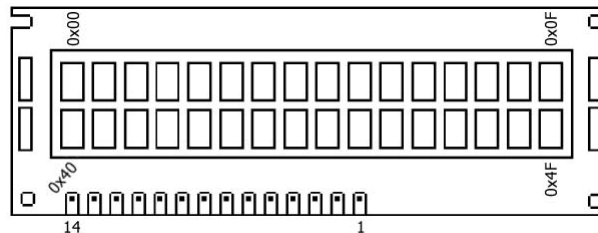
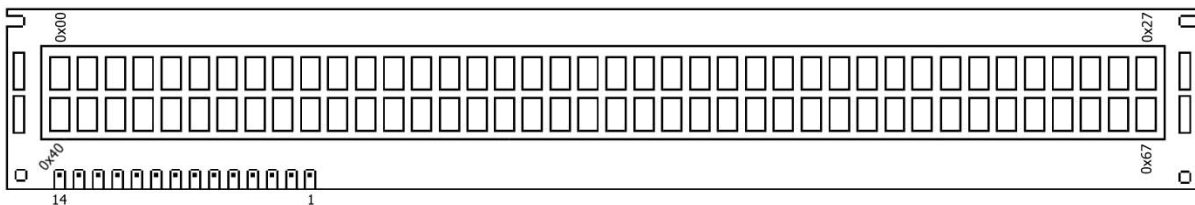


Programming PIC Microcontrollers in PicBasic Pro – LCD Lesson 1 Cornerstone Electronics Technology and Robotics II

- **Administration:**
 - Prayer
- **Introduction:**
 - Two Types of LCDs:
 - Serial LCDs:
 - Serial LCDs are connected to the PIC microcontroller using only one data line.
 - Serial communication is handled with standard RS232 asynchronous data communication protocols. See: http://cornerstonerobotics.org/curriculum/lessons_year2/ejii_rs232_2.pdf
 - Parallel LCDs:
 - Parallel LCDs are connected to the PIC using either 4 or 8 data wires.
 - Data is transferred to the LCD in parallel form.
 - HD44780 LCD Module:
 - One of the most popular LCD modules in industry and by hobbyists.
 - Available with or without backlights.
 - 5 x 8 and 5 x 10 dot matrix possible
 - Comes in line lengths of 8, 16, 20, 24, 32, and 40 characters.
 - Available with 1, 2, or 4 rows.



LCD Display with 2 Lines x 16 Characters



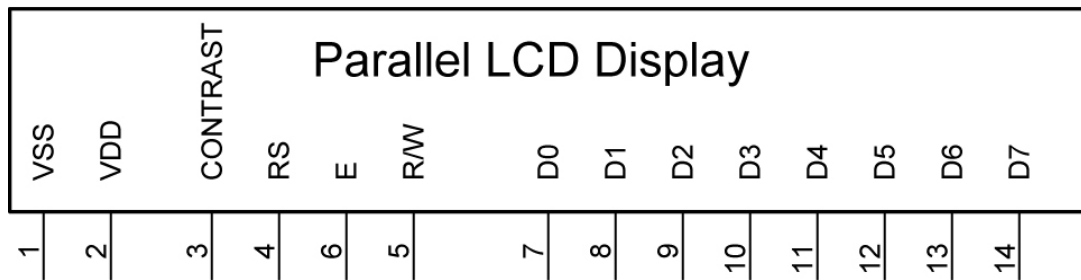
LCD Display with 2 Lines x 40 Characters

From: http://www.electronic-engineering.ch/microchip/datasheets/lcd/the_lcd_data_sheet.pdf

- **LCD (Liquid Crystal Display) Basics:**

- Reference: <http://www.epemag.wimborne.co.uk/lcd1.pdf>
- LCD Display Layout:

Jameco Part # 618003 (No Back Light)

