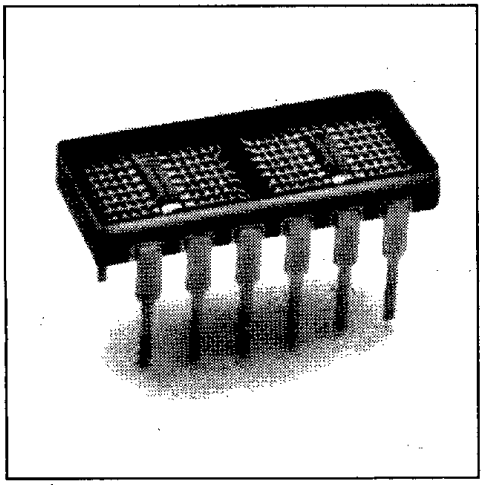
SIEMENS

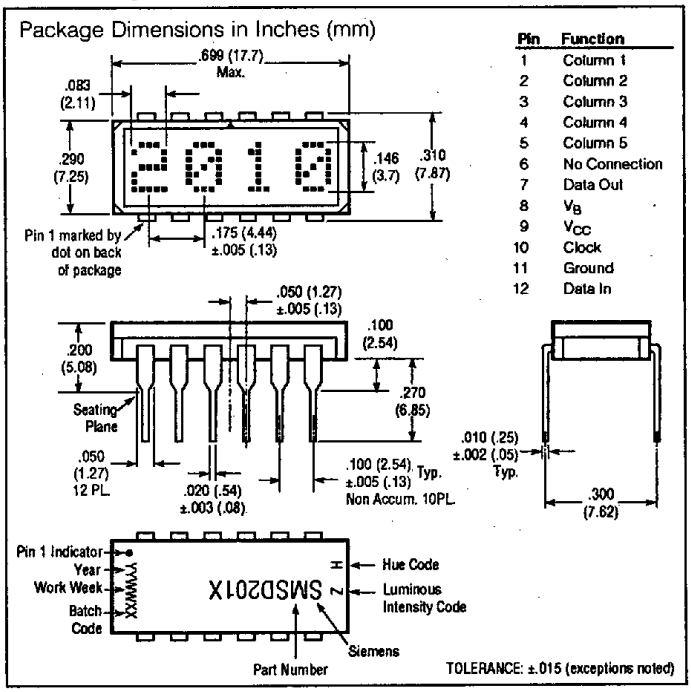
T-41-37

# RED MSD2010TXV/TXVB
# YELLOW MSD2011TXV/TXVB
# HIGH EFF. RED MSD2012TXV/TXVB
# HIGH EFF. GREEN MSD2013TXV/TXVB

## .150" 4-Character 5×7 Dot Matrix Serial Input Alphanumeric Military Display








| Pin | Function |
|---|---|
| 1 | Column 1 |
| 2 | Column 2 |
| 3 | Column 3 |
| 4 | Column 4 |
| 5 | Column 5 |
| 6 | No Connection |
| 7 | Data Out |
| 8 | $V_B$ |
| 9 | $V_{CC}$ |
| 10 | Clock |
| 11 | Ground |
| 12 | Data In |

### FEATURES

- **Four .150" Dot Matrix Characters**
- **Four Colors: Red, Yellow, High Efficiency Red, High Efficiency Green**
- **Wide Viewing Angle**
- **Built-in CMOS Shift Registers with Constant Current LED Row Drivers**
- **Shift Registers Allow Custom Fonts**
- **Easily Cascaded for Multiple Displays**
- **TTL Compatible**
- **End Stackable**
- **Military Operating Temperature Range: −55° to +100°C**
- **Categorized for Luminous Intensity**
- **Ceramic Package, Hermetically Sealed Flat Glass Window**
- **TXVB Process Conforms to MIL-D-87157 Quality Level A Test and Tables I, II, IIIa and IVa**
- **TXV Process Conforms to a Modified MIL-D-87157 Quality Level A Test and Table I**

### DESCRIPTION

The MSD2010 through MSD2013TXV/TXVB are four digit 5×7 dot matrix serial input alphanumeric displays. The displays are available in red, yellow, high efficiency red, or high efficiency green. The package is a standard twelve-pin hermetic DIP package with glass lens. The display can be stacked horizontally or vertically to form messages of any length. The MSD201X has two fourteen-bit CMOS shift registers with built-in row drivers. These shift registers drive twenty-eight rows and enable the design of customized fonts. Cascading multiple displays is possible because of the Data In and Data Out pins. Data In and Out are easily input with the clock signal and displayed in parallel on the row drivers. Data Out represents the output of the 7th bit of digit number four shift register. The shift register is level triggered. The like columns of each character in a display cluster are tied to a single pin. (See Block Diagram). High true data in the shift register enables the output current mirror driver stage associated with each row of LEDs in the 5×7 diode array.

