

# CHARACTER TYPE LCD MODULE

## PVC160203PGL01

### *PRODUCT SPECIFICATIONS*

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#### **CAUTION**

The product described by these specifications is designed to be used with ordinary electronic equipment or devices, such as audio/video equipment, office-automation equipment, communication devices, and other. Should you intend to use this product with equipment or devices that could endanger or affect human life (such as medical instruments, transportation equipment, aerospace machinery, nuclear-reactor controllers, fuel controllers, and all other safety devices and equipment), please be sure to consult our sales representatives in advance.

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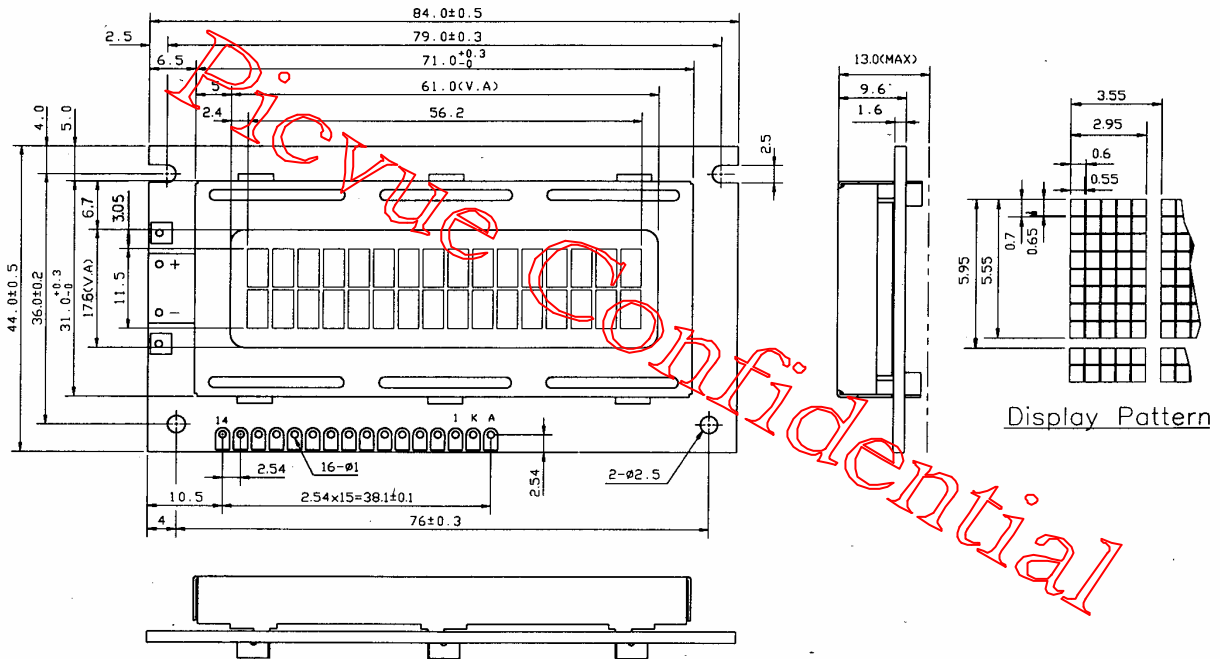
# 1.0 COMPOSITION

Display type: 16 CHARACTERS × 2 LINES DOTs-Matrix LCD Module  
 Driving method: 1/16 DUTY 1/5 BIAS  
 View Direction: 6 O' clock  
 Backlight: LED ( YELLOW / GREEN )

# 2.0 MECHANICAL SPECIFICATIONS

| ITEM              | STANDARD VALUES                      | UNITS |
|-------------------|--------------------------------------|-------|
| LCD type          | STN Transflective/Positive           |       |
| Dot arrangement   | 16 Characters × 2 Lines              | dots  |
| Module size       | 84.0 ( W ) × 44.0 ( H ) × 13.0 ( D ) | mm    |
| View area         | 61.0 ( W ) × 17.6 ( H )              | mm    |
| Active area       | 56.2 ( W ) × 11.5 ( H )              | mm    |
| Dot size          | 0.55 ( W ) × 0.55 ( H )              | mm    |
| Dot pitch         | 0.65 ( W ) × 0.7 ( H )               | mm    |
| Viewing direction | 6 O' clock                           |       |
| Weight            | 45.0                                 | g     |