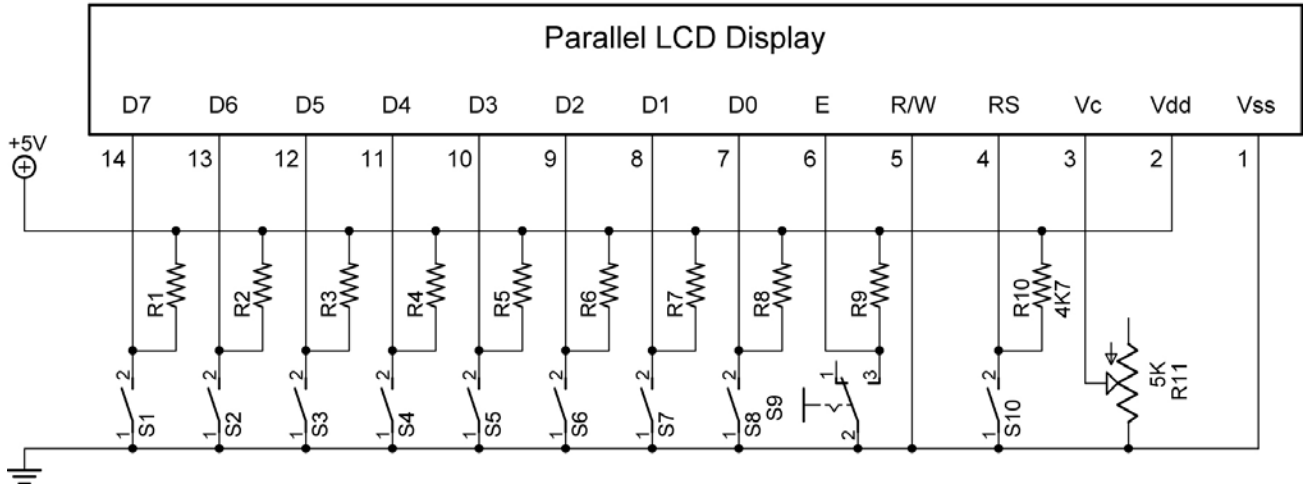


- Pin Functions:

- Pins 1 and 2, V_{SS} and V_{DD} : Pin 1 and 2 are the power source, with Pin 1 connected to ground, and Pin 2 connected to +5 v.
- Pin 3, Contrast: Used to alter the contrast on the display. If incorrectly adjusted, the contrast can cause the display to be invisible.
- Pin 4, Register Select (RS):
 - First of the three command inputs: (RS, R/W, E)
 - 0 = Instruction (Command) Input
 - 1 = Data (Character) Input
- Pin 5, Read/Write (R/W):
 - 0 = Write to LCD module
 - 1 = Read from LCD module
- Pin 6, Enable (E): This input is used to initiate the actual transfer of commands or character data between the module and the data lines. When writing to the display, data is transferred only on the high to low transition of this signal. However, when reading from the display, data will become available shortly after the low to high transition and remain available until the signal falls again.
- Pins 7-14, Data Bus Lines: Data can be transferred to and from the display, either as single 8-bit byte or as two 4-bit nibbles. In the latter case, only the upper four data lines (D4 – D7) are used. This 4-bit mode is beneficial when using a microcontroller, as fewer input/output lines are required. The user may select whether the LCD is to operate with a 4-bit data bus or an 8-bit data bus. If a 4-bit data bus is used the LCD will require a total of 7 data lines (3 control lines plus the 4 lines for the data bus). If an 8-bit data bus is used the LCD will require a total of 11 data lines (3 control lines plus the 8 lines for the data bus).

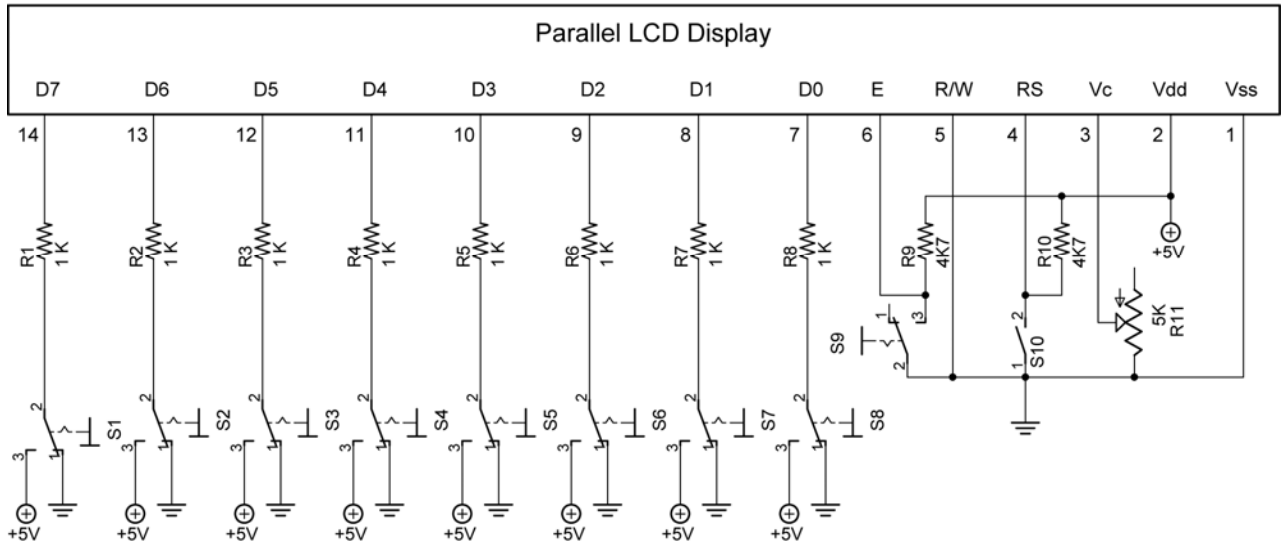
- Manual Experiments:
 - Wire the following circuit:
 - Use a SIP resistor network for R1 – R8
 - Use DIP switch for S1 – S8

