SAPIC-E
Small Alphanumeric
LCD Controller
User's Manual

DENSITRON
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PLC

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Contents

1. Selecting an LCD module

1.1. Introduction

Selecting an LCD module involves 3 basic design decisions.

1) What size and format is required to display the desired information.

2) What optical characteristics will look best in the package and attract the user to the product.

3) What interface is most practical, and what additional benefits it has.

Densitron produces dot-matrix LCDs in two formats: fully functional Alphanumeric Modules; and fully-populated Graphic modules. This application note is for use with the alphanumeric (A/N) or character type modules. Alphanumeric modules display characters, numerals, symbols and some limited graphics. Normally interface is achieved via a bi-directional, parallel ASCII data bus. A more advanced interface is achieved via SAPIC-E card, that controls backlight, keyboard and up to two A/N LCDs via serial line.

Necessary features such as Character Generation, Display RAM Addressing, Cursor Scrolling, Blanking, and Handshake are all included. User programmable fonts are supported. In summary, these modules are the simplest and most economic means to communicate meaningfully between any micro-system and the outside world. Their inclusion adds to any product's appeal.

Alpha-numeric modules range from 8 to 80 characters per line. One, two or four character lines may be chosen. Character height spans 0.130" (3.31 mm) to 0.500" (12.71 mm). Most formats are available in a variety of packages to meet various mounting requirements. Multi-line models offer the best value when analyzed by a "cost per character" basis. Displays are readable both day and night by selecting a backlight option. Extended temperature modules are available which operate between -20 and +70C.

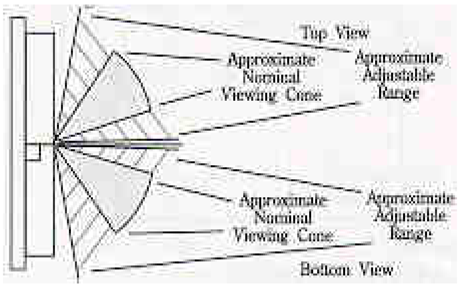
The following sections explains the optical characteristic options available in A/N modules.

1.2. Fluid types

The fluid type determines the contrast ratio, viewing angle, and temperature range of an LCD. Densitron uses 3 basic classes of fluid, TN (Standard type), NTN (high contrast type), and STN (premium high contrast type). Many TN and NTN models are available in extended temperature range. Contact Densitron for current availability.

1.2.1. TN Fluid

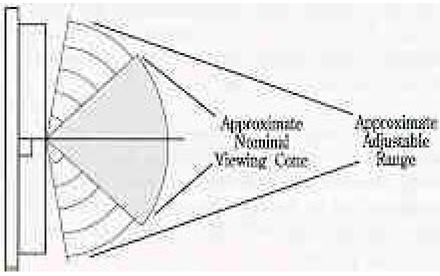
TN Fluid is the least expensive type. The viewing angle is about 40-45, and must be designated "top" or "bottom" view preference. Bottom view is used when the user will be below the plane perpendicular to the display, such as on a desk calculator. Top view is used when the display is mounted on a vertical surface below eye level. See diagram below.



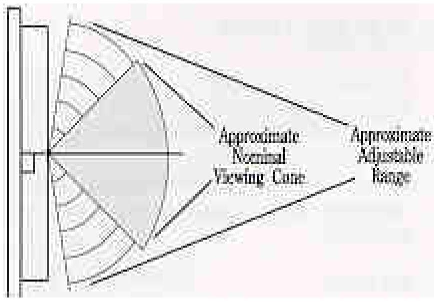
TN Viewing Cone

1.2.2. STN AND NTN Fluid

STN and NTN are both high contrast and wide viewing angle fluids. They differ in the level of contrast and viewing angle they achieve. Both can be seen above and below the plane perpendicular to the display. See the diagram below.



NTN Viewing Cone



STN Viewing Cone

The vertical viewing cone on all fluids can be adjusted by controlling the VO voltage. The range of adjustment is shown in the viewing angle charts below. The horizontal cone is relatively fixed.

Fluid Type	Typical Contrast Ratio	Typical Viewing Angle
TN	3:1	40-45^{o}
NTN	7:1	60^{o}
STN	10:1	75^{o}

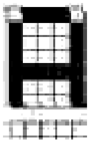
1.3. Viewing modes

The fluid type, polarizers and module construction determine the viewing mode and colour of the display. Displays are either "postive image", dark characters on a light background; or "negative image", light characters on a dark background. Backlight capability is determined by the presence or absence of a reflector or transflecter on the back side of the glass.

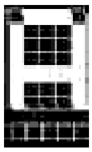
Reflective displays have a full reflector. The cannot be backlit. They offer the lowest power option and the best contrast in high ambient light conditions. They are not available in "positive image".

Transmissive displays are usually negative image and are backlit for best readability. They can be used in well lit indoor conditions to dark environments, typically not recommeded for daylight usage. They offer a different appearance than typical LCDs, bringing a light emitting look to the product.

Transflective displays combine the features of reflective and transmissive modes. These positive image displays can be read in all lighting conditions. The backlight can be turned on for low light levels or operated continuously to add the light-emitting look to a product.



Positive Image



Negative Image

Colors

TN positive image displays will have a silver/grey background and dark, almost black characters. In the negative image, the background will be black and the characters will be the color of the backlight, usually yellow/green or white. (See section on backlighting).

NTN and STN positive image displays can have a silver or yellow background with dark characters. Negative image versions have a dark blue background, characters are the folour of the backlight.

Choice of color is determined by what fits best in the package. Not all NTN displays are available in all colors. Consult Densitron for current availability.

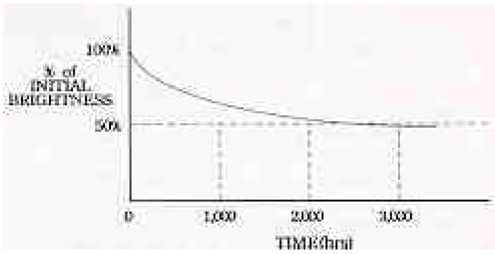
1.4. Backlightighting character modules

Backlighting is used on LCDs to make them readable in low light conditions. Refer to the section on viewing modes for the types and applications of display that are backlit. Densitron currently uses 2 methods to backlight character LCD module: Electroluminescent (EL) and Light Emitting Diode (LED). Selection depends on desired color, available power, and required life.

1.4.1. EL Backlighting

EL backlighting is the original LCD backlight. It is thin, lightweight, low power, and fits between the glass assembly and PCB without any modification to the module. Most positive mode displays are furnished with a blue green lamp. Negative mode displays usually come with a white lamp. Other colors can be specially ordered.

