:

$$V_{RMSON} = \sqrt{\frac{1}{3} \cdot \left[V_{LCD}^{2} + 2 \cdot \left(\frac{V_{LCD}}{3} \right)^{2} \right]} = 0.638 \cdot V_{LCD}$$

$$V_{RMSOFF} = \sqrt{\frac{1}{3} \cdot 3 \cdot \left(\frac{V_{LCD}}{3} \right)^{2}} = 0.333 \cdot V_{LCD}$$

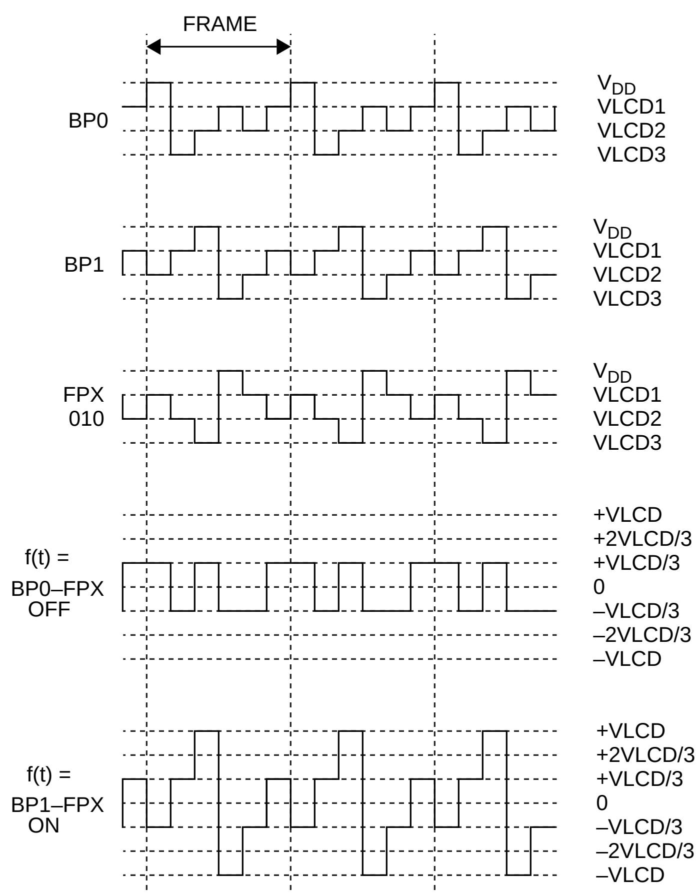


Figure 7. LCD 1/3 Duty and 1/3 Bias Timing Diagram, $V_{LCD1} = V_{DD} – V_{LCD}/3$, $V_{LCD2} = V_{DD} – 2V_{LCD}/3$, $V_{LCD3} = V_{DD} – V_{LCD}$

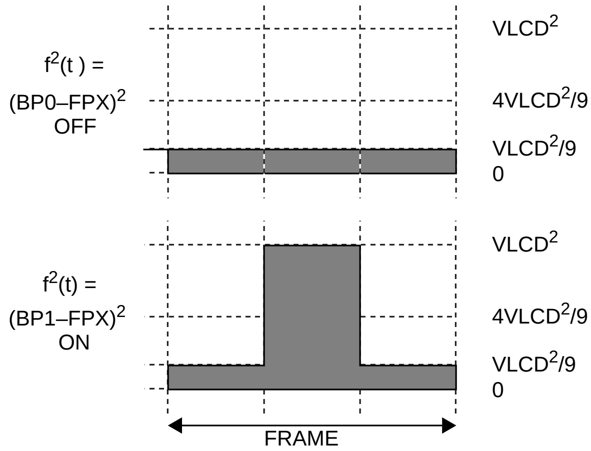


Figure 8. Waveform Components for Calculating ON and OFF RMS Voltages

Quadruplex Mode

The highest multiplexing capable by the MC68HC705L16 is quadruplex (1/4 duty). Large dot matrix displays require much larger multiplexing. For instance, a 4 x 4 0 display (4 rows of 40 pixels) needs 1/32 duty. (See *Automatic Contrast Control of LCD Displays Using the 68HC708LN56 Microcontroller*, Motorola document order number AN1762/D, for information on driving this type of display.) Waveforms for quadruplex multiplexing are shown in **Figure 9**. Again, 1/4 bias is used here.

The components for calculating the RMS waveforms for ON and OFF cases of quadruplex muxing are shown in **Figure 10**.

The voltages are calculated as:

$$V_{RMSON} = \sqrt{\frac{1}{4} \cdot \left[V_{LCD}^{2} + 3 \cdot \left(\frac{V_{LCD}}{3} \right)^{2} \right]} = 0.577 \cdot V_{LCD}$$

$$V_{RMSOFF} = \sqrt{\frac{1}{4} \cdot 4 \cdot \left(\frac{V_{LCD}}{3} \right)^{2}} = 0.333 \cdot V_{LCD}$$

It should now be obvious that as the amount of multiplexing increases, the RMS voltages decrease. Contrast, measured as the ratio of V_{RMSON}/V_{RMSOFF}, is called the discrimination ratio.