Jameco Part # 618003 (No Back Light)



Manual Experiments Circuit on Breadboard

Jameco Part # 618003 (No Back Light)



Manual Experiments Circuit for Analog/Digital Trainer

LCD Command Control Codes

Command	Binary								Hex
	D7	D6	D5	D4	D3	D2	D1	D0	
Clear Display	0	0	0	0	0	0	0	1	01
Display & Cursor Home	0	0	0	0	0	0	1	X	02 or 03
Character Entry Mode	0	0	0	0	0	1	I/D	S	04 to 07
Display On/Off & Cursor	0	0	0	0	1	D	U	B	08 to 0F
Display/Cursor Shift	0	0	0	1	D/C	R/L	x	x	10 to 1F
Function Set	0	0	1	8/4	2/1	10/7	x	x	20 to 3F
Set CGRAM Address	0	1	A	A	A	A	A	A	10 to 7F
Set Display Address	1	A	A	A	A	A	A	A	80 to FF

I/D: 1=Increment*, 0=Decrement	R/L: 1=Right Shift, 0=Left Shift
S: 1=Display Shift On, 0=Display Shift Off	8/4: 1=8-bit Interface*, 0=4-bit Interface
D: 1=Display On, 0=Display Off*	2/1: 1=2 Line Mode, 0=1 Line Mode*
U: 1=Cursor Underline On, 0=Underline Off*	10/7: 1=5x10 Dot Matrix, 0=5x7 Dot Matrix
B: 1=Cursor Blink On, 0=Cursor Blink Off*	
D/C: 1=Display Shift, 0=Cursor Move	X=Don't Care * = Initialization Settings

Note: Underlined commands below refer to the LCD Command Control Codes table above.

- RS Switch (Switch 10)
 - When RS switch is set to *LOW* (ground), it is set in the *command mode* and the LCD module will receive command code.
 - When the RS switch is off the RS pin is pulled up to a *HIGH* (+5V) through the 4.7K pull-up resistor; it is set in the *character mode* and the LCD module will receive character code.
- Blinking cursor and two line mode:
 - Go to LCD1 LAB 1 – Command Control Codes, complete the Display On/Off & Cursor and Function Set command exercises.

- Standard LCD Character Table:
 - Since these LCD modules were designed in Japan, the LCD character table contains some of the Katakana phonetic symbols.
 - The top column codes must be entered before entering the row code.

Char. code

xxxx0000	0	0	0	0	0	0	0	1	1	1	1	1	1
xxxx0001	0	0	0	1	1	1	1	0	0	1	1	1	1
xxxx0010	0	1	1	0	0	1	1	1	1	0	0	1	1
xxxx0011	0	0	1	0	1	0	1	0	1	0	1	0	1
xxxx0100	0	0	0	0	0	0	0	1	1	1	1	1	1
xxxx0101	0	0	0	1	1	1	1	0	0	1	1	1	1
xxxx0110	0	1	1	0	0	1	1	1	1	0	0	1	1
xxxx0111	0	0	1	0	1	0	1	0	1	0	1	0	1
xxxx1000	0	0	0	0	0	0	0	1	1	1	1	1	1
xxxx1001	0	0	0	1	1	1	1	0	0	1	1	1	1
xxxx1010	0	1	1	0	0	1	1	1	1	0	0	1	1
xxxx1011	0	0	1	0	1	0	1	0	1	0	1	0	1
xxxx1100	0	0	0	0	0	0	0	1	1	1	1	1	1
xxxx1101	0	0	0	1	1	1	1	0	0	1	1	1	1
xxxx1110	0	1	1	0	0	1	1	1	1	0	0	1	1
xxxx1111	0	0	1	0	1	0	1	0	1	0	1	0	1