EL lamps operate from an AC power source, typically 400Hz at 70-110 VAC. Densitron supplies a full range of DC to AC inverters to power the lamps from a +5VDC source. There is no hard and fast rule for matching an inverter to a specific lamp. Lamp brightness and life are inversely proportional. That is the harder the lamp is driven the brighter it will be, but the shorter the life. Under rated operating conditions lamp life is about 2,000 to 2,500 hours to half its original brightness. Operating conditions such as temperature and humidity will also effect lamp life. The graph below illustrates the brightness vs life curve.



TYPICAL EL LAMP LIFE

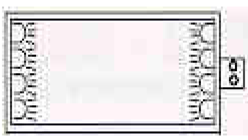
Recommended inverters for various sizes of modules are shown below. Design considerations such as the operating conditions, desired brightness, required light, and lamp life must be balanced when designing with EL backlighting. For example, a negative transmissive display used in normal room lighting may look better when driven with a larger inverter but useful life will be shortened.

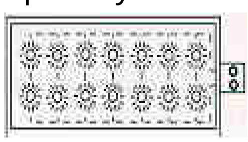
Inverter	Displays
DAS5V4	All A/N Displays except 4x40, 2x40, LM300 & LM4700 Series
DAS5V7	4x40, 2x40, LM300 & LM700 Series Transflective
DAS5V8	4x40, 2x40, LM300 & LM700 Series Transflective

Inverter Recommendations

1.4.2. LED Backlighting

LED backlighting offers a significant life advantage over EL lamps, but at the sacrifice of power and module size. Lamp life is in excess of 50,000 hours, and in most cases, 1 lamp failing does not make the backlight unusable. LED backlit does not make the backlight unusable. LED backlit modules are 2-4mm thicker than an EL or non-backlit module. Standard color is yellow-green. Red amber and other colors may be specially ordered.





Edgelit Style Array Style

LED Backlight Functional Diagram

Densitron offers two types of LED backlights; edgelit and array. Their basic format is shown above.

Edgelit can be used on modules up to 20 characters wide. Beyond 20 characters, the middle of the display begins to dim when compared to the edges. (The LM43X series uses a top mounted edgelight to achieve its balance of light and power). Edgelight is the lower power of the two types. The 4XXX series edgelit modules typically operate 30 to 60mA(at +5VDC) and come with a built in current limit resistor. The 43X series is somewhat higher and must have a limited resistor in series for proper operation.

Array backlighting produces a brighter and more even light. Power is the main consideration when designing with this type of module. It is not recommended for battery powered applications where the lamp will be on all the time. (It may be suitable for "on demand" applications).

Limit resistors must be used for array backlit modules and the LM43X series. Refer to the specific module specification for recommended and/or maximum backlight ratings. LEDs are arranged in serial pairs and operated in parallel (see diagram). The lamp will require 4.2VDC. Brightness can be set or controlled by selecting the proper limit resistor. Select a resistor that will drop the remaining voltage at the desired current. For example, if 200mA produces the desired brightness and the supply voltage is +5VDC, the limit resistor will drop 0.8VDC (5.0 - 4.2). Therefore, E/I = R = 0.8/0.2 - 4ohms.

1.5. Interface

Two interface methods can be usd to connect LCD to host system. In direct connection the host system is responsible for creating all the signals for the LCD. This requires good understanding of the LCD.

Connection via SAPIC-E interface card is much simpler, it is done via serial line. Commands sent to the SAPIC-E are transferred to the LCD or interpreted by the controller.

1.5.1. Direct Interface

A/N modules are an intelligent peripheral which can communicate, bi-directionally, within the master system. Tie the device into the system data bus and treat it as RAM, I/O, or expanded, parallel I/O. The module is "selected" by gating a decoded, "module-address" output, with the host processor's "read or write" strobe. The resultant signal, applied to the LCDs "enable" input, clocks in data. There is no conventional "chip-select".

Interfacing the module to an existing micro-system involves:

a) joining the module to the host's data bus.
b) developing a "strobe" signal for the "E" signal
c) applying appropriate signals to modules "RS" and "R/W"
d) applying the proper "viewing angle" voltage to the display's VO pin.

1.5.2. SAPIC-E Interface

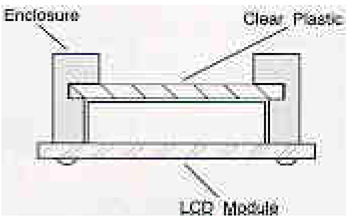
Commands are sent to the SAPIC-E via standard serial line in either RS-232 or TTL level. These commands control the operation of the LCD, the backlight, the software controlled contrast and the keyboard. Interfacing the module to an existing micro-system involves is quite straightforward. Just connect it to a standard free serial line.

1.6. Mounting Suggestion

Care must be taken when mounting an LCD module to ensure that module is not stressed when installed and the surface is not exposed to scratches or harmful material.

Causing any kind of warp on the PCB of the module may product open columns or rows of dots, or intermittent display. Presure on the bezel from the top or against the bezel tabs will lead to similar problems.

The front surface of the module is a sensitive plastic polarizer, not glass. Liquid must not be allowed to condense upon the device. Whenever possible, install an optically correct "protection Barrier" between the outside world and the display. This should be a non-polarized plastic or polycarbonate, which will reduce the incidence of foreign-object invasion and static discharge into the display. To keep glare at a minimum, mount the protective piece as close to the display surface as possible while preventing pressure on the piece from being transmitted to the LCD. Non-glare properties can be added to the protective piece at a slight loss of display clarity.



Mounting Suggestion

2. LCD software

2.1. Introduction

Software determines what, how and where data is displayed on the LCD. All Densitron character modules feature the Hitachi HD44780 or equivalent controller IC. This versatile chip features:

- Built-in character generator with 192 character modified ASCII character set.
- Ability to program up to 8 custom characters.
- Bi-directional 8 or 4 bit bus interface
- 80 character RAM
- Automatic reset on power up
- Wide range of instruction functions including:
  - Display clear, Cursor positioning, Display or cursor shift on data entry, and Display ON/OFF

If the LCD is connected to the host system via SAPIC-E card additional commands are available to control the backlight, the software contrast and the keyboard. LCD instructions are explained in detail on the following pages and the special SAPIC-E commands are explained in SAPIC-E software section.

2.2. Initialization

The module has 2 registers; one for inputting instructions and one for reading or writing data. Instructions are used to tell the module how and where to put the data. If the rise time of the power supply meets the criteria below, the module will default to the following functions via an internal initialization routine:

- Clear Display
- Function Set — DL=1: 8 bits interface
  N=0: 1 line display
  F=0: 5x7 dot font
- Dislay ON/OFF control — D=0: Display OFF
  C=0: Cursor OFF
  B=0: Blink OFF
- Entry Mode Set — I/O=1: +1 increment
- DD RAM is selected

The display will be busy for approximately 15mS after power ON.