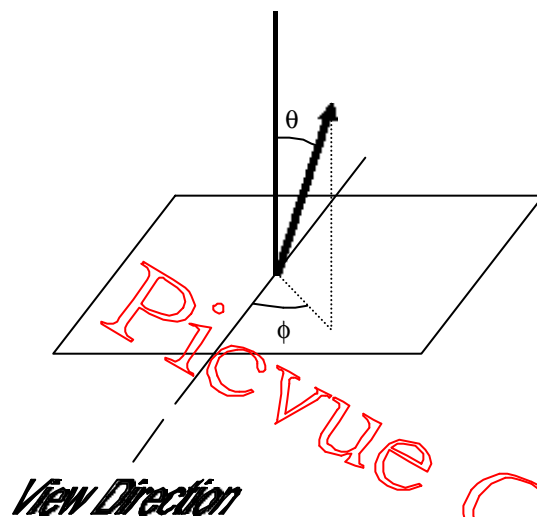
# 3.0 DIMENSIONAL DIAGRAM



## 4.0 OPTICAL CHARACTERISTICS

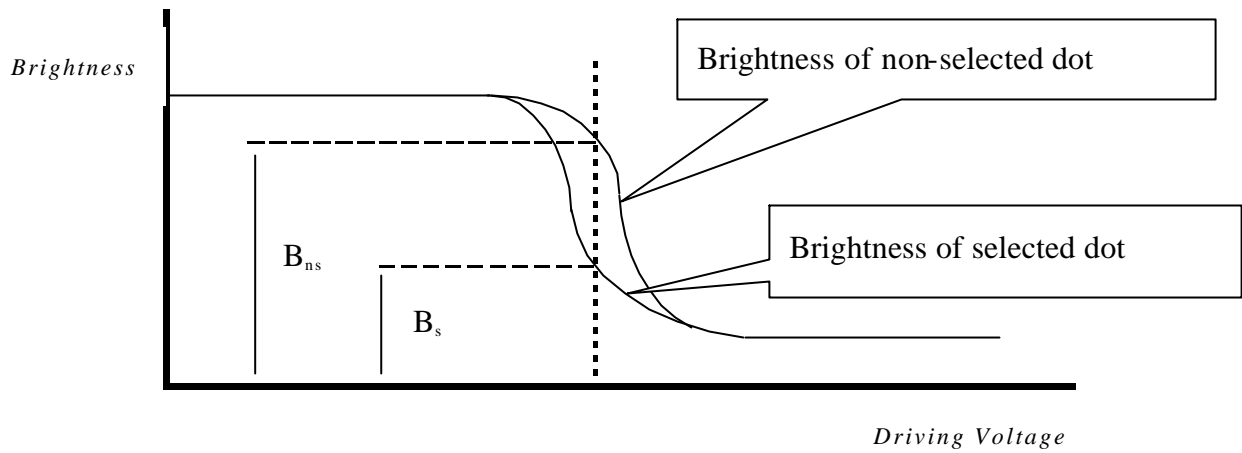
| ITEM            | SYMBOL      | CONDITIONS   | MIN                | TYP | MAX | UNITS |     |
|-----------------|-------------|--|--------------------|-----|-----|-------|-----|
| Viewing Angle   | $\theta$    | $T_a = 25\text{ }^\circ\text{C}$<br>$C_r \geq 2.0$ | $\phi = 0^\circ$   | —   | 40  | —     | Deg |
|                 |             |  | $\phi = 180^\circ$ | —   | 30  | —     |     |
|                 |             |  | $\phi = 90^\circ$  | —   | 30  | —     |     |
|                 |             |  | $\phi = 270^\circ$ | —   | 30  | —     |     |
| Contrast Ratio  | $C_r$ (MAX) | $T_a = 25\text{ }^\circ\text{C}$                   | 6                  | 10  | —   |       |     |
| Response Time   | $T_R$       | $T_a = 25\text{ }^\circ\text{C}$                   | —                  | 65  | 110 | ms    |     |
|                 | $T_F$       |  | —                  | 125 | 220 |       |     |
| Frame Frequency | $f_{FLM}$   | —  | —                  | 78  | —   | Hz    |     |

### 4.1 $\theta$ and $\phi$



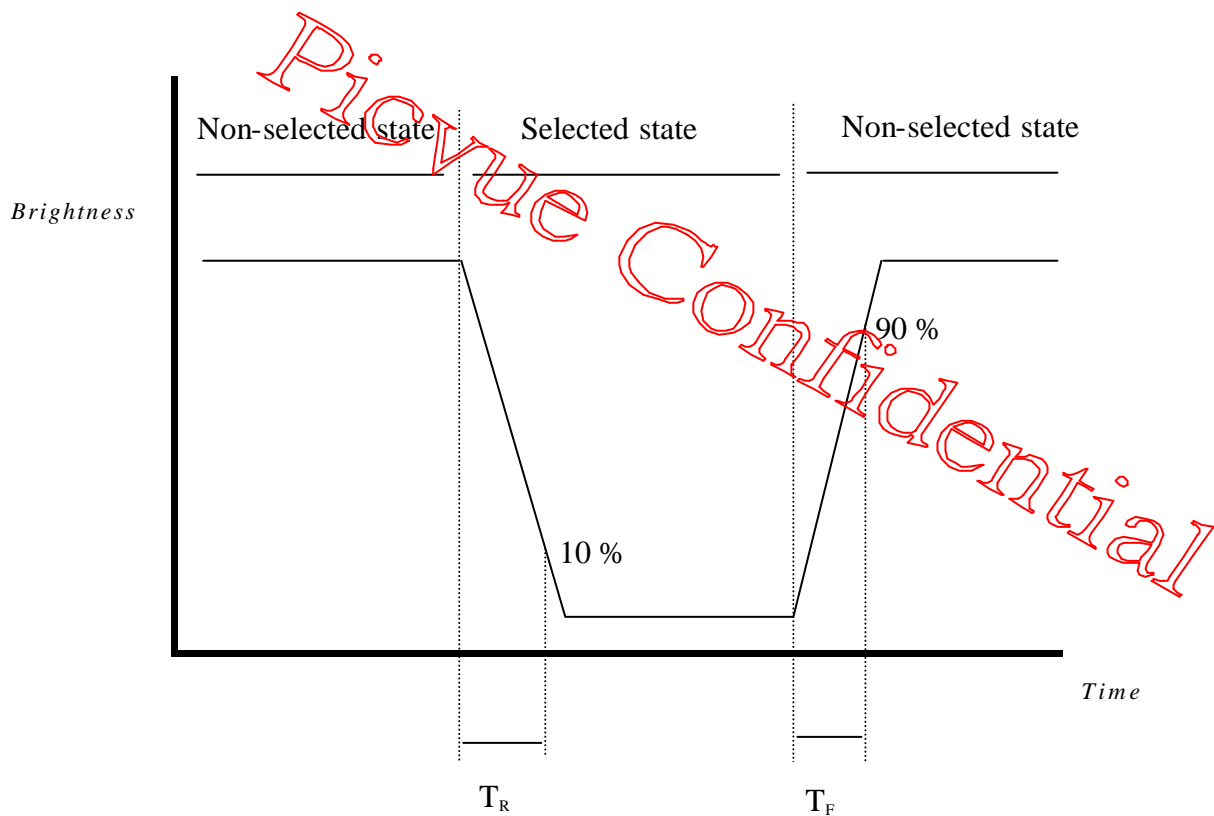
- The contrast of the display is optimal when viewed in the “View Direction” ( $\theta = 0^\circ$ ).
- $0^\circ \leq \theta < 90^\circ$ ;  $0^\circ \leq \phi < 360^\circ$