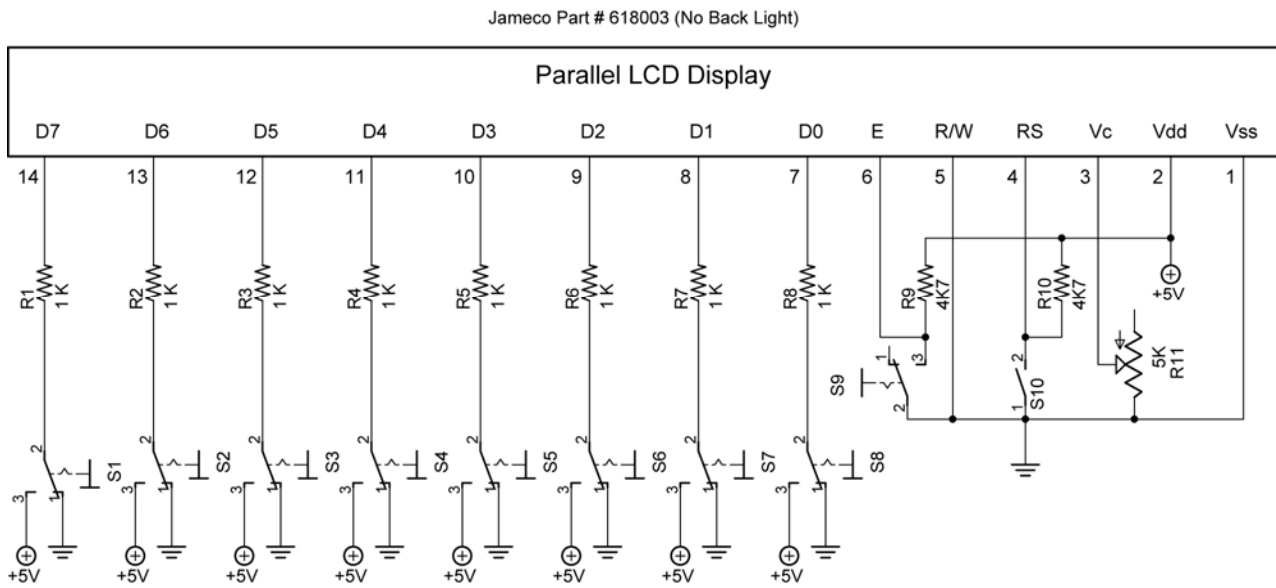
Standard LCD Character Table

- Entering Text:
 - When entering text or characters, the RS pin must be set to HIGH. This is accomplished with the 4.7 K pull-up resistor when Switch 10 is opened.
 - Return to LCD1 LAB 1 – Command Control Codes, complete the Clearing Display command, Entering Text, and Display & Cursor Home command exercises.

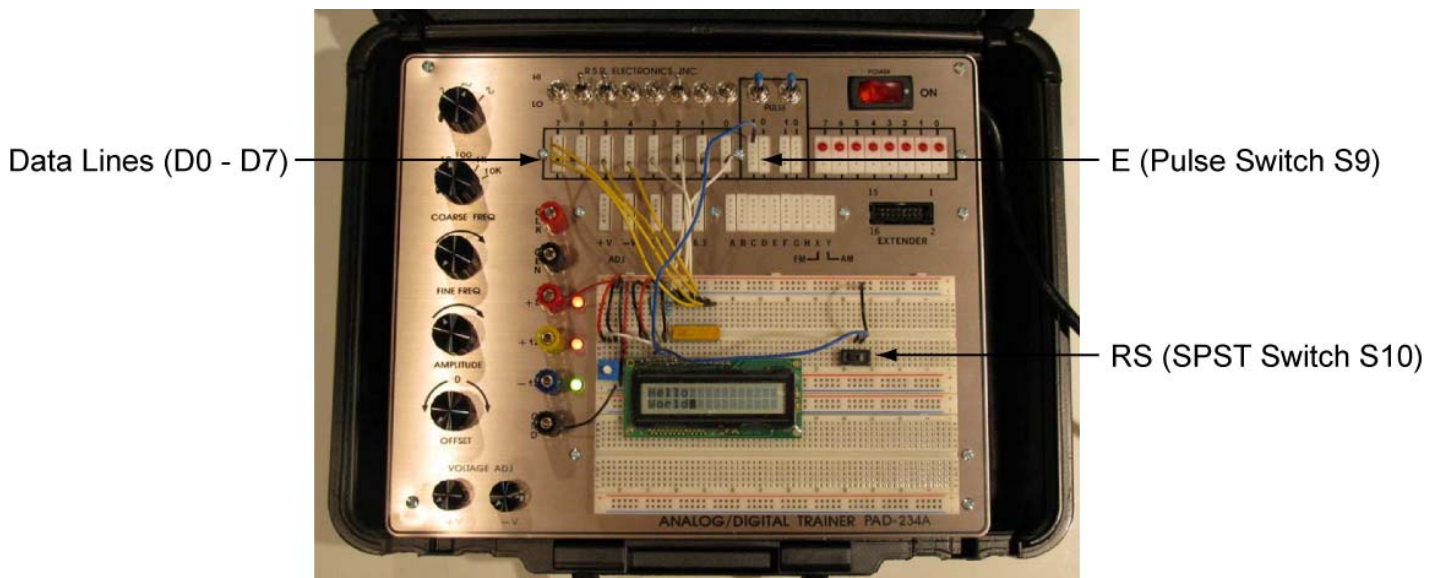
- Moving the Cursor to Another Display Location:
 - The LCD can hold 80 total characters even though only 16 may be displayed on each line at any time on the 16x2 LCD screen.
 - In the single line mode, all 80 characters can be stored on that one line.
 - In the 2-line mode, each line can hold up to 40 characters.
 - Go to LCD1 LAB 1 – Command Control Codes, complete the Set Display Address Command exercises.
- Display/Cursor Shift:
 - Characters written off the face of the display may be shown by shifting the character string to the left or right.
 - Go to LCD1 LAB 1 – Command Control Codes, complete the Display/Cursor Shift Command exercises.
- Character Entry Mode:
 - Characters can be entered as a calculator would enter numbers.
 - Go to LCD1 LAB 1 – Command Control Codes, complete the Character Entry Mode Command exercise.
- User-Defined Graphics:
 - The users can create their own custom graphical displays on the LCD display.
 - Notice that in the Standard LCD Character Table, the first column (%00000000 to %00001111) is blank. This is the CGRAM (Character-Generator Random-Access Memory).
 - LCDs which use the Hitachi HD44780 module can generate and store 8 characters in the CGRAM.
 - Complete LCD1 LAB2 – User-Defined Graphics