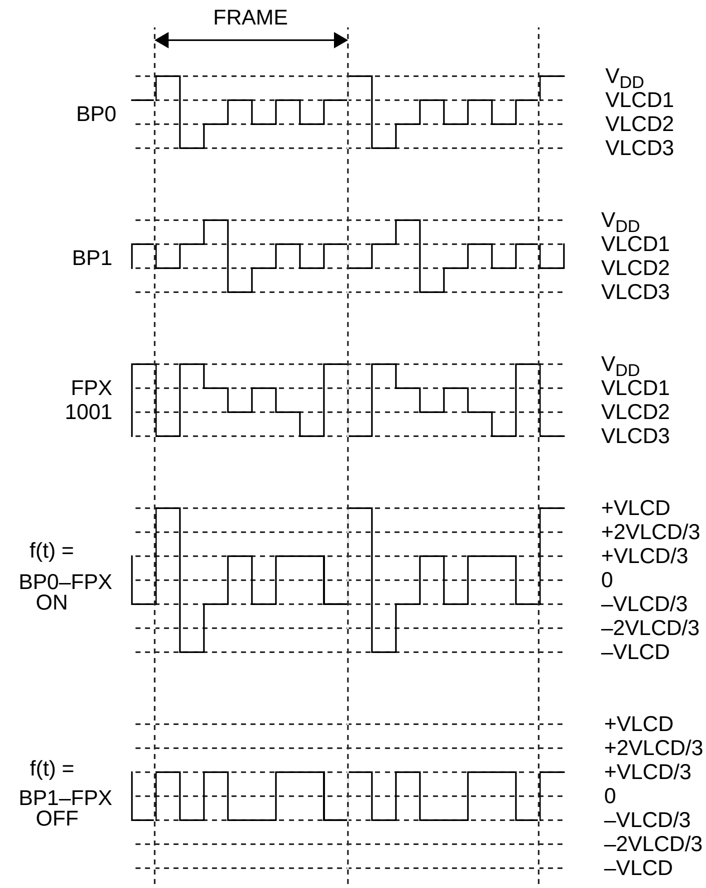


Figure 9. LCD 1/4 Duty and 1/3 Bias Timing Diagram
$V_{LCD1} = V_{DD}–V_{LCD}/3$, $V_{LCD2} = V_{DD}–2V_{LCD}/3$, $V_{LCD3} = V_{DD}–V_{LCD}$

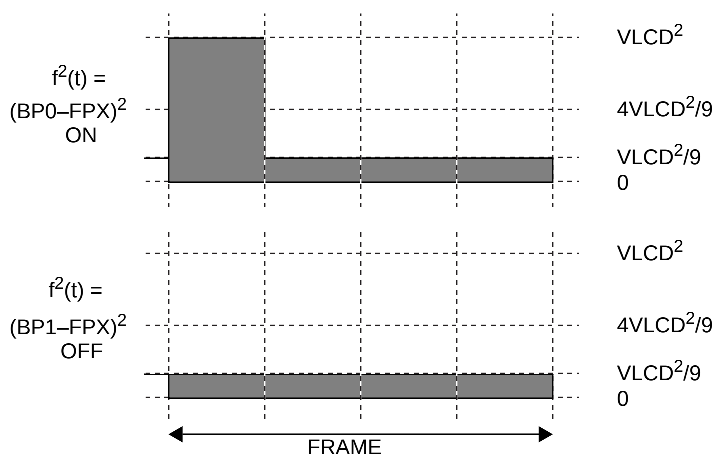


Figure 10. Waveform Components for Calculating ON and OFF RMS Voltages

Sample Application

To demonstrate how simple it is to use the MC68HC705L16 to drive an LCD panel directly, a simple application is described in which a text message is displayed on an 8-digit, 15-segment display (Planar-Standish Model 4228). The display will be driven by 1/4 duty and 1/3 bias.

Figure 11 shows a schematic diagram of the circuit with all connections labelled. A resistor divider from V_{DD} is used to generate the three voltage levels, V_{LCD1}, V_{LCD2}, and V_{LCD3}, for the waveforms. A variable resistor at the bottom of the divider allows manual contrast adjustment. The four backplane pins from the MCU are connected to the four common pins on the LCD panel. Since the 1/4 duty is being used, four segments can be driven by each frontplane driver and, therefore, 32 frontplanes drivers are needed. The first 32 frontplane pins from the MCU are connected to the LCD panel, while the remaining seven are not used.

These connections from the MCU to the LCD panel determine the mapping of the LCD data registers to the segments of the LCD panel. Each digit on the panel is composed of 16 segments, controlled by two consecutive 8-bit LCD data registers. Each LCD data register controls two frontplanes. Therefore, four frontplanes are required to drive each digit of the display. **Figure 12** shows the mapping of the register bits to the segments in one of the characters on the display.

For example, the letter G would be represented by the two bytes: $05E4. The first byte in register LCDR1 would be 00000101. The second byte in register LCDR2 would be 11100100. Together, the lit segments would create the letter G. See **Figure 13**.