Power Supply Timing Requirements for Internal Initialization

If power supply rise time cannot be assured of meeting the requirements above, or if different parameters are required (such as for a 2 line display), an initialization routine will have to be sent from the host. When first setting up the display, Densitron recommends the following initialization routines for 8 bit interfaces:

- 1 line display with 5x7 font:
- 30H, 30H, 06H, 0EH, 01H
- 1 line display with 5x10 font:
- 34H, 34H, 06H ,0EH, 01H
- 2 line display with 5x7 font:
- 38H, 38H, 06H, 0EH, 01H

Wait states should be programmed to allow 15mS after power up before initialization begins. Waiting 4.1mS between the "3X" codes and 100S after the second "3X" code add a safety margin and ensure proper initialization.

After sending this routine, you should have a clear display with a flashing cursor in the upper left position. The cursor will then increment to the right with each data RAM write command. If, you do not have this display, see Troubleshooting Tips in the appendix.

2.3. 4-bit Operation

The modules will operate from a 4-bit wide data bus. Data is transferred over data lines D7-D4. D3-D0 may float. 8-bit hex code is sent one nibble at a time, with the most significant nibble sent first. The function set in the initialization routine must change to accommodate this mode. A recommended initialization routine is as follows:

2 line display with 5x7 font:

02H, 08H, 02H, 08H, 00H, 06H, 00H, 0EH, 00H, 01H

If SAPIC-E interface is used the LCD module is always programmed to 4-bit operation.

2.4. Display Addressing

The display RAM is 8 characters. If the display is less than 80 characters, what is on the screen is a "window" on the RAM. What is displayed depends on the Entry Mode Set instruction. Address diagrams on the next page show RAM addresses as they appear after a Clear Display or Return Home instruction, or when Entry Mode Set instruction S=0.

If a 2-line display has less than 40 characters per line, the cursor will advance off the screen after the last character of the first line. To put data on the secone line, a Set DD RAM Address instruction must be sent.

When instruction S=1, the display is shifted. This makes the characters look as though they are marching across the screen on entry. It also lets small displays (2x16s, for example) to have data stored in non-visible areas of the

RAM and shifted in to view with one command. The last diagram shows how the addresses "wrap" in this mode.

<table>
<tr><td colspan="20">Entire memory</td></tr>
<tr><td colspan="17">1x40</td><td></td><td></td><td></td></tr>
<tr><td colspan="13">1x24</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="10">1x20</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">1x16</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">1x8</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>80</td><td>…</td><td>87</td><td>88</td><td>…</td><td>8F</td><td>90</td><td>91</td><td>92</td><td>93</td><td>94</td><td>95</td><td>96</td><td>97</td><td>98</td><td>…</td><td>A7</td><td>A8</td><td>...</td><td>CF</td></tr>
</table>

1 Line Display Addresses

<table>
<tr><td colspan="17">Entire memory</td></tr>
<tr><td colspan="17">2x40</td></tr>
<tr><td colspan="13">2x24</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="10">2x20</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">2x16</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">2x8</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>80</td><td>…</td><td>87</td><td>88</td><td>…</td><td>8F</td><td>90</td><td>91</td><td>92</td><td>93</td><td>94</td><td>95</td><td>96</td><td>97</td><td>98</td><td>…</td><td>A7</td></tr>
<tr><td>C0</td><td>…</td><td>C7</td><td>C8</td><td>…</td><td>CF</td><td>D0</td><td>D1</td><td>D2</td><td>D3</td><td>D4</td><td>D5</td><td>D6</td><td>D7</td><td>D8</td><td>…</td><td>E7</td></tr>
</table>

2 Line Display Addresses

<table>
<tr><td colspan="17">Entire memory</td></tr>
<tr><td colspan="17">2x40</td></tr>
<tr><td colspan="13">2x24</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="10">2x20</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">2x16</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">2x8</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>81</td><td>…</td><td>88</td><td>89</td><td>…</td><td>90</td><td>91</td><td>92</td><td>93</td><td>94</td><td>95</td><td>96</td><td>97</td><td>98</td><td>99</td><td>…</td><td>80</td></tr>
<tr><td>C1</td><td>…</td><td>C8</td><td>C9</td><td>…</td><td>D0</td><td>D1</td><td>D2</td><td>D3</td><td>D4</td><td>D5</td><td>D6</td><td>D7</td><td>D8</td><td>D9</td><td>…</td><td>C0</td></tr>
</table>

2 Line Display Addresses with Display Shifted Left
(I/D=1, S=1. See Entry Mode Set Instruction)

2.5. Specially Coded Displays

Three types of displays have different addressing than typical 1 or 2 line displays. They are:

- 1 chip 1 line by 16 character displays
- 4 line by 16 or 20 character displays
- 4 line by 40 character displays

1 chip 1x16 - The HD44780 has the ability to control up to 16 characters without any other driver ICs. A lower cost 1 line by 16 character display can be manufactured to take advantage of this feature. To do this, it is necessary to initialize the display in the 2 line mode. The display is then addressed as a 2 line display. Line 1 addresses the first 8 characters; line 2, the second 8. When the cursor gets to the ninth character of the first line, it will "disappear" into undisplayed RAM (assuming no display shift). A Set DD

RAM Address must be sent to reposition the cursor to the ninth displayed character which is logically the first position of the second line.

80	81	82	83	84	85	86	87	C0	C1	C2	C3	C4	C5	C6	C7

1 Chip 1 Line by 16 Character Addresses

4x40 - The maximum capacity of the HD44780 is 80 characters. The 160 characters on the 4x40 displays are accessed with 2 controllers. The first controller handles the top two lines; the second controller is conected to the bottom two lines. They share all I/O lines except the "E". Logically, the display is like two displays connected to the MPU as the "E" lines must be independent. Remember to turn off the cursor when moving from one half of the display to the other to avoid viewer distraction.

E1 used	80	81	82	...	8F	90	91	92	93	94	95	96	97	...	A5	A6	A7
E1 used	C0	C1	C2	...	CF	D0	D1	D2	D3	D4	D5	D6	D7	...	E5	E6	E7
E2 used	80	81	82	...	8F	90	91	92	93	94	95	96	97	...	A5	A6	A7
E2 used	C0	C1	C2	...	CF	D0	D1	D2	D3	D4	D5	D6	D7	...	E5	E6	E7

4 Line by 40 Character Addresses

4x16/20 - Because of the way the controller and drivers are connected to make maximum use of their outputs, special attention must be paid to the addresses of these displays. Logically, line 3 follows line 1, and line 4 follows line 2. When the cursor gets to the end of line 1, it will jump to line 3. Keeping track of cursor location for proper positioning is important.