Cornerstone Electronics Technology and Robotics II LCD1 LAB 1 – Command Control Codes

- **Purpose:** The purpose of this lab is to acquaint the student with the LCD pin functions and sending LCD command control codes to the LCD.
- **Apparatus and Materials for Analog/Digital Trainer Circuit:**
 - 1 – Analog/Digital Trainer
 - 1 – 16x2 Parallel LCD Display, Jameco Part # 618003
 - 1 – 1K DIP Resistor Package
 - 2 – 4K7 Resistors
 - 1 – 5K Ohm Potentiometer
 - 1 – SPST Switch
 - 1 – NO Momentary Switch
- **Discussion and Procedure:**
 - Wire the circuit below.



Manual Experiments Circuit for Analog/Digital Trainer



○ **Display On/Off & Cursor Commands:**

Display On/Off & Cursor	0	0	0	0	1	D	U	B
-------------------------	---	---	---	---	---	---	---	---

- Adjust the potentiometer until the squares are slightly visible.
- RS is LOW (RS is LOW whenever using LCD command control codes)
- Set Display On/Off & Cursor commands as follows: S1 – S8 in the schematic to %00001111 (\$0F)
 - D=1, Display On; D=0, Display Off (from LCD Command Control Codes in table above)
 - U=1, Cursor Underline On; U=0, Cursor Underline Off
 - B=1, Cursor Blink On; B=0, Cursor Blink Off
- Press S9 momentarily (E) which enables the chip to accept the command.
- Upper left hand corner cursor should be blinking and underlined.
- Referring to the LCD Command Control Codes Table, turn off the underline mode and leave the blinking mode on. Now turn off the blinking mode and turn the underline mode back on. **Remember, RS is LOW when sending commands to the LCD and that E must be triggered when sending each command.**

○ **Function Set Commands:**

Function Set	0	0	1	8/4	2/1	10/7	x	x
--------------	---	---	---	-----	-----	------	---	---

- RS is LOW
- Set Function Set commands as follows:
 - S1 – S8 to %00111000 (\$38)
 - 8/4: 1=8-bit interface. 0=4-bit interface
 - 2/1: 1=2 line mode, 0=1 line mode
 - 10/7: 0=5x7 dot matrix, 1=5x10 dot matrix
 - This sets the Function Set commands to 8-bit data, two lines, and 5x7 dot matrix format.
- Press S9 momentarily (E) which enables the chip to accept the command.
- Change the 2/1 entry to 1 line mode then back to 2 line mode.
- Increase contrast to increase drive to two lines.
- **Return to the lesson.**

○ **Clearing Display Command:**

Clear Display	0	0	0	0	0	0	0	1
---------------	---	---	---	---	---	---	---	---

- Set RS back to LOW
- Set the Clear Display command as follows:
 - S1 – S8 to %00000001
- Press S9 momentarily (E) which enables the chip to accept the command.