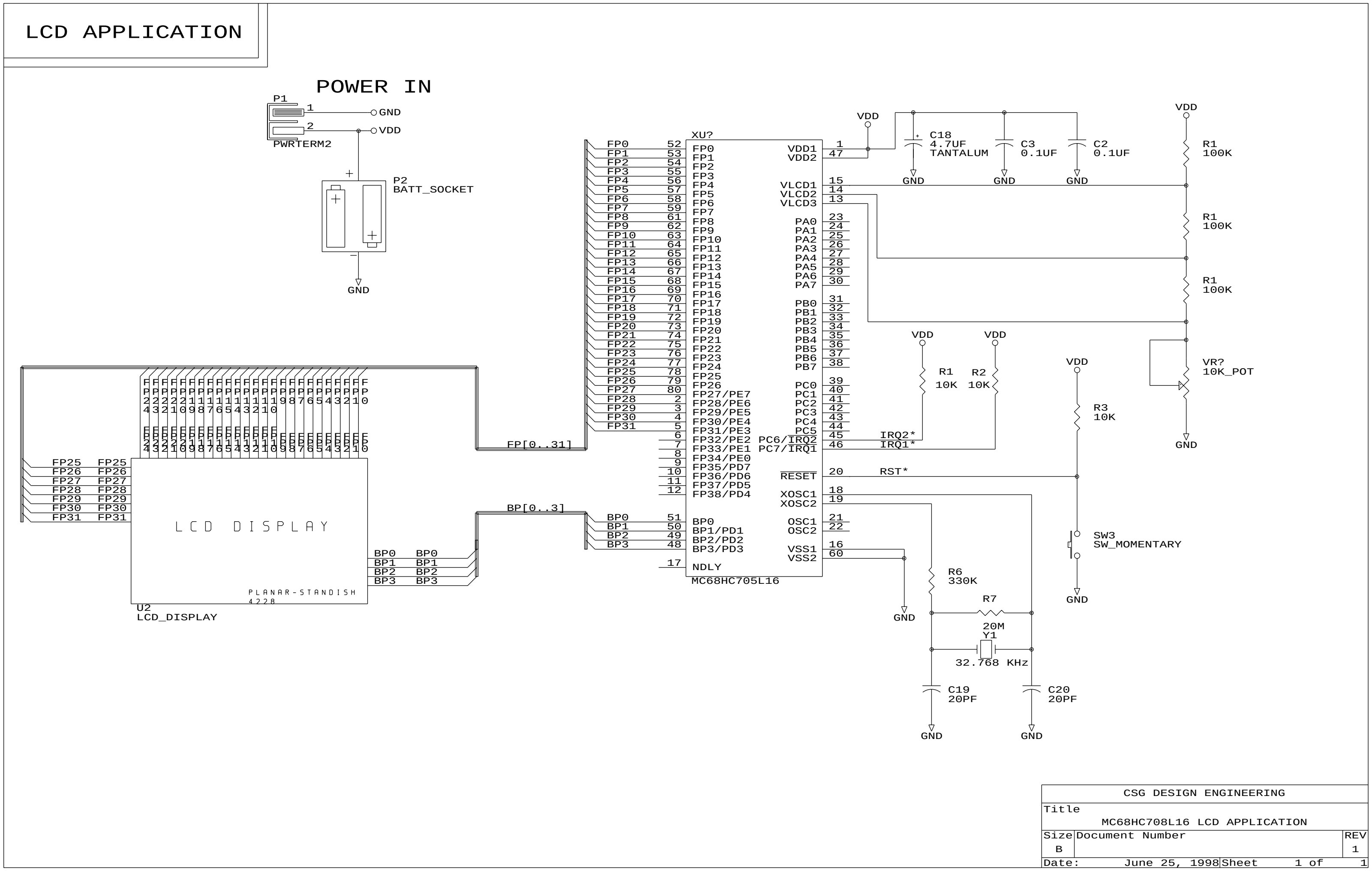
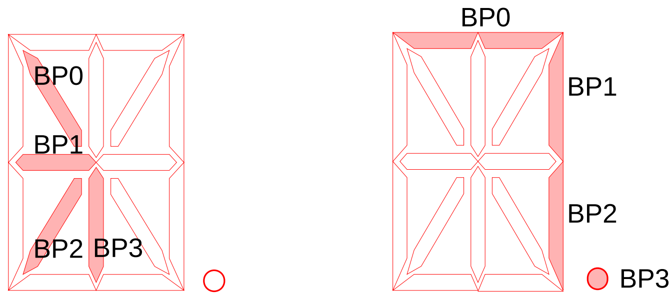
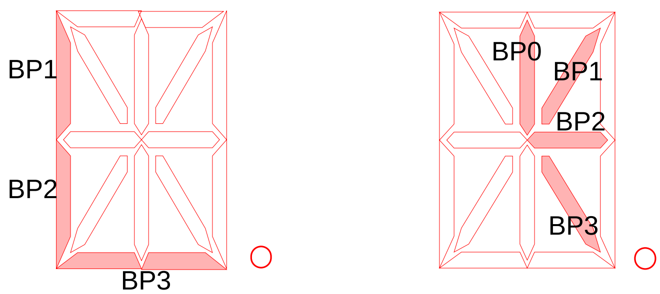