The TTL compatible $V_B$ input may either be tied to $V_{CC}$ for maximum display intensity or pulse width modulated to achieve intensity control and reduce power consumption.

*—Continued*

*See Appnote 44 for application information, and Appnotes 18, 19, 22, and 23 for additional information.*

## DESCRIPTION (Continued)

In the normal mode of operation, input data for digit four, column one is loaded into the seven on-board shift register locations one through seven. Column one data for digits 3, 2, and 1 is shifted into the display shift register locations. Then column one input is enabled for an appropriate period of time, T. A similar process is repeated for columns 2, 3, 4, and 5. If the decode time and load data time into the shift register is t, then with five columns, each column of the display is operating at a duty factor of:

$$DF = \frac{T}{5(T+t)}$$

T+t, allotted to each display column, is generally chosen to provide the maximum duty factor consistent with the minimum refresh rate necessary to achieve a flicker free display. For most strobed display systems, each column of the display should be refreshed (turned on) at a minimum rate of 100 times per second.

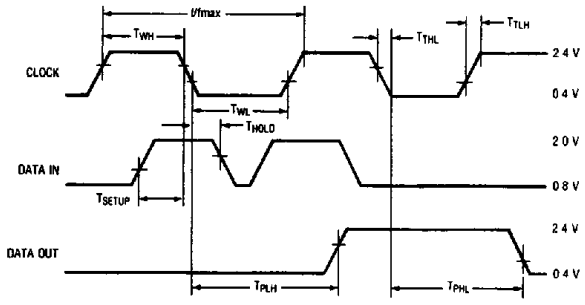
With columns to be addressed, this refresh rate then gives a value for the time T+t of: 1/[5×(100)]=2 msec. If the device is operated at 5.0 MHz clock rate maximum, it is possible to maintain t<<T. For short display strings, the duty factor will then approach 20%.

### Maximum Ratings

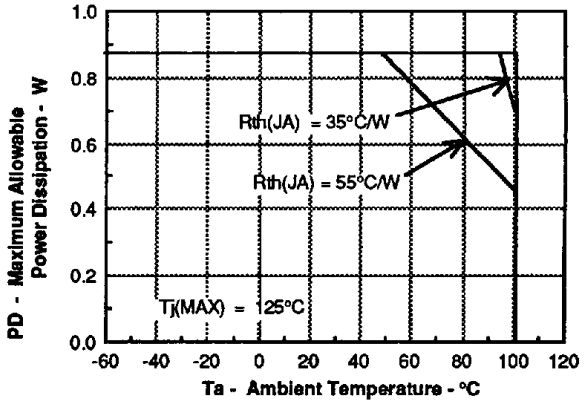
Supply Voltage $V_{CC}$ to GND . . . −0.5 V to +7.0 V
Inputs, Data Out and $V_B$ . . . . . −0.5 V to $V_{CC}$ +0.5 V
Column Input Voltage, $V_{COL}$ . . . . . −0.5 V to +6.0 V
Operating Temperature Range[1,2] . . −55°C to +100°C
Storage Temperature Range . . . . . −65°C to +125°C
Maximum Solder Temperature, 0.063″ (1.59 mm) below Seating Plane, t<5 sec . . . . . 260°C
Maximum Power Dissipation at $T_{amb}$ = 25°C[2]
Red . . . . . .0 91 W
Yellow, HER, High Eff. Green . . . . . .0.86 W

**Notes:**
1 Operation above +100°C ambient is possible provided the following condition are met The junction should not exceed $T_J$ = 125°C and the case temperature (as measured at pin 1 or the back of the display) should not exceed $T_C$ = 100°C
2. Maximum dissipation is derived from $V_{CC}$ = 5 25 V, $V_B$ = 2 4 V, $V_{COL}$ = 3 5 V 20 LEDs on per character, 20% DF