- **Entering Text:**
 - Set RS to HIGH (Open switch 10).
 - Set S1 – S8 to %01000001
 - Press S9 momentarily (E) which enables the chip to accept the character.
 - The capital letter A should appear in the upper left corner.
 - Enter other text:
 - RS remains on HIGH
 - Set S1 – S8 to the character code found in the Standard LCD Character Table above for the desired character.
 - Press S9 momentarily (E) which enables the chip to accept the characters.
 - Input your name with capital and small letters.
 - The code for a blank space is %11111110.
 - If you want to correct a letter entry, set RS to LOW, enter %00010000, and then toggle S9 (E). Set RS back to HIGH.

- **Display & Cursor Home Command:**

Display & Cursor Home	0	0	0	0	0	0	1	X
-----------------------	---	---	---	---	---	---	---	---

- Start by entering some text
- Now set RS to LOW
- Set the Display & Cursor Home command as follows:
 - S1 – S8 to %0000001x where x can be HIGH or LOW, it doesn't matter.
- Press S9 momentarily (E) which enables the chip to accept the command.
- **Return to the lesson.**

- **Set Display Address Command:**

Set Display Address	1	A	A	A	A	A	A	A
---------------------	---	---	---	---	---	---	---	---

- RS is LOW
- LCD display address command must be %10000000 greater than the display address. For example, the display address %00001111 must be input as %10000111 and the display address %1000101 must be input as %11000101.
- Press S9 momentarily (E) which enables the chip to accept the command.
- Clear the LCD
- Move cursor to different locations on the LCD
- Enter "Cornerstone Academy" on the first line starting in display address %0000000. Notice that only "Cornerstone Acad" will show up on the display.
- Enter "Gainesville, FL 32605" on the second line indented one space on the display. Only "Gainesville, FL " will appear on the display.
- Keep "Cornerstone Academy" and "Gainesville, FL 32605" on the display for the next exercise.
- **Return to the lesson.**

0000000	0000001	0000010	0000011	0000100	0000101	0000110	0000111	0001000	0001001	0001010	0001011	0001100	0001101	0001110	0001111
1000000	1000001	1000010	1000011	1000100	1000101	1000110	1000111	1001000	1001001	1001010	1001011	1001100	1001101	1001110	1001111

7-Bit Display Addresses for 16 Character 2 Line Display in Binary

○ **Display/Cursor Shift Command:**

Display/Cursor Shift	0	0	0	1	D/C	R/L	x	x
----------------------	---	---	---	---	-----	-----	---	---

- The display or the cursor may be shifted to the right or left on the LCD screen.
- RS is LOW
- Set Display/Cursor Shift commands as follows:
 - S1 – S8 to %000100xx where x can be HIGH or LOW – it doesn't matter.
 - D/C: 1=Display Shift, 0=Cursor Move
 - R/L: 1=Right Shift, 0=Left Shift
 - This sets the Display/Cursor Shift commands to move the *cursor* to the left so you are able to reenter a letter.
- To shift the *display* to the left enter %00011000
- Pulse the Enable switch for each shift to the left. Continue pulsing until the string cycles back to the beginning position.
- Move your Enable lead to the clock terminal (CLK) on the analog/digital trainer and change the frequency of your clock.
- Enter the code to shift right.
- **Return to the lesson.**

○ **Character Entry Mode Command:**

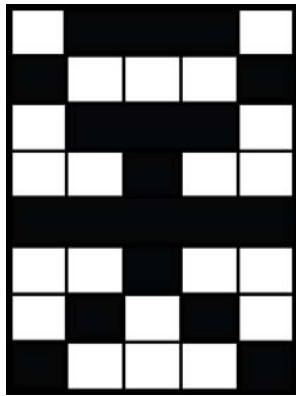
Character Entry Mode	0	0	0	0	0	1	I/D	S
----------------------	---	---	---	---	---	---	-----	---

- Clear the display
- RS is LOW
- Enter %10010000 which shifts the cursor to one location to the right of the right-most top row position, i.e., the cursor is just off the LCD display by one spot.
- Enter the Character Entry Mode command %00000111.
 - I/D: 1=Increment*, 0=Decrement
 - S: 1=Display Shift On, 0=Display Shift Off
- Set RS HIGH.
- Now enter the characters "195".
- **Return to the lesson.**