## 4.2 Contrast ratio Cr

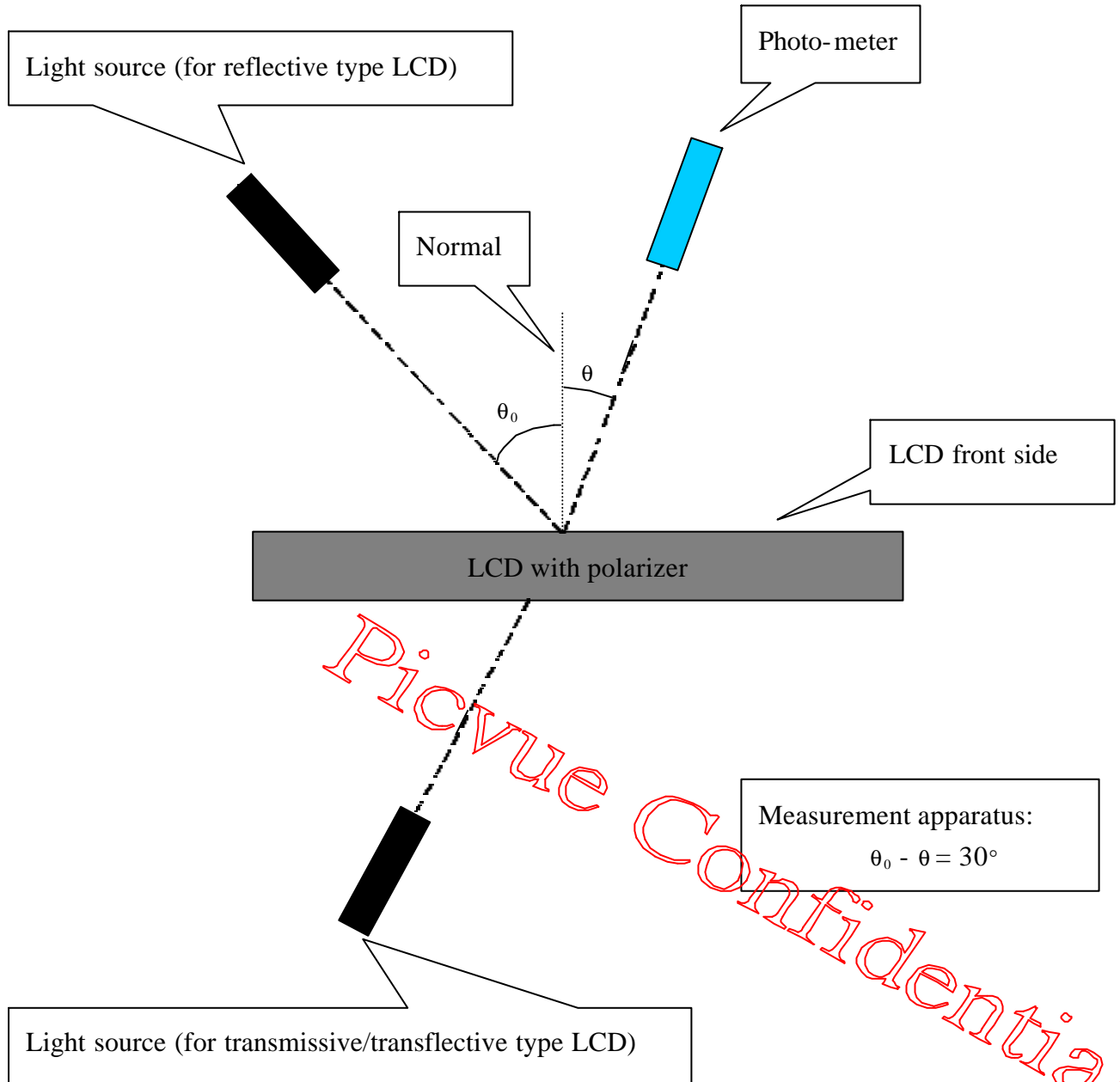


$$\text{Contrast Ratio: } C_r = B_{ns} / B_s$$

## 4.3 Response times $T_R$ and $T_F$



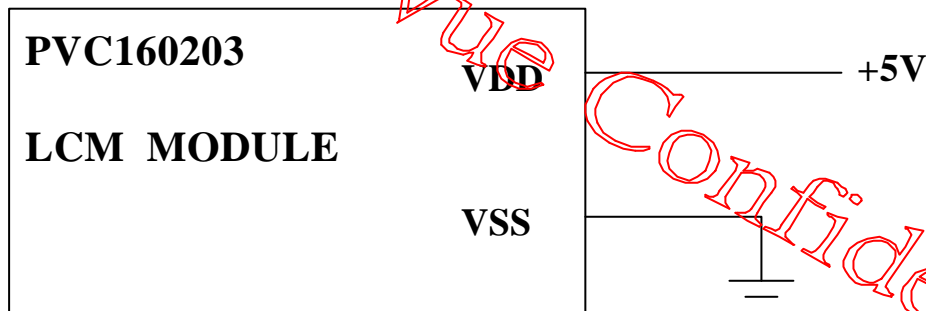
## 4.4 Optical measurement system



## 5.0 ELECTRICAL SPECIFICATIONS

| ITEM                 | SYMBOL                      | MIN         | TYP | MAX         | UNITS |
|----------------------|-----------------------------|-------------|-----|-------------|-------|
| Power-supply voltage | $V_{DD}$                    | 4.7         | 5.0 | 5.3         | V     |
| Power-supply current | $I_{DD}$<br>( $V_{DD}=5V$ ) | -           | 1.6 | 2.5         | mA    |
| Vop output voltage   | $V_O$                       | ----        | 4.5 | ----        | V     |
| Input voltage        | $V_{IH}$                    | $0.8V_{DD}$ | -   | $V_{DD}$    | V     |
|                      | $V_{IL}$                    | 0           | -   | $0.2V_{DD}$ |       |