Figure 11. Schematic Diagram of Sample LCD Application

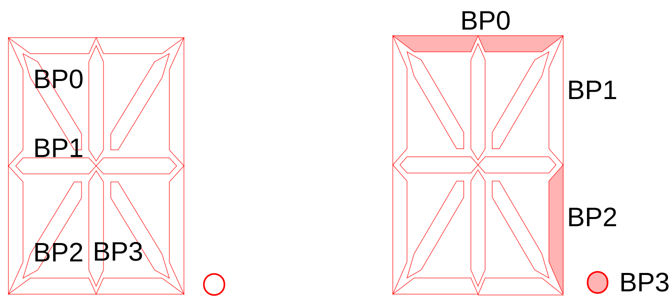


	FP(2X-1)				FP(2X-2)			
	Bit 7	6	5	4	3	2	1	Bit 0
LCDR1	BP3	BP2	BP1	BP0	BP3	BP2	BP1	BP0

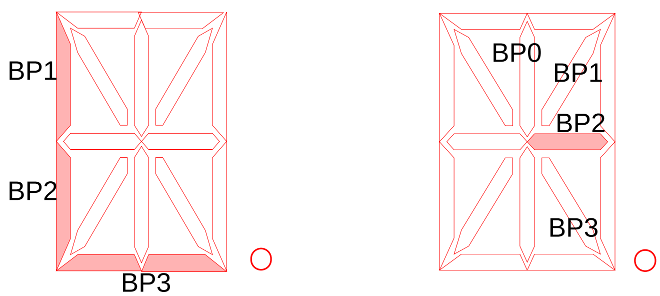


	FP(2X-1)				FP(2X-2)			
	Bit 7	6	5	4	3	2	1	Bit 0
LCDR2	BP3	BP2	BP1	BP0	BP3	BP2	BP1	BP0

Figure 12. Mapping of LCD Register Bits to Display Segments



	FP(2X-1)				FP(2X-2)			
	Bit 7	6	5	4	3	2	1	Bit 0
LCDR1	0	0	0	0	0	1	0	1



	FP(2X-1)				FP(2X-2)			
	Bit 7	6	5	4	3	2	1	Bit 0
LCDR2	1	1	1	0	0	1	0	0

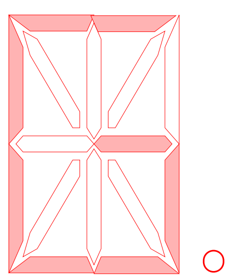


Figure 13. Example Display of the Letter G

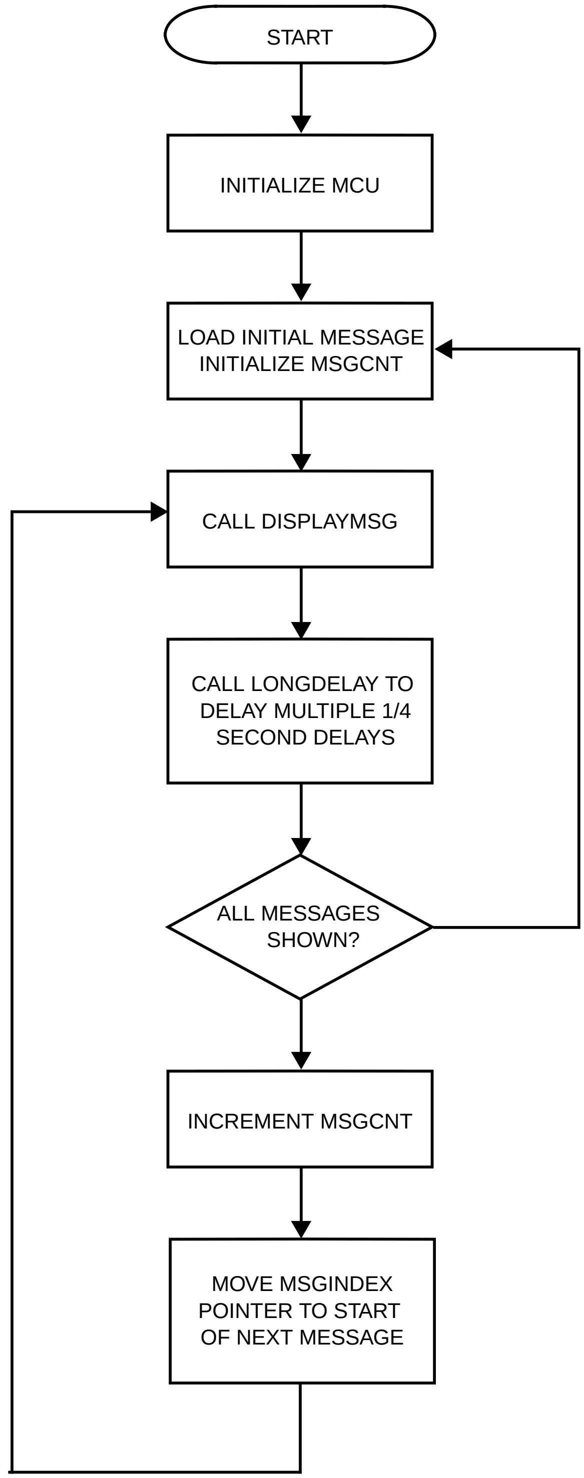


Figure 14. Main Program Flow

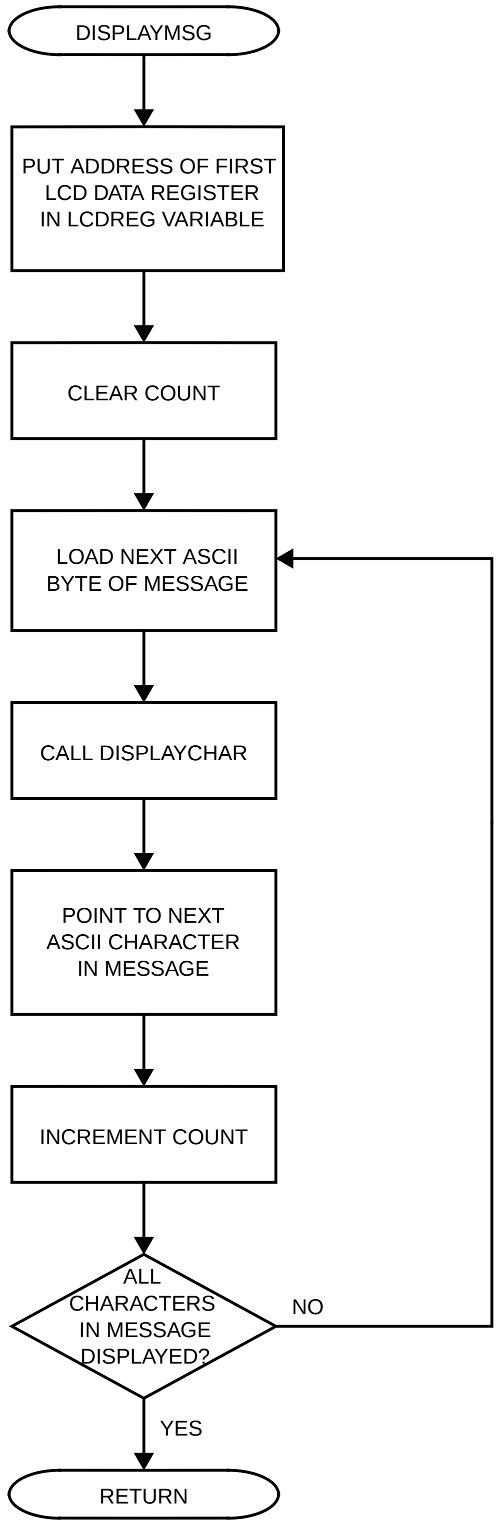


Figure 15. DisplayMsg Subroutine

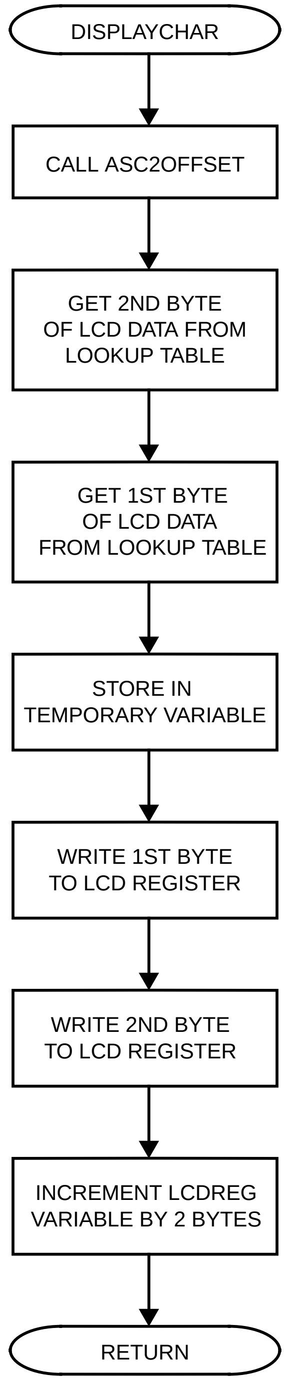


Figure 16. DisplayChar Subroutine

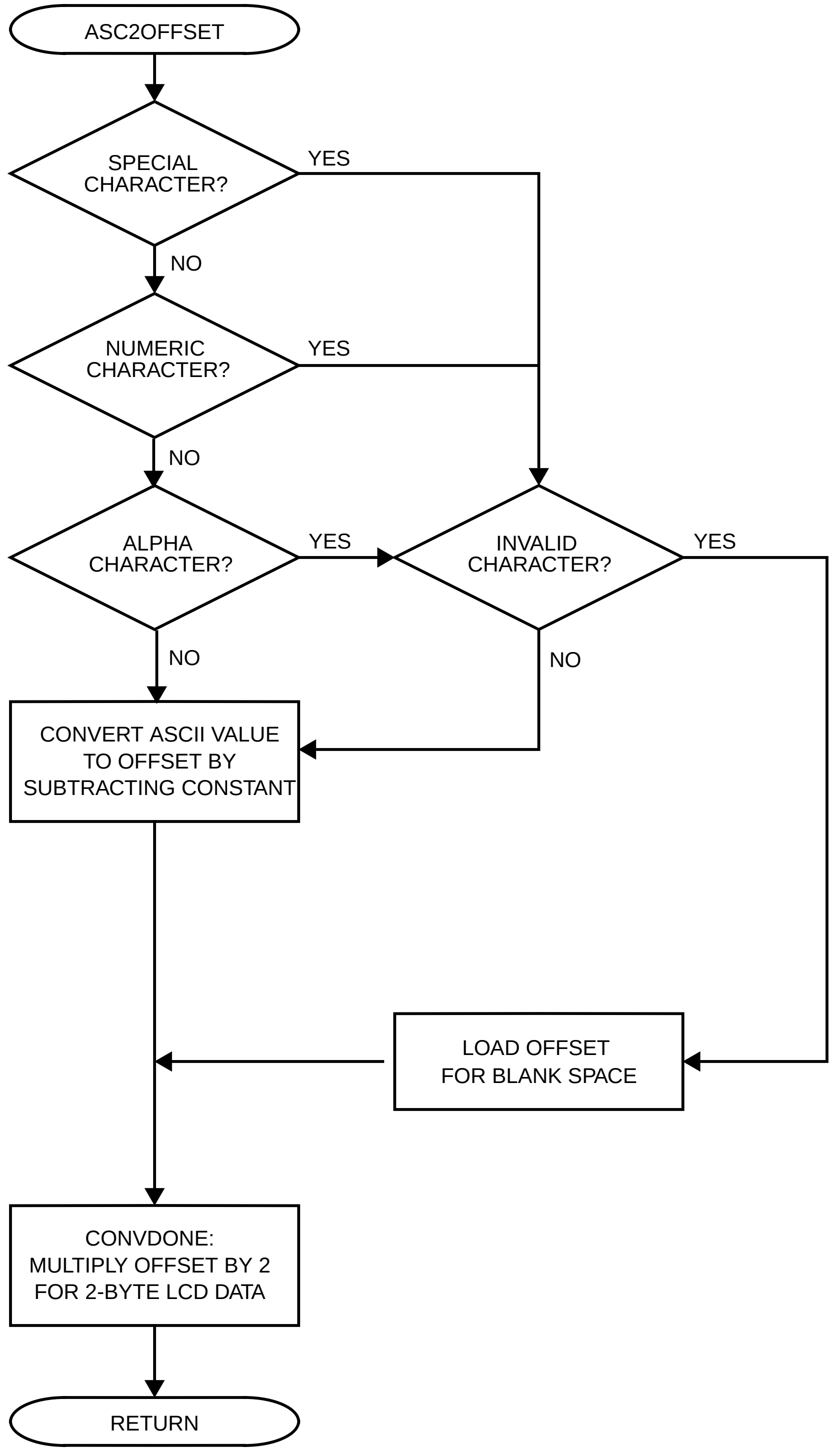


Figure 17. ASC2OFFSET Subroutine

Code Listings

```
*************************************************************************************
* LCD_DISPLAY.ASM
*************************************************************************************
* Ed Stellini, 06/06/98
* CSG Design Engineering
* Motorola SPS
*
* Software written to demonstrate direct drive of LCD display
* using MC68HC705L16 microcontroller.
*
* The LCD used is a Planar-Standish Model 4228 Multiplex
* 15-segment, 8-digit panel. (1/4 duty, 1/3 bias)
*
*************************************************************************************
$BASE         10T                          ;Default assembler number base

*************************************************************************************
* Memory Equates
*************************************************************************************
RAMSPACE      EQU     $0040                ;Start of user RAM
ROMSPACE      EQU     $1000                ;Start of user ROM
RESETVEC      EQU     $FFFE                ;Reset vector

************************************************************************************
* Register Equates
************************************************************************************
* Registers
MISC          EQU     $3E                  ;Miscellaneous register
TBCR1         EQU     $10                  ;Time base control register 1
LCDCR         EQU     $20                  ;LCD control register
LCDDR         EQU     $21                  ;First LCD data register location

* Bit locations
LCDE          EQU     $07                  ;LCD enable bit in LCDCR
SYS0          EQU     $02                  ;SYS0 bit in MISC
SYS1          EQU     $03                  ;SYS1 bit in MISC

*************************************************************************************
* LCD Equates
*************************************************************************************
MAXCHARS      EQU     $08                  ;Maximum characters per line of LCD
NUMMSGS       EQU     $05                  ;Number of message lines to display
QTRSECS       EQU     $14                  ;20 quarterseconds = 5 seconds
EOT           EQU     $04                  ;End of string marker (ASCII EOT)
```

```
*******************************************************************************
* RAM Variables
*******************************************************************************
               ORG      RAMSPACE              ;Start of user RAM
TempX          RMB      1                     ;Temporary register storage
TempA          RMB      1                     ;Temporary register storage