### FIGURE 1. TIMING CHARACTERISTICS




### FIGURE 2. MAX. ALLOWABLE POWER DISSIPATION VS. TEMPERATURE




### AC ELECTRICAL CHARACTERISTICS

($V_{CC}$ = 4.75 to 5.25 V, $T_{amb}$ = −55°C to +100°C)

| Symbol | Description | Min. | Typ.[1] | Max.[2] | Units | Fig. |
|---|---|---|---|---|---|---|
| $T_{SETUP}$ | Setup Time | 50 | 10 | | ns | 1 |
| $T_{HOLD}$ | Hold Time | 25 | 20 | | ns | 1 |
| $T_{WL}$ | Clock Width Low | 75 | 45 | | ns | 1 |
| $T_{WH}$ | Clock Width High | 75 | 45 | | ns | 1 |
| $F_{(CLK)}$ | Clock Frequency | | 6 | 5 | MHz | 1 |
| $T_{THL}$, $T_{TLH}$ | Clock Transition Time | | 75 | 200 | ns | 1 |
| $T_{PHL}$, $T_{PLH}$ | Propagation Delay Clock to Data Out | | 50 | 125 | ns | 1 |

**Notes:**
1 All typical values specified at $V_{CC}$ = 5 0 V and $T_{amb}$ = 25°C unless otherwise noted
2 $V_B$ Pulse Width Modulation Frequency — 50 KHz (max)

### CLEANING THE DISPLAYS

**IMPORTANT — Do not use cleaning agents containing alcohol of any type with this display.** The least offensive cleaning solution is hot D.I. water (60°C) for less than 15 minutes. Addition of mild saponifiers is acceptable Do not use commercial dishwasher detergents.

For post solder cleaning use water or non-alcohol mixtures formulated for vapor cleaning processing or non-alcohol mixtures formulated for room temperature cleaning. Non-alcohol vapor cleaning processing for up to two minutes in vapors at boiling is permissible. For suggested solvents refer to Siemens Appnote 19.

## RECOMMENDED OPERATING CONDITIONS

| Parameter | Symbol | Min. | Nom. | Max. | Units |
|---|---|---|---|---|---|
| Supply Voltage | $V_{CC}$ | 4 75 | 5 0 | 5.25 | V |
| Data Out Current, Low State | $I_{OL}$ | | | 1.6 | mA |
| Data Out Current, High State | $I_{OH}$ | | | -0 5 | mA |
| Column Input Voltage, Column On[1] | $V_{COL}$ | 2 75 | | 3 5 | V |
| Setup Time | $T_{SETUP}$ | 70 | 45 | | ns |
| Hold Time | $T_{HOLD}$ | 30 | | | ns |
| Width of Clock | $T_{W(CLK)}$ | 75 | | | ns |
| Clock Frequency | $T_{CLK}$ | | | 5 | MHz |
| Clock Transition Time | $T_{THL}$ | | | 200 | ns |
| Free Air Operating Temperature Range | $T_{amb}$ | -55 | | +100 | °C |

**Note:**
1 See Figure 3 - Peak Column Current vs Column Voltage

## OPTICAL CHARACTERISTICS

### Red MSD2010

| Description | Symbol | Min. | Typ.[4] | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| Peak Luminous Intensity per LED[1 3] (Character Average) | $I_{VPEAK}$ | 105 | 200 | | µcd | $V_{CC}$ = 5 0 V, $V_{COL}$ = 3 5 V $T_J$[5] = 25°C, $V_B$ = 2 4 V |
| Peak Wavelength | $\lambda_{PEAK}$ | | 655 | | nm | |
| Dominant Wavelength[2] | $\lambda_D$ | | 639 | | nm | |

### Yellow MSD2011

| Description | Symbol | Min. | Typ.[4] | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| Peak Luminous Intensity per LED[1 3] (Character Average) | $I_{VPEAK}$ | 400 | 750 | | µcd | $V_{CC}$ = 5.0 V, $V_{COL}$ = 3.5 V $T_J$[5] = 25°C, $V_B$ = 2.4 V |
| Peak Wavelength | $\lambda_{PEAK}$ | | 583 | | nm | |
| Dominant Wavelength[2] | $\lambda_D$ | | 585 | | nm | |

### High Efficiency Red MSD2012

| Description | Symbol | Min. | Typ.[4] | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| Peak Luminous Intensity per LED[1 3] (Character Average) | $I_{VPEAK}$ | 400 | 1430 | | µcd | $V_{CC}$ = 5.0 V, $V_{COL}$ = 3.5 V $T_J$[5] = 25°C, $V_B$ = 2.4 V |
| Peak Wavelength | $\lambda_{PEAK}$ | | 635 | | nm | |
| Dominant Wavelength[2] | $\lambda_D$ | | 626 | | nm | |