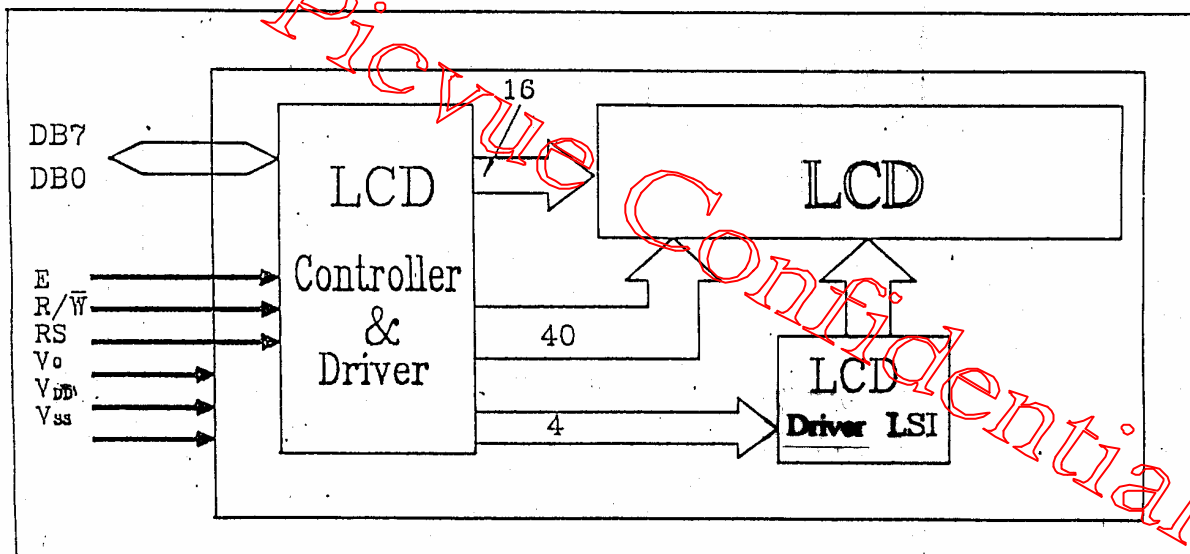
## 5.1 POWER SUPPLY CIRCUIT DIAGRAM



## 6.0 INTERFACE PIN DESCRIPTION

| PIN NO. | SYMBOL          | I/O | FUNCTION                                    |
|---------|-----------------|-----|---|
| 1       | V <sub>ss</sub> | I   | Ground                                      |
| 2       | V <sub>DD</sub> | I   | Power Supply for Logic                      |
| 3       | V <sub>o</sub>  | O   | Power Supply for LCD                        |
| 4       | RS              | I   | Register select . H : Data L : Instruction. |
| 5       | R/W             | I   | READ /WRITE                                 |
| 6       | E               | I   | ENABLE SIGNAL                               |
| 7~14    | DB0 ~ DB7       | I   | Data BUS                                    |
| 15      | NC              |     |   |
| 16      | NC              |     |   |

## 7.0 BLOCK DIAGRAM





## 8.0 AC CHARACTERISTICS

### 8.1 INTERFACE TIMING

Read Cycle ( $T_a=25^\circ\text{C}$ ,  $V_{dd}=5\text{V}$ )

| Symbol                         | Parameter                    | Min | Typ | Max | Unit | Conditions |
|--------------------------------|------------------------------|-----|-----|-----|------|------------|
| $t_{\text{CYCE}}$              | Enable Cycle Time            | 500 | —   | —   | ns   | Figure 1   |
| $t_{\text{WEM}}$               | Enable "H" Level Pulse Width | 300 | —   | —   | ns   | Figure 1   |
| $t_{\text{RE}}, t_{\text{FE}}$ | Enable Rise/Fall Time        | —   | —   | 25  | ns   | Figure 1   |
| $t_{\text{AS}}$                | RS, R/W Setup Time           | 60  | —   | —   | ns   | Figure 1   |
| $t_{\text{AH}}$                | RS, R/W Address Hold Time    | 10  | —   | —   | ns   | Figure 1   |
| $t_{\text{RD}}$                | Read Data Output Delay       | —   | —   | 190 | ns   | Figure 1   |
| $t_{\text{DHR}}$               | Read Data Hold Time          | 20  | —   | —   | ns   | Figure 1   |

#### Timing Waveforms

##### Read Operation

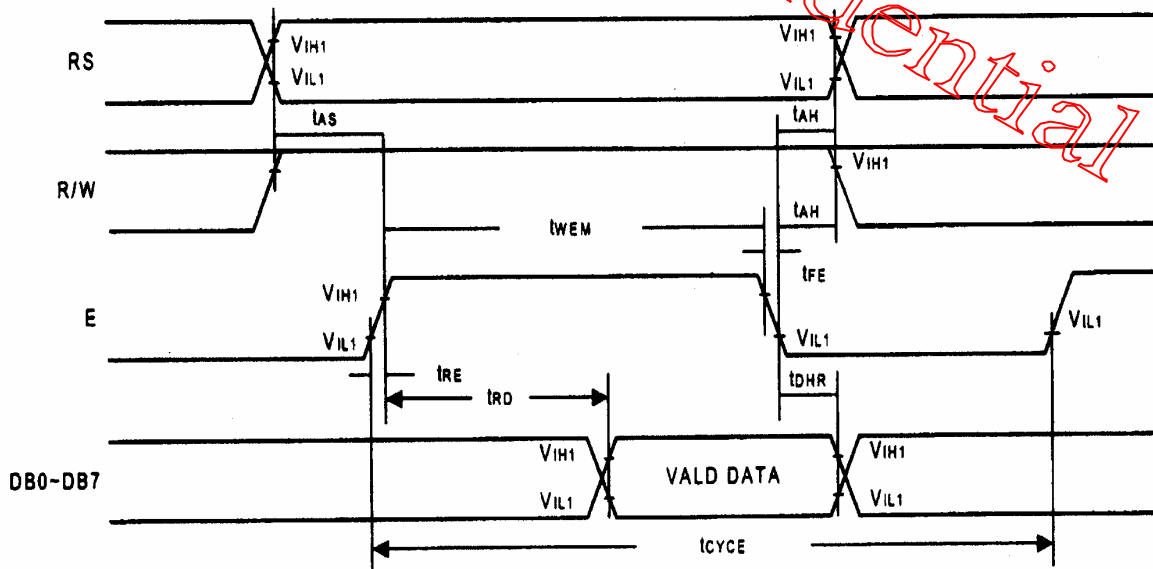


Figure 1. Bus Read Operation Sequence

Write Cycle ( $T_a=25^{\circ}\text{C}$ ,  $V_{dd}=5\text{V}$ )