TempData       RMB      1                     ;Temp storage for LCD segment data
LCDReg         RMB      1                     ;8-bit address pointer
Count          RMB      1                     ;Counter variable
MsgIndex       RMB      1                     ;Index counter variable
MsgCount       RMB      1                     ;Current message count

*******************************************************************************
* Start of program code
*******************************************************************************
               ORG      ROMSPACE              ;Start of user EPROM
Start          BCLR     SYS0,MISC             ;Setup for f_op = f_osc/2
               BCLR     SYS1,MISC
               LDA      #$20                  ;XOSC for time base
               STA      TBCR1                 ;LCD clock = XOSC/128 = 256Hz
               BSET     LCDE,LCDCR            ;Enable LCD

*******************************************************************************
* Initialize string to be initially displayed.
*******************************************************************************
Initial        LDA      #Msg1                 ;Load offset of desired string
               STA      MsgIndex              ;Setup the message index
               LDA      #!1                   ;
               STA      MsgCount              ;

*******************************************************************************
* Main loop
* Display each message from memory in sequential order.
*******************************************************************************
MainLoop       LDX      MsgIndex              ;Start at current message
               JSR      DisplayMsg            ;Show current message
               JSR      LongDelay             ;Delay for #QTRSECS quarterseconds

               LDA      MsgCount              ;Get current count
               CMP      #NUMMSGS              ;Check if through all messages
               BEQ      Initial               ;Start with Msg1 again
               INC      MsgCount              ;Next message
               LDA      MsgIndex              ;Get current message index
               ADD      #MAXCHARS             ;Move index to next message
               STA      MsgIndex              ;Store new message index
               BRA      MainLoop              ;Repeat
```

```
******************************************************************************
* SUBROUTINES
******************************************************************************

******************************************************************************
* Show the current string portion on the display.
* When called, the X register contains the index offset.
******************************************************************************
DisplayMsg     LDA      #LCDDR                ;First LCD data register
               STA      LCDReg                ;LCDReg = First LCD data register
               CLR      Count                 ;Clear the counter variable
NextByte       LDA      Msgs,X                ;Load ASCII byte of string
               JSR      DsplayChar            ;Display character
               INCX                           ;Increment the index
               INC      Count                 ;Increment the counter
               LDA      Count                 ;Check the counter
               CMP      #MAXCHARS             ;for LCD display length
               BEQ      Done                  ;End of display line reached
               BRA      NextByte              ;Ready the next byte