80	81	82	83	84	85	86	87	88	89	8A	8B	8C	8D	8E	8F
C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	CA	CB	CC	CD	CE	CF
90	91	92	93	94	95	96	97	98	99	9A	9B	9C	9D	9E	9F
D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	DA	DB	DC	DD	DE	DF

4 Line by 16 Character Addresses

80	81	82	83	84	85	86	87	88	89	8A	8B	8C	8D	8E	8F	90	91	92	93
C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	CA	CB	CC	CD	CE	CF	D0	D1	D2	D3
94	95	96	97	98	99	9A	9B	9C	9D	9E	9F	A0	A1	A2	A3	A4	A5	A6	A7
D4	D5	D6	D7	D8	D9	DA	DB	DC	DD	DE	DF	E0	E1	E2	E3	E4	E5	E6	E7

4 Line by 20 Character Addresses

2.6. Instruction Table

<table>
<tr><th>Instruction</th><th>RS</th><th>R/W</th><th>D7</th><th>D6</th><th>D5</th><th>D4</th><th>D3</th><th>D2</th><th>D1</th><th>D0</th><th>Description</th><th>Time</th></tr>
<tr><td>Clear Display</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>Clears Display and returns cursor to the Home Position (Address 00)</td><td>80us-1.6ms</td></tr>
<tr><td>Return Home</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>*</td><td>Returns cursor to Home Position. Returns shifted display to original position. Does not clear display</td><td>40us-1.6ms</td></tr>
<tr><td>Entry Mode Set</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>ID</td><td>S</td><td>Sets DD RAM counter to increment or decrement (ID) Specifies cursor or display shift during to Data Read or Write (S)</td><td>40us</td></tr>
<tr><td>Display ON/OFF Control</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>D</td><td>C</td><td>B</td><td>Sets Display ON/OFF (D), cursor ON/OFF (C), and blink character at cursor position</td><td>40us</td></tr>
<tr><td>Cursor or Display Shift</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>SC</td><td>RL</td><td>*</td><td>*</td><td>Moves cursor or shifts the display w/o changing DD RAM contents</td><td>40us</td></tr>
<tr><td>Function Set</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>DL</td><td>N</td><td>F</td><td>*</td><td>*</td><td>Sets data bus length (DL), # of display lines (N), and character font (F)</td><td>40us</td></tr>
<tr><td>Set CG RAM Address</td><td>0</td><td>0</td><td>0</td><td>1</td><td colspan="6">A_{CG}</td><td>Sets CG RAM address. CG RAM data is sent and received after this instruction</td><td>40uS</td></tr>
<tr><td>Set DD RAM Address</td><td>0</td><td>0</td><td>1</td><td colspan="7">A_{DD}</td><td>Sets DD RAM address. DD RAM data is sent and received after this instruction</td><td>40uS</td></tr>
<tr><td>Read Busy Flag & Address</td><td>0</td><td>1</td><td>BF</td><td colspan="7">AC</td><td>Reads Busy Flag (BF) and address counter contents</td><td>1uS</td></tr>
<tr><td>Write Data to RAM</td><td>1</td><td>0</td><td colspan="8">Write Data</td><td>Writes data to DD or CG RAM and increments or decrements address counter (AC)</td><td>40uS</td></tr>
<tr><td>Read Data from RAM</td><td>1</td><td>1</td><td colspan="8">Read Data</td><td>Reads data from DD or CG RAM and increments or decrements address counter (AC)</td><td>40uS</td></tr>
</table>

ID=1: Increment S=1: Display Shift on data entry SC=1: Display Shift (RAM unchanged) RL=1: Shift to the Right DL=1: 8 bits N=1: 2 Lines F=1: 5x10 Dot Font D=1: Display ON C=1: Cursor ON B=1: Blink ON BF=1: Cannot accept instruction	ID=0: Decrements S=0: Cursor Shift on data entry SC=0: Cursor Shift (RAM unchanged) RL=0: Shift to the Left DL=0: 4 bits N=0: 1 Line F=0: 5x7 Dot Font D=0: Display OFF C=0: Cursor OFF B=0: Blink OFF BF=0: Can accept instruction
Definitions: DD RAM: Display data RAM CG RAM: Character generator RAM A_{CG}: CG RAM Address A_{DD}: DD RAM Address(Cursor Address) AC: Address Counter used for both DD and CG RAM Address	Execution Time changes when Frequency changes per the following example: If F_{CP} or f_{osc} is 27 KHz 40uS x 250/270 = 37uS * Don't Care

2.7. LCD Instruction Description

2.7.1. Clear Display

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0	0	1

Writes space code 20H into all the DD RAM addresses. The cursor returns to Address 0 (ADD=80H) and display, if it has been shifted, returns to the original position. In other words, display disappears and the cursor goes to the left edge of the display (the first line if a 2 or 4 line display module is used).

2.7.2. Return Home

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0	1	*

* Don't Care

Returns the cursor to Address 0 (ADD=80H) and display, if it has been shifted, to the original position. The DD RAM contents remain unchanged.

2.7.3. Entry Mode Set

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	1	ID	S

ID: Increments (ID=1) or decrements (ID=0) the DD RAM address by one when writing or reading a character code from DD RAM. The cursor moves to the right when incremented by one. The same applies to writing and reading CG RAM.

S: Shifts the entire display to either the right or the left when S is 1; to the left when ID=1 and to the right when ID=0. Therefore, the cursor looks as if stood stil while only the display has moved. Display is not shifted when reading from DD RAM. Display is not shifted when S=0.

2.7.4. Display On/Off Control

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	1	D	C	B

D: Display is turned ON when D=1 and OFF when D=0. When display is turned off due to D=0, the display data remains in the DD RAM and it can be displayed immediately by setting D=1.

C: The cursor is displayed when C=1 and not displayed when C=0. Even if the cursor disappears, function of I/D, etc. does not change during display data write. The cursor is displayed using 5 dots in the 8th lines when the 5 x 7 dot character font is selected and in the 11th line when 5 x 10 dot character font is selected.

B: The character residing at the cursor position blinks when B=1. The blink is done by switching between all dots ON and display characters at 0.4 second interval. The cursor and the blink can be set concurrently.

Detached Attached Blinking Character

Cursor Position

2.7.5. Cursor or Display Shift

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	1	SC	RL	*	*

* Don't Care

Shifts the cursor position or display to the right or left without writing or reading the display data. This function is used for correction or search of display.

SC	RL	
0	0	Shifts the cursor position to the left. (AC is decremented by one.)
0	1	Shifts the cursor position to the right. (AC is incremented by one).
1	0	Shifts the entire display to the left. The cursor follows the display shift.
1	1	Shifts the entire display to the right. The cursor follows the display shift.