| Symbol                         | Parameter                    | Min | Typ | Max | Unit | Conditions |
|--------------------------------|------------------------------|-----|-----|-----|------|------------|
| $t_{\text{CYCE}}$              | Enable Cycle Time            | 500 | —   | —   | ns   | Figure 2   |
| $t_{\text{WEM}}$               | Enable “H” Level Pulse Width | 300 | —   | —   | ns   | Figure 2   |
| $t_{\text{RE}}, t_{\text{FE}}$ | Enable Rise/Fall Time        | —   | —   | 25  | ns   | Figure 2   |
| $t_{\text{AS}}$                | RS, R/W Setup Time           | 60  | —   | —   | ns   | Figure 2   |
| $t_{\text{AH}}$                | RS, R/W Address Hold Time    | 10  | —   | —   | ns   | Figure 2   |
| $t_{\text{RD}}$                | Data Output Delay            | 100 | —   | —   | ns   | Figure 2   |
| $t_{\text{DHW}}$               | Data Hold Time               | 10  | —   | —   | ns   | Figure 2   |

Write Operation

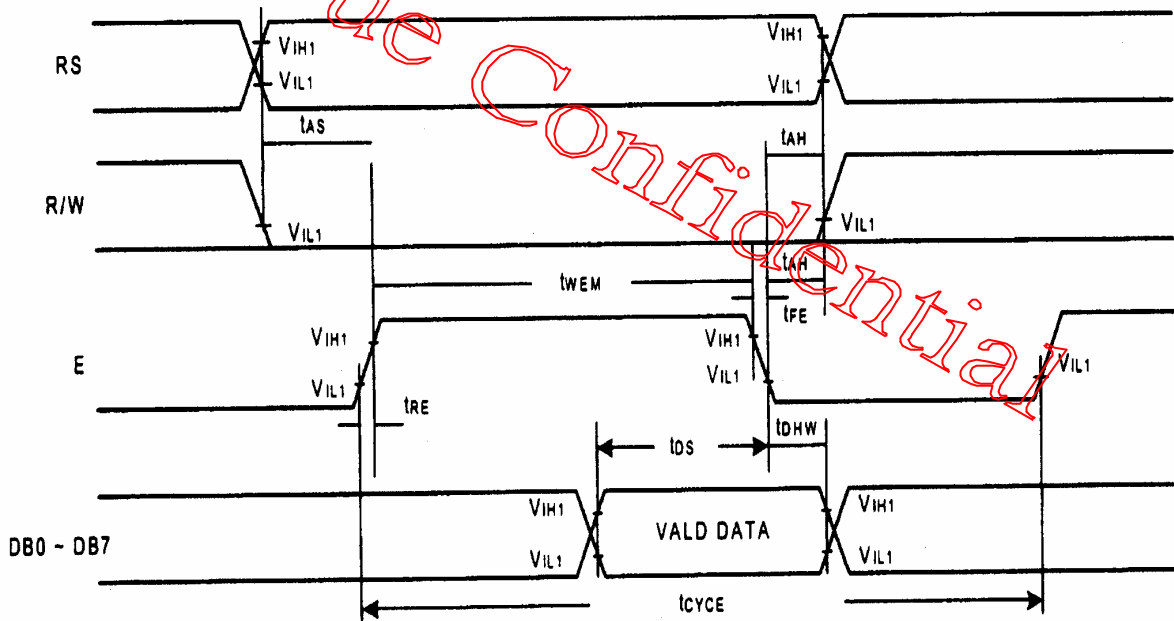


Figure 2. Bus Write Operation Sequence

### Timing Characteristics of Interface Signals with Segment Driver

( $T_a=25^{\circ}\text{C}$ ,  $V_{dd}=5\text{V}$ )

| Symbol    | Parameter              | Min   | Typ | Max  | Unit | Conditions |
|-----------|------------------------|-------|-----|------|------|------------|
| $t_{cWH}$ | Clock Pulse Width High | 800   | —   | —    | ns   | Figure 3   |
| $t_{cWL}$ | Clock Pulse Width Low  | 800   | —   | —    | ns   | Figure 3   |
| $t_{sU}$  | Data Setup Time        | 300   | —   | —    | ns   | Figure 3   |
| $t_{dH}$  | Data Hold Time         | 300   | —   | —    | ns   | Figure 3   |
| $t_{cSU}$ | Clock Setup Time       | 500   | —   | —    | ns   | Figure 3   |
| $t_{dM}$  | M Delay Time           | -1000 | —   | 1000 | ns   | Figure 3   |