Done           RTS                            ;Return

******************************************************************************
* DsplayChar converts an ASCII character value in Register A to
* an offset into the character table. The two bytes at the offset
* location of the table define the segment values for displaying
* the character on the display. Then use the offset into the LCD
* data table to get the 2 bytes for the LCD position, and store
* them in the appropriate LCD data registers.
******************************************************************************
DsplayChar     STX      TempX                 ;Save X register
               JSR      ASC2Offset            ;Convert ASCII byte into table offset
               TAX                            ;Put offset into X
               LDA      Table+1,X             ;Get second LCD data byte
               STA      TempData              ;Store it temporarily
               LDA      Table,X               ;Load A with first LCD data byte
               LDX      LCDReg                ;Point X to current LCD data register
               STA      0,X                   ;Store first byte to LCD data register
               LDA      TempData              ;Load A with second data byte
               STA      1,X                   ;Store it to second LCD data register
               INC      LCDReg                ;Increment LCDreg pointer to
               INC      LCDReg                ;point to the next position's regs.
               LDX      TempX                 ;Restore X register
               RTS                            ;Return
```

```
******************************************************************************
* Convert ASCII character byte in A to an offset value into
* the table of LCD segment values.
* The software also checks for an invalid or unusable ASCII
* character value, and shows a blank space in its place.
* Valid ASCII values are (decimal): 32-47, 48-57, 65-90
******************************************************************************
ASC2Offset     CMP     #!48                 ;Check for "special" character
               BLO     Special
               CMP     #!65                 ;Check for numeric character
               BLO     Numeric
Alpha          CMP     #!90                 ;Check for invalid value
               BHI     ConvError
               SUB     #!39                 ;Convert to table offset
               BRA     ConvDone
Special        CMP     #!32                 ;Check for invalid value
               BLO     ConvError
               SUB     #!32                 ;Convert to table offset
               BRA     ConvDone
Numeric        CMP     #!57                 ;Check for invalid value
               BHI     ConvError
               SUB     #!32                 ;Convert to table offset
               BRA     ConvDone
ConvError      CLRA                         ;Invalid value shows as blank space
ConvDone       ROLA                         ;Multiply offset by 2
               RTS                          ;(2 bytes data per LCD position)
******************************************************************************
* BlankSpace shows a space ($0000) at the current display position's
* LCD data registers.
******************************************************************************
BlankSpace     LDX     LCDReg               ;Point to current LCD data register
               CLR     0,X                  ;Clear first data byte