2.7.6. Function Set

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	1	DL	N	F	*	*

* Don't Care

DL: Sets interface data length. Data is sent or received in 8 bit length (DB7-DB0) when DL=1 and 4 bit length (DB7-DB4) when DL=0. When 4 bit length is selected, data must be sent or received in 2 operations.

N: Sets number of display lines.

F: Sets character font. (Together, N & F set the duty cycle).

2.7.7. Set CG RAM Address

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	1	A	A	A	A	A	A

Sets the CG RAM address in a binary number of AAAAAA to the address counter, and data is written or read from the MPU related to the CG RAM after this. This is used for programming the Character Generator (CG) RAM.

2.7.8. Set DD RAM Address

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
0	0	1	A	A	A	A	A	A	A

Sets the DD RAM address in a binary number of AAAAAAA in the address counter. Data is written or read from the MPU related to the DD RAM after this. When N=0 (1 line display), AAAAAAA is 00H to 47H. When N=1 (2 line display),

AAAAAAA for the first line is 00H to 27H and 40H to 67H, for the second line. Because the MSB is set to "1", the hex codes are actually 80H to C0H, 80H to A7H, and C0H to E7H respectively. See Display Addressing for more information.

2.7.9. Read Busy Flag and Address

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
0	1	BF	A	A	A	A	A	A	A

When BF=1, the system is internally operating on a previously received instruction. The next instruction will not be received until BF=0. The value of the address counter also to read during this operation, and is given in binary AAAAAAA. Whether CG or DD RAM address is read is determined by the previous instruction.

2.7.10. Write Data to CG RAM or DD RAM

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
1	0	D	D	D	D	D	D	D	D

Writes binary 8 bit data DDDDDDD to the CG or the DD RAM. Whether the CG or the DD RAM is to be written is determined by the previous designation (CG RAM address setting or DD RAM address setting). After write, the address is automatically incremented or decremented by one according to entry mode. Display shift also follows the entry mode.

2.7.11. Read Data from CG RAM or DD RAM

RS	RW	D7	D6	D5	D4	D3	D2	D1	D0
1	1	D	D	D	D	D	D	D	D

Reads binary 8 bit data DDDDDDD from the CG or the DD RAM. Whether the CG RAM or the DD RAM is to be read is determied by the previous designation. Prior to inputting this read instruction, either the CG RAM address set instruction or the DD RAM address set instruction must be executed. If it is not done, the first read data becomes invalid, and data of the next address is read normally from the second read. After read, the address is automatically incremented or decremented by one according to the entry mode. However, display shift is not performed regardless of entry mode types.

2.7.12. The Use of CG RAM

Character Generator (CG) RAM is a useful accessory. It does not have to be used or attended to during any normal display operation. CG RAM allows the creation of up to 8 special character or symbols. Once programmed, the newly formed characters may be accessed as if they were in the "normal" CG ROM. This ROM contains 192 unchangeable characters. Thus the CG RAM expands the character representation available to the user.

NOTE: This is a RAM, and must be reprogrammed if display power is interrupted. If used regularly, programming can be made part of the initialization routine.

There are two distinct areas of RAM within the display module. The main area, 80 bytes wide, is dedicated to the display and is called Display Data (DD) RAM. CG RAM consists of 64 bytes which range from 40 to 7F (hex), or 4 5x10 (or 5x11) symbols. 40-47 locate the first, custom 5x7 character. 40 is the top row of this character, 47 is the 8th row. Similarly, 48-4F locate the second CG character, and 78-7F locate the 8th custom character. The locations 40-7F are the CG "Programming" locations only! Once programmed, these special characters are displayed by writing to character font locations 00-07 (hex). 00 will retun that character residing in locations 40-47, 01 returns 48-4F. etc. (See Font Chart).

While the CG RAM byte is 8 bits wide, only the 5 least significant bits appear on the LCD. Thus D4 represents the left-most dot and D0 the right-most dot. To illustrate, loading a CG RAM byte with 1F turns all dots in that row on; loading a byte with 00 turns all dots off. All 7 or 8 rows must be programmed at each desired CG location.

Programming procedure is:

a) with RS=0 enter the address of the top row of the character to be programmed (i.e. 40,48,50, etc.)

b) with RS=1 enter pattern data for row 1 (top row)

c) continue to enter pattern data for rows 2-8; it is not necesary to enter additional addresses if the module has been initialized with command 06 (auto increment of cursor). This procedure may be continued until all CG bytes have been loaded.

The CG RAM can create an attractive, "reverse-video" 3 x 5 pattern. Numerals look especially good in this format. Most letters can be executed. The limitation of 8 characters can be circumvented by creating a "library" of custom symbols, each totalling 8, resident in the host system. Eight custom symbols can be displayed at any ONE time. The CG RAM can be periodically reloaded as display requirements change. If you reload a CG location which is currently on the display, the change will be immediately apparent. Displays employing multiple controllers (ie. 4 x 40, 2 x 80. 4 x 80) may create 8 symbols per controller. The CG RAM adds interest and flexibility to the LCD module.

CG RAM, DD RAM, and pattern examples for 5x7 dot patterns

Character Codes (DD RAM Data)	CG RAM Address	Character Patterns (CG RAM Data)
7 6 5 4 3 2 1 0	5 4 3 2 1 0	4 3 2 1 0
	0 0 0 0 0 0	1 1 1 1 0
	0 0 0 0 0 1	1 0 0 0 1
	0 0 0 0 1 0	1 0 0 0 1 - Character
	0 0 0 0 1 1	1 1 1 1 0 - Pattern
0 0 0 0 * 0 0 0	0 0 0 1 0 0	1 0 1 0 0 - Example (1)
	0 0 0 1 0 1	1 0 0 1 0
	0 0 0 1 1 0	1 0 0 0 1
	0 0 0 1 1 1	0 0 0 0 0 - Cursor Position
	0 0 1 0 0 0	1 0 0 0 1
	0 0 1 0 0 1	0 1 0 1 0
	0 0 1 0 1 0	1 1 1 1 1 - Character
	0 0 1 0 1 1	0 0 1 0 0 - Pattern
0 0 0 0 * 0 0 1	0 0 1 1 0 0	1 1 1 1 1 - Example (2)
	0 0 1 1 0 1	0 0 1 0 0
	0 0 1 1 1 0	0 0 1 0 0
	0 0 1 1 1 1	0 0 0 0 0 - Cursor position

*Don't Care

Notes:

a) Character code bits 0-2 correspond to CG RAM address bits 3-5 for a total of 8 patterns.

b) CG RAM address codes 0-2 designate character pattern line. The 8th line is the cursor position. It is logically "OR'ed" with the cursor instruction.

c) Character patterns are loaded into CG RAM data bits 0-4 as shown in the table. (Bit 4 is the left side). Since CG RAM bits 5-7 are not used, they may be used for general data RAM.

d) CG RAM patterns are displayed on the LCD when character code bits 4-7 are all "0". Bit 3 is a don't care bit. Therefore, character pattern (1) can be selected with character code 00H or 08H.

e) "1" in the character pattern turn a dot "ON". "0" indicates a non-selected dot.