### Timing Waveforms (continued)

#### Interface Signals with Segment Driver

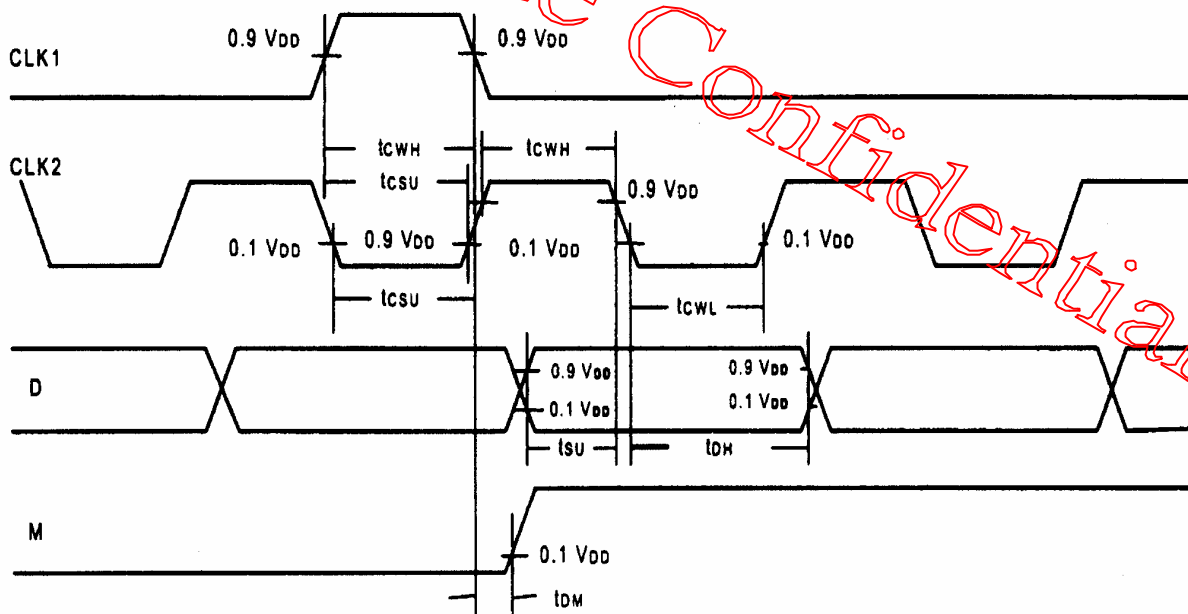


Figure 3. Sending Data to Segment Driver

### Power Supply Conditions Using Internal Reset Circuit

| Symbol    | Parameter              | Min | Typ | Max | Unit | Conditions |
|-----------|------------------------|-----|-----|-----|------|------------|
| $t_{RON}$ | Clock Pulse Width High | 0.1 | —   | 10  | ms   | Figure 4   |
| $t_{OFF}$ | Clock Pulse Width Low  | 1   | —   | —   | ms   | Figure 4   |

### Interface Signals with Segment Driver

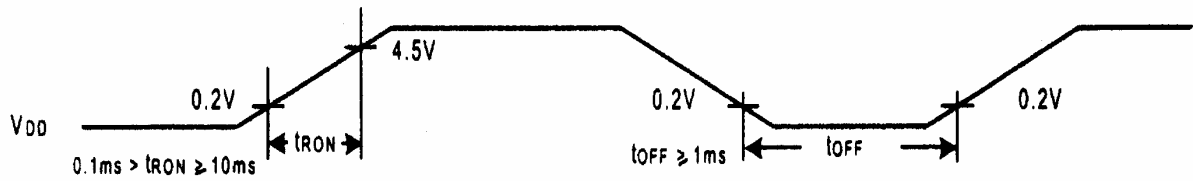


Figure 4.  $t_{OFF}$  stipulates the time of power OFF for instantaneous power supply to or when power supply repeats ON and OFF.

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## 8.2 COMMAND

### Instruction Set

| Instruction                        | Code   |    |            |     |     |     |     |     |     |                                  | Function  | Execution time (max)<br>( $f_{osc} = 250\text{KHz}$ )  |  |  |
|------------------------------------|--|----|------------|-----|-----|-----|-----|-----|-----|----------------------------------|---|--|--|--|
|                                    | RS   | RW | DB7        | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0                              |   |  |  |  |
| Display Clear                      | 0  | 0  | 0          | 0   | 0   | 0   | 0   | 0   | 0   | 0                                | 1   | Clear entire display area, restore display from shift, and load address counter with DD RAM address 00H.                       | 1.64ms   |  |
| Display/<br>Cursor Home            | 0  | 0  | 0          | 0   | 0   | 0   | 0   | 0   | 0   | 1                                | *   | Restore display from shift and load address counter with DD RAM address 00H.   | 1.64ms   |  |
| Entry Mode Set                     | 0  | 0  | 0          | 0   | 0   | 0   | 0   | 0   | 1   | I/D                              | S   | Specify direction of cursor movement and display shift mode. This operation takes place after each data transfer (read/write). | 40 $\mu$ s   |  |
| Display ON/OFF                     | 0  | 0  | 0          | 0   | 0   | 0   | 0   | 1   | D   | C                                | B   | Specify activation of display (D) cursor (C) and blinking of character at cursor position (B).                                 | 40 $\mu$ s   |  |
| Display/<br>Cursor Shift           | 0  | 0  | 0          | 0   | 0   | 0   | 1   | S/C | R/L | *                                | *   | Shift display or move cursor.  | 40 $\mu$ s   |  |
| Function Set                       | 0  | 0  | 0          | 0   | 1   | DL  | N   | F   | *   | *                                | *   | Set interface data length (DL), number of display line (N), and character font (F).  | 40 $\mu$ s   |  |
| RAM Address Set                    | 0  | 0  | 0          | 1   | ACG |     |     |     |     |                                  |   | Load the address counter with a CG RAM address. Subsequent data access is for CG RAM data.                                     | 40 $\mu$ s   |  |
| DD RAM Address Set                 | 0  | 0  | 1          | ADD |     |     |     |     |     |                                  | Load the address counter with a DD RAM address. Subsequent data access is for DD RAM data.  | 40 $\mu$ s   |  |  |
| Busy Flag/<br>Address Counter Read | 0  | 1  | BF         | AC  |     |     |     |     |     |                                  | Read Busy Flag (BF) and contents of Address Counter (AC).   | 40 $\mu$ s   |  |  |
| CG RAM/<br>DD RAM Data Write       | 1  | 0  | Write data |     |     |     |     |     |     | Write data to CG RAM or DD RAM.  | 40 $\mu$ s  |  |  |  |
| CG RAM/<br>DD RAM Data Read        | 1  | 1  | Read data  |     |     |     |     |     |     | Read data from CG RAM or DD RAM. | 40 $\mu$ s  |  |  |  |
|                                    | I/D = 1 : Increment<br>S = 1 : Display Shift On<br>D = 1 : Display On<br>C = 1 : Cursor Display On<br>B = 1 : Cursor Blink On<br>S/C = 1 : Shift Display<br>R/L = 1 : Shift Right<br>DL = 1 : 8-Bit<br>N = 1 : Dual Line<br>F = 1 : 5x10 dots<br>BF = 1 : Internal Operation<br>BF = 1 : Ready for Instruction |    |            |     |     |     |     |     |     |                                  | I/D = 0 : Decrement<br>S/C = 0 : Move Cursor<br>R/L = 0 : Shift Left<br>DL = 0 : 4-Bit<br>N = 0 : Signal Line<br>F = 0 : 5x8 dots |  | DD RAM : Display Data RAM<br>CG RAM : Character Generator RAM<br>ACG : Character Generator RAM Address<br>ADD : Display Data RAM Address<br>AC : Address Counter |  |

Note 1: Symbol "\*" signifies an insignificant bit (disregard).