               CLR     1,X                  ;Clear second data byte
               INC     LCDReg               ;Increment LCDreg pointer to
               INC     LCDReg               ;point to the next position's regs.
               RTS                          ;Return

******************************************************************************
* Delay for number of quarterseconds = QTRSEC
******************************************************************************
LongDelay      CLRX                         ;
Delayloop      LDA     #!250                ;Load accumulator with #ms to delay
               JSR     Delay                ;Jump to #ms delay subroutine
               INCX                         ;
               TXA
               CMP     #QTRSECS             ;
               BEQ     Finish               ;
               BRA     Delayloop            ;
Finish         RTS                          ;Return
```

```
*********************************************************************************
* Delay for time = Accumulator*1ms (fop = 1MHz)
* Accumulator contains the number of 1ms delays desired
*********************************************************************************
Delay          CMP     #$00                    ;Check for remaining delays
               BEQ     DDone                   ;Done?

MsDelay        STA     TempA
               LDA     #$5A
MsLoop         CMP     #$00
               BEQ     MsDone
               DECA
               BRA     MsLoop
MsDone         LDA     TEMPA

               DECA                            ;Decrement count
               BRA     Delay                   ;Repeat
DDone          RTS                             ;Return

*********************************************************************************
* ROM Constants
*********************************************************************************
*********************************************************************************
* LCD Messages
* Each individual message is identified by its offset into the
* base address labelled Msgs.
* This limits user to 8 bits of offset (255 characters worth.
* If more than 255 characters are desired for messages, one can
* use some 2-byte variable which can contain multiple base addresses.
*
* Valid characters are 0-9, A-Z (UPPERCASE ONLY!), and certain
* special characters defined in the table as valid.
*********************************************************************************
Msgs           EQU     *                       ;Base address of messages
*********************************************************************************
Msg1           EQU     *-Msgs                  ;First message offset
               FCB     "THE L16 "
*********************************************************************************
Msg2           EQU     *-Msgs                  ;Second message offset
               FCB     "DRIVES  "
*********************************************************************************
Msg3           EQU     *-Msgs                  ;Third message offset
               FCB     "LCD     "
*********************************************************************************
Msg4           EQU     *-Msgs                  ;Fourth message offset
               FCB     "DISPLAYS"
*********************************************************************************
Msg5           EQU     *-Msgs                  ;Fifth message offset
               FCB     "DIRECTLY"
*********************************************************************************
EndMsgs        EQU     *-Msgs                  ;End of messages label