CG RAM, DD RAM, and pattern examples for 5x10 dot patterns

Character Codes (DD RAM Data)	CG RAM Address	Character Patterns (CG RAM Data)
7 6 5 4 3 2 1 0	5 4 3 2 1 0	4 3 2 1 0
0 0 0 0 * 0 0 *	0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 1 1 0 0 0 1 0 0 0 0 0 1 0 1 0 0 0 1 1 0 0 0 0 1 1 1 0 0 1 0 0 0 0 0 1 0 0 1 0 0 1 0 1 0	0 0 0 0 0 0 0 0 0 0 1 0 1 1 0 1 1 0 0 1 - Character 1 0 0 0 1 - Pattern 1 0 0 0 1 - Example (1) 1 1 1 1 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 - Cursor Position

*Don't Care

Notes:

a) Character code bits 1 & 2 correspond to CG RAM address bits 4 & 5 for a total of 4 patterns.

b) CG RAM address codes 0-3 designate character pattern line. The 11th line is the cursor position. It is logically "OR'd" with the cursor instruction. Since lines 12-16 are not used for the display, they may be used as general data RAM.

c) Character patterns are loaded into CG RAM data bits 0-4 as shown in the table. (Bit 4 is the left side). Since CG RAM bits 5-7 are not used, they may be used for general data RAM.

d) CG RAM patterns are displayed on the LCD when character code bits 4-7 are all "0". Bits 0 & 3 are a "don't care" bits. Therefore, character pattern (1) can be selected with character code 00H, 01H, 08H, 09H.

e) "1" in the character pattern turn a dot "ON". "0" indicates a non-selected dot.

3. SAPIC-E hardware

3.1. Introduction

SAPIC-E can interface most small alphanumeric LCDs, that uses the Hitachi HD44780 chip, to PC or other type of computer. It has the following features:

- Software compatible with other SA cards.
- Support for 1 or 2 controller LCDs.
- Small keyboard interface (max. 4x4 keys).
- Serial quasi RS-232 interface.
- Jumper selectable baud rates (2400, 9600)
- No external power supply is required.
- Demo mode

3.2. Demo mode

SAPIC-E works in demo mode it the baud rate jumper is left unconnected. In this mode the keypresses on a 3x4 key telephone keypeds are echoed on a 2x16 LCD.

3.3. Connectors

3.3.1. LCD

SAPIC-E can drive one or two one-controller or one two-controller LCDs. Some LCD has the same pinout as the SAPIC-E card, others have different. SAPIC-E drives the LCD in 4 bit mode, so there is no need to connect D0-D3 lines.

#	Name	#	Name
1	GND	2	+5V
3	VO	4	RS
5	R/-W	6	E1
7	NC (D0)	8	NC (D1)
9	NC (D2)	10	NC (D3)
11	D4	12	D5
13	D6	14	D7
15	E2	16	E2

3.3.2. Backlight

SAPIC-E can directly drive a LED backlight, or supply power for external inverter for CFL backligh.

The LED backlight shall be connected to the backlight connector observing polarity. By default two 100 ohm resistor are installed in parallel.

After shorting the current limiting resistors an inverter for CFL backlight can be connected to the backlight connector.

3.3.3. Contrast

Most LCD requires a VO voltage between 0 and +5V. Others require VO voltage to be between -5V and +5V. SAPIC-E supports only the former. The best value depends on the LCD type and the temperature, therefore adjustments are often needed.

There are four ways of controlling the contrast:

- Using the internal trimmer.

It is the most common way of setting the optimal contrast.

- Using an external potmeter connected to the contrast connector.

Changing the contrast by external potmeter is convenient when the card operates at widely varying temperature.

- Setting a fixed value.

In cost sensitive applications, two SMD resistor can be installed instead of the trimmer.

3.3.4. Power

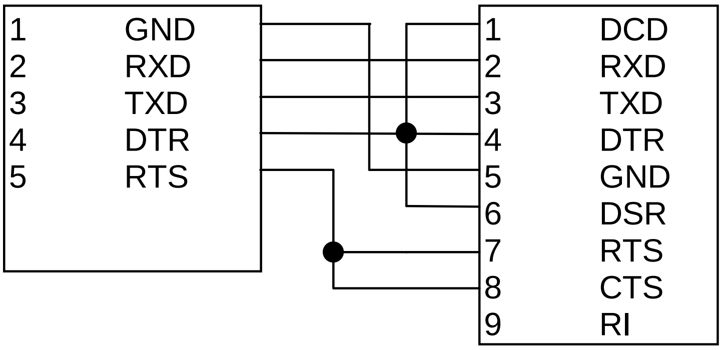
SAPIC-E can generate its power from the DTR line, if backlight is not used, or 5V (±20%) power can be supplied on either of the connector. SAPIC-E is a low power device. Without LCD it consumes less than 1mA typical.

3.3.5. Serial Line

Either RS-232, or inverted TTL serial signals can be used. The RS-232 or the inverted TTL signals should be connected to RXD and TXD pins. The DTR and RTS signals can be used to supply power to SAPIC-E and the LCD. The DTR and RTS signals, when high, can supply power for the SAPIC-E card and the LCD, but not for the backlight. Sometimes additional +5V power is required for the LCD.

#	Name	Description
1	GND	Ground
2	RXD	RS-232 PC receive, SAPIC-E transmit data
3	TXD	RS-232 PC transmit, SAPIC-E receive data
4	DTR	Power
5	RTS	Power

Standard RS-232 cable connection between PC and SAPIC-E:



The baud rate is jumper selectable by a small jumper at the solder side of the card. The format is always 8 data bits, 1 stop bit, no parity.

Jumper	Baud rate
2400 side connected	9600 baud
9600 side connected	4800 baud
Unconnected	Demo mode

The RS-232 interface is not fully RS-232 compatible, it cannot drive long cables.