Note 2: Correct input value for "N" is predetermined for each model.

|   |            | Higher 4-bit (D4 to D7) of Character Code (Hexadecimal) |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|---|------------|---|----|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|   |            | 0   | 1  | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
| 0 | CG RAM (1) |   |    | 0 | 1 | P | Q | R |   |   |   |   | ー | 夕 | ミ | α | P |
| 1 | CG RAM (2) |   | !  | 1 | A | Q | a | q |   |   |   | 。 | ア | チ | △ | △ | q |
| 2 | CG RAM (3) |   | "  | 2 | B | R | b | r |   |   |   | 「 | イ | ツ | × | β | θ |
| 3 | CG RAM (4) |   | #  | 3 | C | S | c | s |   |   |   | 」 | ウ | テ | モ | ε | ω |
| 4 | CG RAM (5) |   | \$ | 4 | D | T | d | t |   |   |   | 、 | エ | ト | ヤ | μ | Ω |
| 5 | CG RAM (6) |   | %  | 5 | E | U | e | u |   |   |   | 。 | オ | ナ | 1 | ε | Ω |
| 6 | CG RAM (7) |   | &  | 6 | F | V | f | v |   |   |   | ヲ | カ | ニ | ヨ | P | Σ |
| 7 | CG RAM (8) |   | '  | 7 | G | W | g | w |   |   |   | ア | キ | ヌ | ラ | g | π |
| 8 | CG RAM (1) |   | (  | 8 | H | X | h | x |   |   |   | イ | ク | ネ | リ | γ | Σ |
| 9 | CG RAM (2) |   | )  | 9 | I | Y | i | y |   |   |   | ウ | ケ | ル | ル | γ | γ |
| A | CG RAM (3) |   | *  | : | J | Z | j | z |   |   |   | エ | コ | ン | レ | j | γ |
| B | CG RAM (4) |   | +  | : | K | [ | k | [ |   |   |   | オ | サ | ヒ | ロ | * | π |
| C | CG RAM (5) |   | ,  | △ | L | ¥ | l | l |   |   |   | ヤ | シ | フ | ワ | φ | π |
| D | CG RAM (6) |   | -  | ≡ | M | ∫ | m | ∫ |   |   |   | ユ | ヌ | ン | ン | π | ÷ |
| E | CG RAM (7) |   | .  | > | N | ∞ | n | ∞ |   |   |   | ヨ | セ | ホ | ° | π |   |
| F | CG RAM (8) |   | /  | ? | O | _ | o | + |   |   |   | ッ | ソ | マ | ° | π | ■ |

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## 9.0 SPECIFICATIONS OF LED BACKLIGHT:

| ITEM                         | SYMBOL         | MIN | TYPE | MAX | UNITS             | TEST CONDITION |
|------------------------------|----------------|-----|------|-----|-------------------|----------------|
| Supply Current               | I              |     | 170  |     | mA                | V= 4.2V        |
| Supply voltage               | V              | 4.0 | 4.2  | 4.5 | V                 |                |
| Luminous intensity           | I <sub>v</sub> |     | 100  |     | Cd/m <sup>2</sup> | IF= 170 mA     |
| Peak Emission wavelength     | λ              |     | 565  |     | nm                | IF=170 mA      |
| Spectrum radiation Bandwidth |                |     | 30   |     | nm                | IF= 170 mA     |
| Reverse Current              | I <sub>R</sub> |     |      | 1.2 | mA                | VR = 5V        |
| Color                        | Yellow / Green |     |      |     |                   |                |

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## 10.0 MAXIMUM ABSOLUTE VALUES

| ITEM                           | SYMBOL                            | MIN                   | MAX                   | UNITS |
|--------------------------------|-----------------------------------|-----------------------|-----------------------|-------|
| Operating temperature          | T <sub>OP</sub>                   | 0                     | 50                    |       |
| Storage temperature            | T <sub>ST</sub>                   | -20                   | 70                    |       |
| Supply voltage for logic       | V <sub>DD</sub> - V <sub>SS</sub> | -0.3                  | 7.0                   | V     |
| Supply voltage for LCD driving | V <sub>DD</sub> - V <sub>O</sub>  | -0.3                  | 6.5                   |       |
| Logic input voltage            | V <sub>I</sub>                    | V <sub>SS</sub> - 0.3 | V <sub>DD</sub> + 0.3 |       |

## 11.0 RELIABILITY

| ITEM                       | CONDITIONS  | CRITERIA   |
|----------------------------|---|--|
| High temperature operation | 50 °C for 200 hours   | <ul style="list-style-type: none"> <li>◆ No defect in cosmetic and operational functions.</li> <li>◆ Total current consumption below double of initial value.</li> </ul> |
| Low temperature operation  | 0 °C for 200 hours  |  |
| High humidity storage      | 40 °C, 90 % RH for 240 hours  |  |
| High temperature storage   | 70 °C for 200 hours   |  |
| Low temperature storage    | -20 °C for 200 hours  |  |
| Temperature cycling        | -20 °C (30 min)<br>↓↑<br>25 °C (5 min)<br>↓↑<br>60 °C (30 min)<br><br><b>CYCLES: 10</b> |  |
| Vibration                  | Random Wave: 40~500 Hz<br>Acceleration: 5g<br>Each Direction (x, y, z): 50 sec          |  |