```

```
******************************************************************************************
* Lookup table of LCD segment values for ASCII character values
* Some characters can not be displayed on 15-segment LCD, so
* they are marked as invalid, and will be displayed as a blank space.
******************************************************************************************
Table          FDB     $0000                 ;' '
               FDB     $0000                 ;'!' INVALID
               FDB     $0201                 ;'"'
               FDB     $0000                 ;'#' INVALID
               FDB     $A5A5                 ;'$'
               FDB     $0000                 ;'%' INVALID
               FDB     $0000                 ;'&' INVALID
               FDB     $0001                 ;'''
               FDB     $000A                 ;'('
               FDB     $5000                 ;')'
               FDB     $F00F                 ;'*'
               FDB     $A005                 ;'+'
               FDB     $0000                 ;',' INVALID
               FDB     $2004                 ;'-'
               FDB     $0800                 ;'.'
               FDB     $4002                 ;'/'
               FDB     $47E2                 ;'0'
               FDB     $0602                 ;'1'
               FDB     $23C4                 ;'2'
               FDB     $2784                 ;'3'
               FDB     $2624                 ;'4'
               FDB     $21A8                 ;'5'
               FDB     $25E4                 ;'6'
               FDB     $0700                 ;'7'
               FDB     $27E4                 ;'8'
               FDB     $27A4                 ;'9'
               FDB     $2764                 ;'A'
               FDB     $8785                 ;'B'
               FDB     $01E0                 ;'C'
               FDB     $8781                 ;'D'
               FDB     $21E4                 ;'E'
               FDB     $2164                 ;'F'
               FDB     $05E4                 ;'G'
               FDB     $2664                 ;'H'
               FDB     $8181                 ;'I'
               FDB     $06C0                 ;'J'
               FDB     $206A                 ;'K'
               FDB     $00E0                 ;'L'
               FDB     $1662                 ;'M'
               FDB     $1668                 ;'N'
               FDB     $07E0                 ;'O'
               FDB     $2364                 ;'P'
               FDB     $07E8                 ;'Q'
               FDB     $236C                 ;'R'
               FDB     $25A4                 ;'S'
               FDB     $8101                 ;'T'
```

```
               FDB      $06E0                 ;'U'
               FDB      $4062                 ;'V'
               FDB      $4668                 ;'W'
               FDB      $500A                 ;'X'
               FDB      $9002                 ;'Y'
               FDB      $4182                 ;'Z'
EndTable       EQU      *-Table               ;End of table label

*************************************************************************************
* Vector definitions
*************************************************************************************
               ORG      RESETVEC              ;Reset vector
               FDB      Start
```

Application Note

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