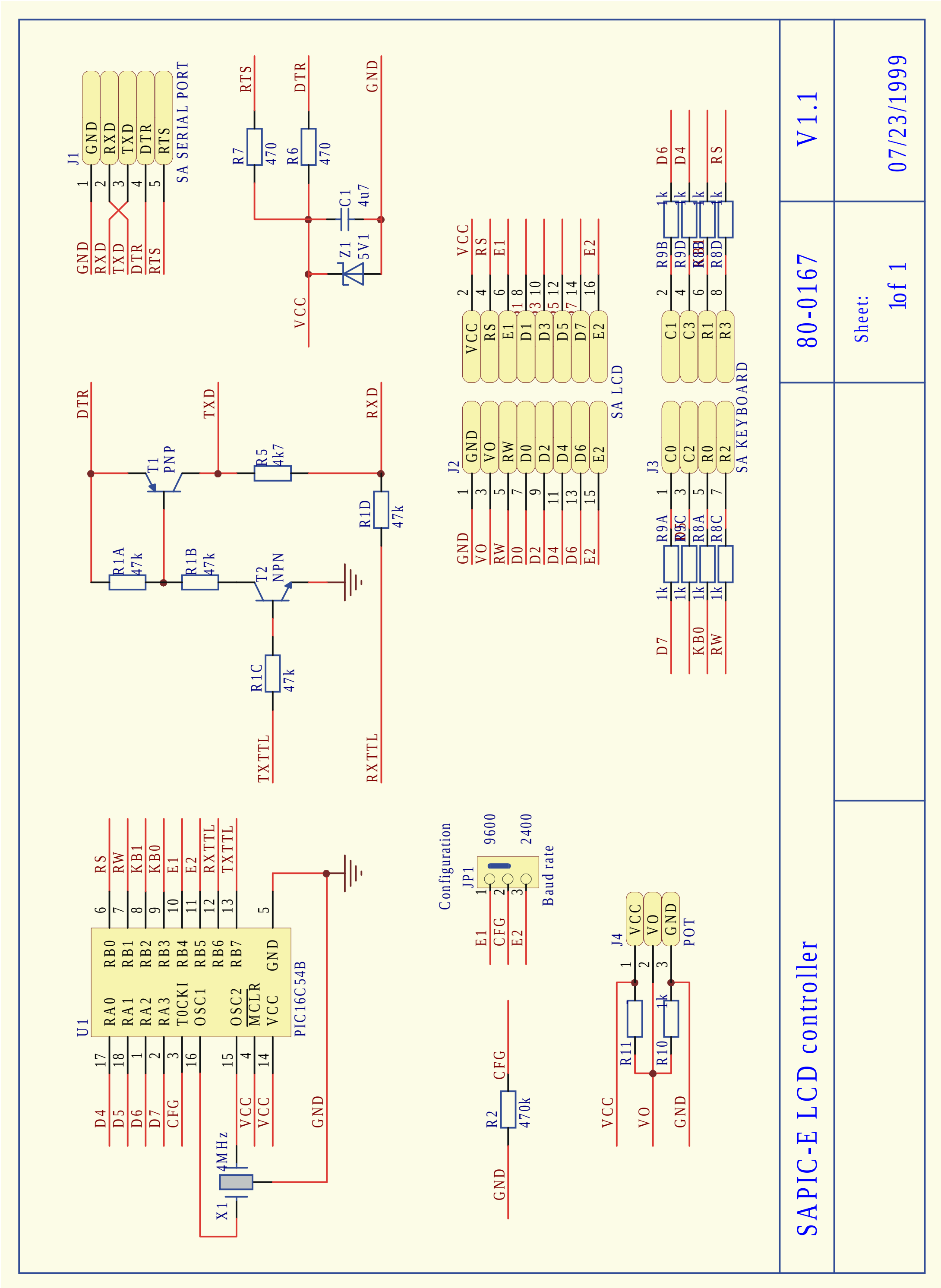
3.3.6. Keyboard

SAPIC-E directly supports a 4x4 keyboard, and via expansion registers a 60x4 keyboard. The additinal key are connected via HC164 shift registers. One HC164 shift register is required for each 8x4 keyfield. Max. 7 HC164 can be used. The maximum number of keys are 240. Two connector type is used: simple and extended. The simple connector supports only the first 16 keys, the extended one the first 48 keys. Both connector type can be further extended by using additional shift registers.

Keyboard connector

#	Name	#	Name
1	COLUMN0	2	COLUMN1
3	COLUMN2	4	COLUMN3
5	ROW0	6	ROW1
7	ROW2	8	ROW3
9	GND	10	+5V

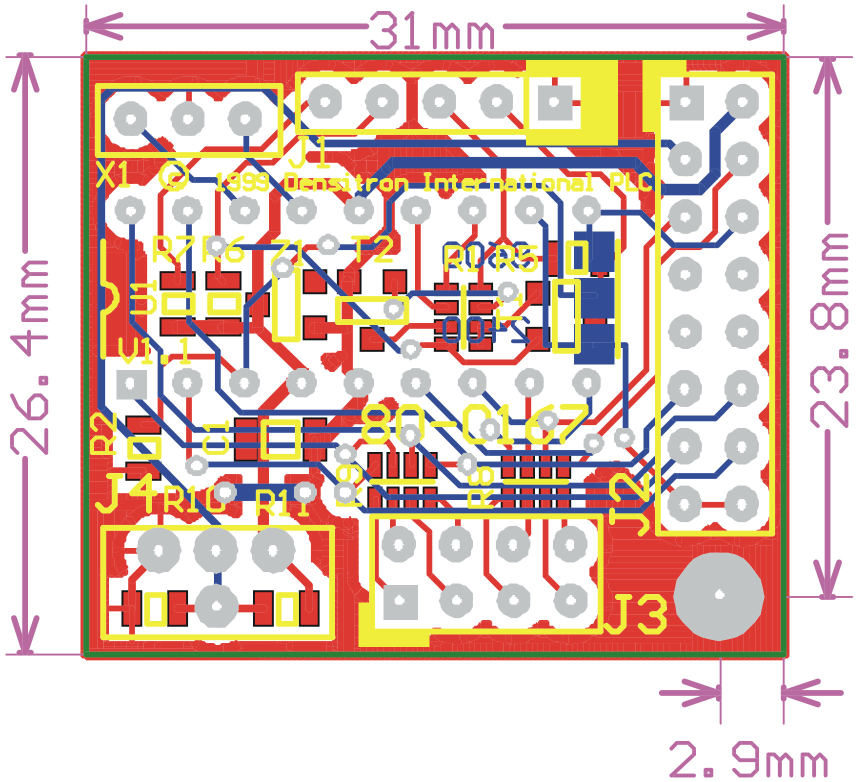
3.4. Circuit diagram



3.5. Board Outline

SAPIC-E is available in three versions:

- Card form
- Evaluation version with 3x4 key keypad and 2x16 LCD
- DIP chip version
- SOIC chip version



4. SAPIC-E software

4.1. SAPIC-E Commands

In addition to the LCD commands that are directly passed to the HD44780 LCD controller, SAPIC-E has an additional commands.