Cornerstone Electronics Technology and Robotics II

LCD1 LAB 2 – User-Defined Graphics

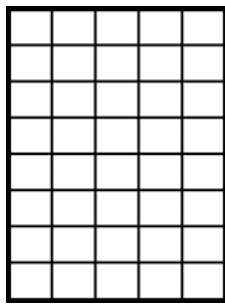
- **Purpose:** The purpose of this lab is to teach the student how to create their own graphical displays on an LCD display.
- **Apparatus and Materials for Analog/Digital Trainer Circuit:**
 - 1 – Analog/Digital Trainer
 - 1 – 16x2 Parallel LCD Display, Jameco Part # 618003
 - 1 – 1K DIP Resistor Package
 - 2 – 4K7 Resistors
 - 1 – 5K Ohm Potentiometer
 - 1 – SPST Switch
 - 1 – NO Momentary Switch
- **Procedure:**
 - **RS is LOW**
 - Set Display On/Off & Cursor commands as 00001111.
 - Set Function Set commands as %00111000.
 - Set Clear Display command as %00000001.
 - Set Set Display Address command to %10000000.
 - **Set RS HIGH**
 - Enter %00000000 to %00000111 in order, i.e., %00000000, %00000001, %00000010, %00000011, %00000100, %00000101, %00000110, %00000111. These characters will initially show up as garbage or a series of stripes.
 - **Set RS LOW**
 - Set CGRAM Address command %01000000. The cursor should jump to the second line.
 - **Set RS HIGH**
 - Enter the following data to build a stick man row by row in the upper left corner (see the graphic below for a visual representation of the data).
 - %00001110, toggle S9
 - %00010001, toggle S9
 - %00001110, toggle S9
 - %00000100, toggle S9
 - %00011111, toggle S9
 - %00000100, toggle S9
 - %00001010, toggle S9
 - %00010001, toggle S9



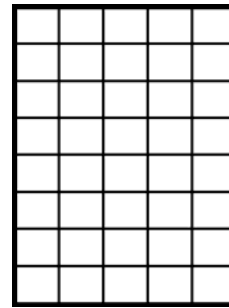
00001110
 00010001
 00001110
 00000100
 00011111
 00000100
 00001010
 00010001

Stick Man Layout, Character Code %00000000

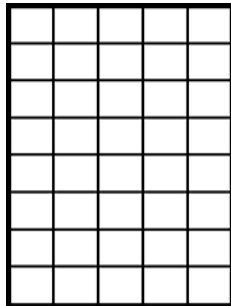
- Use the charts to create up to seven more graphics.



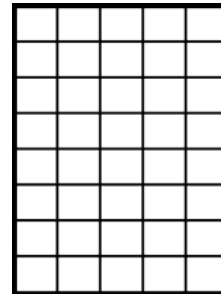
Char. Code %00000001



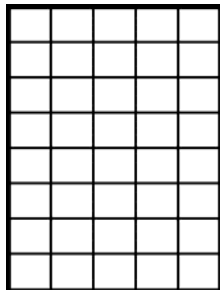
Char. Code %00000010



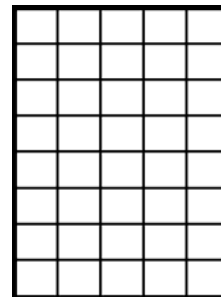
Char. Code %00000011



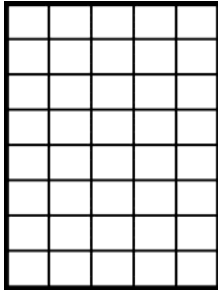
Char. Code %00000100



Char. Code %00000101



Char. Code %00000110



Char. Code %00000111

- Continue entering character code for each custom graphic you have created in the order you have set (from Char Code %00000001 to %00000111).
- After completing all of the character code inputs, you can move the cursor to another location on the LCD screen and call up any of your graphics by entering the character code for that graphic just as you would for any other character code from the Standard LCD Character Table.
- **THE CGRAM MEMORY IS VOLATILE, IF YOU TURN OFF YOUR ANALOG/DIGITAL TRAINER, YOU WILL LOOSE YOUR USER-DEFINED CHARACTERS.**
- **Also, keep your circuit wired for the beginning section of the next lesson.**

Quick Guide to LCD Command Control Codes
See LCD Command Control Codes Table for Details

- RS set to **LOW** for all command control code inputs
- RS set to **HIGH** for all character inputs
- Complete all command inputs by momentarily bringing the Enable pin 6 to **LOW** by toggling Switch 9.