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## 12.0 COSMETIC CRITERIA OF LCD SCREEN

| DEFECT   | JUDGMENT CRITERION     |   |   |
|--|------------------------|---|---|
| <b>Spots</b>   | <b>Size d (mm)</b>     | <b>Acceptable quantity in active area</b> |   |
|  | $d \leq 0.1$           | Disregard                                 |   |
|  | $0.1 < d \leq 0.2$     | 6   |   |
|  | $0.2 < d \leq 0.3$     | 2   |   |
|  | $d > 0.3$              | 0   |   |
| Note: $d = (\text{Length} + \text{Width})/2$                                       |                        |   |   |
| <b>Polarizer Bubbles</b>   | <b>Size d (mm)</b>     | <b>Acceptable quantity in active area</b> |   |
|  | $d \leq 0.3$           | Disregard                                 |   |
|  | $0.3 < d \leq 1.0$     | 3   |   |
|  | $1.0 < d \leq 1.5$     | 1   |   |
|  | $d > 1.5$              | 0   |   |
| Note: $d = (\text{Length} + \text{Width})/2$                                       |                        |   |   |
| <b>Lines</b>   | <b>Width W (mm)</b>    | <b>Acceptable quantity in active area</b> |   |
|  | <b>Length L (mm)</b>   |   |   |
|  | $W \leq 0.02$          | Disregard                                 |   |
|  | $0.02 < W \leq 0.05$   | $L \leq 5.0$                              | 6 |
|  |                        | $L > 5.0$                                 | 0 |
|  | $0.05 < W \leq 0.1$    | $L \leq 2.0$                              | 6 |
|  |                        | $L > 2.0$                                 | 0 |
| $W > 0.1$  | See criteria for Spots |   |   |
| Testing conditions: 20W fluorescent lamp at 30 cm distance at normal viewing angle |                        |   |   |

## 13.0 PRECAUTIONS

### 13.1 Static charge

Since this LCD module contains CMOS LSIs that are sensitive to static charge, care must be taken when handling it.

### 13.2 Power on sequence

1. Input signals should not be applied to the LCD module before the logic system voltage has reached the specified voltage. If the above sequence is not kept the LCD module might be permanently damaged.
2. When connecting the power supply, connect the LCD bias voltage *after* connecting the logic system voltage.
3. When disconnecting the power supply, disconnect the logic system voltage *after* the LCD bias voltage.
4. It is recommended to connect a serial resistor or fuse to the LCD bias power supply of the system, as a current limiter. The value of the resistor depends on the kind of LCD used, but is typically 50 ~ 100  $\Omega$ .

### 13.3 Operation

1. It is essential to drive the LCD within the specified voltage limits, since a higher driving voltage than allowed causes a shorter LCD lifetime. Under these circumstances, electrochemical reactions will result in undesirable deterioration of the LCD.
2. The response time of the LC fluid is considerably longer at low temperatures than in the normal operating temperature range. On the other hand, the LCD will show a dark blue color at high temperatures. Those phenomena do not indicate a malfunction or defect of the LCD. Back at normal temperatures, the LCD will return to its original behavior.
3. If the display area is pressed hard during operation, some abnormal display patterns might appear. However, the display will resume normal operation after turning the module off and on.
4. Moisture on the terminals could cause an electrochemical reaction resulting in an open terminal connection. If the environmental temperature is higher than 40 °C, it is required that the relative humidity is 50% or less.

### 13.4 Packaging

1. Do not leave the product in a place of high humidity for a long period. For storage in a location where the temperature is 35 °C or higher, special care to protect the product from high humidity is required. A combination of high temperature and high humidity may cause polarization degradation and damage as well. Please keep the temperature and humidity within the specified range for storing.

2. Since LCD panels tend to be easily damaged, they should be handled with full care. Avoid any contact with materials that have a hardness of more than 2H.
3. Adhesives used for adhering upper/lower polarizers and aluminum plates are made of organic substances that will deteriorate by chemical reactions with for example chemicals such as acetone, toluene, ethanol, and isopropylalcohol. Please prevent the use of these chemicals and contact us when it is necessary for you to use other chemicals.
4. Immediately wipe off saliva or water drops from the display area with an absorbent cotton cloth, without scrubbing it. If adhered for a long period, such particles might cause deformation or faded color.
5. Moisture deposited on the display surface and contact terminals due to low temperatures will be a cause for polarizer damage, stains, and dirt. Before use, such panels should be slowly warmed up to a temperature that is higher than room temperature.
6. Touching the display area and contact terminals with bare hands is harmful to polarizer and may lead to poor insulation at the terminals.
7. The glass is fragile and can be cracked or chipped easily by handling, in particular on near its edge. Please prevent sudden shocks or exposing the glass to other sorts of stress.

### **13.5 Long-term storage**

For long-term storage the following methods are highly recommended:

1. Store the product in a polyethylene bag with a sealed opening to prevent fresh air entering from the outside. Placing it with a desiccant is not necessary.
2. Store the product in a dark place, with the temperature in the range from 0 to 35 .
3. Keep the sensitive polarizer surface of the LCD panels clear of any contact. We recommend using the container that was used by Picvue to deliver the products.

### **13.6 Cleaning of the product**

To clean the product make sure to use absorbent cotton cloth or other soft material like chamois. Make sure to rub it gently, and do not use chemicals when cleaning.

### **14.0 FINAL REMARKS**

1. The above specifications are the binding criteria for Picvue' s outgoing quality inspection.
2. The customer is kindly requested to inform Picvue as soon as possible on any questions, remarks, and disagreements regarding these specifications.
3. Picvue is not responsible for damage to its products due to neglect of the precautions as described in the previous chapter.

**APPENDIX—**

**REVISION RECORD**

| <b>REV</b> | <b>REVISION ITEM</b> | <b>DATE</b> |
|------------|----------------------|-------------|
| NEW        | —                    | 2000/6/15   |
| A          |                      |             |
| B          |                      |             |
| C          |                      |             |
| D          |                      |             |
| E          |                      |             |
| F          |                      |             |
| G          |                      |             |
| H          |                      |             |
| I          |                      |             |
| J          |                      |             |
| K          |                      |             |
| L          |                      |             |
| M          |                      |             |
| N          |                      |             |

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