4.1.1. Instruction Table

Instruction	D7	D6	D5	D4	D3	D2	D1	D0	Description
Select Data	0	0	0	0	1	0	0	0	Select LCD data register
Select Command	0	0	0	0	1	0	1	0	Select LCD command register
Use E1	0	0	0	1	0	0	1	0	Use E1 in the following instructions
Use E2	0	0	0	1	1	0	1	0	Use E2 in the following instructions
Read LCD	0	0	0	0	1	0	0	1	Read data from LCD
Read Keyboard	0	0	0	1	1	0	0	1	Read keyboard code

4.1.2. Select Data

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	1	0	0	0

Select LCD data registers. RS=1. Subsequent commands will be send to the LCD with RS=1, therefore the LCD will interpret them as data.

4.1.3. Select Command

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	1	0	1	0

Select LCD command registers. RS=0. Subsequent commands will be sent to the LCD with RS=1, therefore the LCD will interpret them as data.

4.1.4. Use E1

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	1	0	0	1	0

Use E1 for the following operations. Subsequent commands will be sent to the first LCD controller. You can use 1BH code too for compatibility with earlier versions of SAPIC.

4.1.5. Use E2

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	1	1	0	1	0

Use E2 for the following oparations. Subsequent commands will be sent to the first LCD controller. Used only if either a two controller LCD, or if two one-controller LCD is connected to SAPIC-E.

4.1.6. Read LCD

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	1	0	0	1

Read the busy flag or the data register of the LCD, depending on RS. Reading the busy flag will always return "not busy", because the speed of the serial line is less than the LCD.

4.1.7. Read Keyboard

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	1	1	0	0	1

Check the keyboard. Return the keycode or if no key is pressed then return 0FFH. The keycodes are lised in the following table:

COLUMN	0	1	2	3
ROW0	001H	002H	003H	004H
ROW1	005H	006H	007H	008H
ROW2	009H	00AH	00BH	00CH
ROW3	00DH	00EH	00FH	010H

The SAPIC-E software debounces the key, but additional debouncing may also be required especially for larger matrices in noisy environment.

4.1.7.1. Special Codes

As the SAPIC-E can access the LCD in 4 bit wide interface modes, commands that changes to 8-bit wide interface has no effect. SAPIC-E automatically convert these commands to their 4-bit equivalent.

In data mode the code 0FH is replaced with 00H. This is for the convenience of users who are unable to send the 00H code.

4.1.8. Resolving command conflict

Most of the codes that are received by the SAPIC-E card are sent to the LCD. However the special codes that control the SAPIC-E card are interpreted first. Sometimes the user want to send these codes to the LCD. Depending on the operating mode it is possible to send other codes to the LCD to have the same effect. The LCD has three operating mode:

- Command mode
- In data mode writing the data memory
- In data mode writing the character generator memory

The following table list alternate codes that has the same effect on the LCD.

Code	SAPIC-E command	LCD command	LCD data	LCD char. gen.
00H	User defined char. #0	00H	0FH	80H
08H	Select data	0BH	00H	88H
09H	Read data	0BH	01H	89H
0AH	Select command	0BH	02H	8AH
12H	Use E1	10H	10H	92H
19H	Read keys	18H	10H	98H
1AH	Use E2	18H	10H	9AH

4.2. Programming Example

Assuming that a 16x2 LCD is connected to the SAPIC-E the following code sequence will write the text "DENSITRON" to the first line of the LCD. You can send the codes to the SAPIC-E by any terminal program.

0AH	Command mode
12H	Use E1
28H	2 lines 5x7 dots
01H	Clear display
12H	No operation, (use E1)
0CH	Display on, no cursor
08H	Data mode
44H	Letter 'D'
45H	Letter 'E'
4EH	Letter 'N'
53H	Letter 'S'
49H	Letter 'I'
54H	Letter 'T'
52H	Letter 'R'
4FH	Letter 'O'
4EH	Letter 'N'

The following C code sends this sequence to the LCD:

```
// example.c
#include <stdio.h>
#include <bios.h>

// Define serial port
#define PORT 1 // COM2

// Send this string to SA
const char message[]=
  "\x0A\x12\x28\x01\x12\x0C\x08"
  "DENSITRON";

// Example
int main(int argc, char *argv[]){
  int i;
// Send data to serial line
  for (i=0; message[i]; i++){
    bioscom(_COM_SEND,message[i],PORT);
  }
  return(0);
}
```

4.3. Toubleshooting

When you first connect SAPIC-E to the PC and the LCD fails to respond, check the following:

1) Using SPLITCOM or another terminal program send Use E1 (12H) commands to SAPIC-E. SAPIC-E should echo the codes.
2) Send Read keys (19H) code. SAPIC-E should return 19H, 0FFH if no key is pressed.
3) Measure VO, and set it correctly.

5. Instruction Summary

The following tables show both the LCD and the SAPIC-E commands.

Command mode

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0		Cursor left	1 line, 5x7 dots	1 line, 5x7 dots	CG RAM address				DD RAM address							
1	Clear display	**Reser-ved**	1 line, 5x7 dots	1 line, 5x7 dots												
2	Home	**Use E1**	1 line, 5x7 dots	1 line, 5x7 dots												
3	Home	Cursor left	1 line, 5x7 dots	1 line, 5x7 dots												
4	Auto cur-sor left	Cursor right	1 line, 5x11 dots	1 line, 5x11 dots												
5	Auto shift left	**Reser-ved**	1 line, 5x11 dots	1 line, 5x11 dots												
6	Auto cur-sor right	**Reser-ved**	1 line, 5x11 dots	1 line, 5x11 dots												
7	Auto shift right	Cursor right	1 line, 5x11 dots	1 line, 5x11 dots												
8	**Select data**	Shift left	2 lines, 5x7 dots	2 lines, 5x7 dots												
9	**Read LCD**	**Read keys**	2 lines, 5x7 dots	2 lines, 5x7 dots												
A	**Select cmd**	**Use E2**	2 lines, 5x7 dots	2 lines, 5x7 dots												
B	Display off	**Reser-ved**	2 lines, 5x7 dots	2 lines, 5x7 dots												
C	Display on	Shift right	2 lines, 5x7 dots	2 lines, 5x7 dots												
D	Cursor blink	**Reser-ved**	2 lines, 5x7 dots	2 lines, 5x7 dots												
E	Cursor line	**Reser-ved**	2 lines, 5x7 dots	2 lines, 5x7 dots												
F	Cursor line blink	**Reser-ved**	2 lines, 5x7 dots	2 lines, 5x7 dots												

Data mode

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	User defined		Characters								Characters					
1		**Reser-ved**														
2		**Use E1**														
3																
4																
5		**Reser-ved**														
6		**Reser-ved**														
7																
8	**Select data**															
9	**Read LCD**	**Read keys**														
A	**Select cmd**	**Use E2**														
B		**Reser-ved**														
C																
D		**Reser-ved**														
E		**Reser-ved**														
F	Same as 00	**Reser-ved**														