- **Clear Display:** %00000001
- **Display & Cursor Home:** %00000010
- **Display On/Off & Cursor:** %00001111
 - Display On (1)
 - Cursor Underline (1)
 - Cursor Blink On (1)
- **Display/Cursor Shift:** %00011000 %00011100
 - Display Shift (1) Left Shift (0) Right Shift (1)
- **Function Set:** %00111000
 - 8-Bit Interface
 - 2 Line Mode (Increase Contrast w/ Potentiometer)
 - 5x7 Dot Matrix Format
- **Set Display Address:** %1 Plus Seven Position Code

0000000	0000001	0000010	0000011	0000100	0000101	0000110	0000111	0001000	0001001	0001010	0001011	0001100	0001101	0001110	0001111
1000000	1000001	1000010	1000011	1000100	1000101	1000110	1000111	1001000	1001001	1001010	1001011	1001100	1001101	1001110	1001111

Display Addresses for 16 Character 2 Line Display in Binary

- **Typical Startup Settings:**
 - **Display On/Off & Cursor:** %00001111
 - Features:
 - Display On
 - Cursor Underline
 - Cursor Blink On
 - **Function Set:** %00111000
 - Features:
 - 8-Bit Interface
 - 2 Line Mode
 - 5x7 Dot Matrix

Command	Binary								Hex
	D7	D6	D5	D4	D3	D2	D1	D0	
Clear Display	0	0	0	0	0	0	0	1	01
Display & Cursor Home	0	0	0	0	0	0	1	X	02 or 03
Character Entry Mode	0	0	0	0	0	1	I/D	S	04 to 07
Display On/Off & Cursor	0	0	0	0	1	D	U	B	08 to 0F
Display/Cursor Shift	0	0	0	1	D/C	R/L	x	x	10 to 1F
Function Set	0	0	1	8/4	2/1	10/7	x	x	20 to 3F
Set CGRAM Address	0	1	A	A	A	A	A	A	10 to 7F
Set Display Address	1	A	A	A	A	A	A	A	80 to FF

I/D: 1=Increment*, 0=Decrement	R/L: 1=Right Shift, 0=Left Shift
S: 1=Display Shift On, 0=Display Shift Off	8/4: 1=8-bit Interface*, 0=4-bit Interface
D: 1=Display On, 0=Display Off*	2/1: 1=2 Line Mode, 0=1 Line Mode*
U: 1=Cursor Underline On, 0=Underline Off*	10/7: 1=5x10 Dot Matrix, 0=5x7 Dot Matrix
B: 1=Cursor Blink On, 0=Cursor Blink Off*	
D/C: 1=Display Shift, 0=Cursor Move	X=Don't Care * = Initialization Settings

Char. code

	0	0	0	0	0	0	1	1	1	1	1	1	1
	0	0	0	1	1	1	1	0	0	1	1	1	1
	0	1	1	0	0	1	1	1	0	0	1	1	1
	0	0	1	0	1	0	1	0	1	0	1	0	1
xxxx0000			0	1	P	\	P	-	9	3	α	ρ	
xxxx0001		!	1	A	Q	a	q	。	ア	チ	4	ä	Q
xxxx0010		"	2	B	R	b	r	「	イ	ツ	×	β	θ
xxxx0011		#	3	C	S	c	s	」	ウ	テ	ε	ω	
xxxx0100		\$	4	D	T	d	t	、	エ	ト	μ	Ω	
xxxx0101		%	5	E	U	e	u	・	オ	ナ	1	ç	Ü
xxxx0110		&	6	F	V	f	v	ヲ	カ	ニ	ヨ	ρ	Σ
xxxx0111		'	7	G	W	g	w	フ	キ	ヌ	ラ	q	π
xxxx1000		(	8	H	X	h	x	イ	ク	ネ	リ	ル	ア
xxxx1001		)	9	I	Y	i	y	ッ	ケ	ル	リ	ル	ウ
xxxx1010		*	:	J	Z	j	z	エ	コ	ハ	レ	i	≠
xxxx1011		+	;	K	[	k	[	オ	サ	ヒ	ロ	×	斤
xxxx1100		,	<	L	¥	l	l	ハ	シ	フ	ワ	≠	円
xxxx1101		-	=	M	]	m	]	ユ	ズ	ハ	ン	ト	÷
xxxx1110		.	>	N	^	n	^	ヨ	セ	ホ	ハ	ン	
xxxx1111		/	?	O	_	o	_	ッ	ツ	マ	°	ö	■

0000000 0000001 0000010 0000011 0000100 0000101 0000110 0000111 0001000 0001001 0001010 0001011 0001100 0001101 0001110 0001111
1000000 1000001 1000010 1000011 1000100 1000101 1000110 1000111 1001000 1001001 1001010 1001011 1001100 1001101 1001110 1001111