### High Efficiency Green MSD2013

| Description | Symbol | Min. | Typ.[4] | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| Peak Luminous Intensity per LED[1, 3] (Character Average) | $I_{VPEAK}$ | 850 | 1550 | | µcd | $V_{CC}$ = 5 0 V, $V_{COL}$ = 3 5 V $T_J$[5] = 25°C, $V_B$ = 2 4 V |
| Peak Wavelength | $\lambda_{PEAK}$ | | 568 | | nm | |
| Dominant Wavelength[2] | $\lambda_D$ | | 574 | | nm | |

**Notes:**
1 The displays are categorized for luminous intensity with the intensity category designated by a letter code on the bottom of the package
2 Dominant wavelength $\lambda_D$, is derived from the CIE chromaticity diagram, and represents the single wavelength which defines the color of the device
3 The luminous sterance of the LED may be calculated using the following relationships $L_V$ (cd/m²) = $I_V$ (Candela)/A (Meter)²
$L_V$ (Footlamberts) = π$I_V$ (Candela)/A (Foot)²
A = 5 3 x 10⁻⁸ M² = 5 8 x 10⁻⁷ (Foot)²
4 All typical values specified at $V_{CC}$ = 5 0 V and $T_{amb}$ = 25°C unless otherwise noted
5 The luminous intensity is measured at $T_{amb}$ = $T_J$ = 25°C No time is allowed for the device to warm up prior to measurement

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**ELECTRICAL CHARACTERISTICS** (-55°C to +100°C) (unless otherwise specified)

| Description | Symbol | Min. | Typ.(1) | Max. | Units | Test Conditions | |
|---|---|---|---|---|---|---|---|
| Supply Current (quiescent) | $I_{CC}$ | | 2 | 5.0 | mA | $V_B$ = 0.4 V | $V_{CC}$ = 5.25 V<br>$V_{CLK}$ = $V_{DATA}$ = 2.4 V<br>All SR Stages = Logical 1 |
| | | | 2.5 | 5.0 | mA | $V_B$ = 2.4 V | |
| Supply Current (operating) | $I_{CC}$ | | 3 | 10.0 | mA | $F_{CLK}$ = 5 MHz | |
| Column Current at any Column Input(2) | | | | | | | $V_{CC}$ = 5.25 V<br>$V_{COL}$ = 3.5 V<br>All SR Stages = Logical 1 |
| All | $I_{COL}$ | | | 10 | µA | $V_B$ = 0.4 V | |
| Red | $I_{COL}$ | | 350 | 435 | mA | $V_B$ = 2.4 V | |
| Yellow, HER, Green | $I_{COL}$ | | 335 | 410 | mA | | |
| $V_B$, Clock or Data Input Threshold Low | $V_{IL}$ | | | 0.8 | V | $V_{CC}$ = 4.75 V - 5.25 V | |
| $V_B$, Clock or Data Input Threshold High | $V_{IH}$ | 2.0 | | | V | | |
| Data Out Voltage | $V_{OH}$ | 2.4 | 3.6 | | V | $I_{OH}$ = -0.5 mA | $V_{CC}$ = 5.25 V<br>$I_{COL}$ = 0 mA |
| | $V_{OL}$ | | 0.2 | 0.4 | V | $I_{OL}$ = 1.6 mA | |
| Input Current Logical 0 $V_B$ only | $I_{IL}$ | -30 | -110 | -300 | µA | $V_{CC}$ = 4.75 V - 5.25 V, $V_{IL}$ = 0.8 V | |
| Input Current Logical 0 Data, Clock | $I_{IL}$ | | -1 | -10 | µA | | |
| Input Current Logical 1 Data, Clock | $I_{IH}$ | | | 10 | µA | $V_{CC}$ = 4.75 V - 5.25 V, $V_{IH}$ = 2.4 V | |
| Input Current Logical 1 $V_B$ | $I_{IH}$ | | | 200 | µA | | |
| Power Dissipation per Package | $P_D$ | | 0.44 | | W | $V_{CC}$ = 5.0 V, $V_{COL}$ = 3.5 V, 17.5% DF<br>15 LEDs on per character, $V_B$ = 2.4 V | |
| Thermal Resistance IC Junction-to-Pin | $R_{\theta J-PIN}$ | | 30 | | °C/W/ Device | | |

**Notes:**
1 All typical values specified at $V_{CC}$ = 5.0 V and $T_{amb}$ = 25°C unless otherwise noted
2 See Figure 3 - Peak Column Current vs Column Voltage

**FIGURE 3. PEAK COLUMN CURRENT VS. COLUMN VOLTAGE**

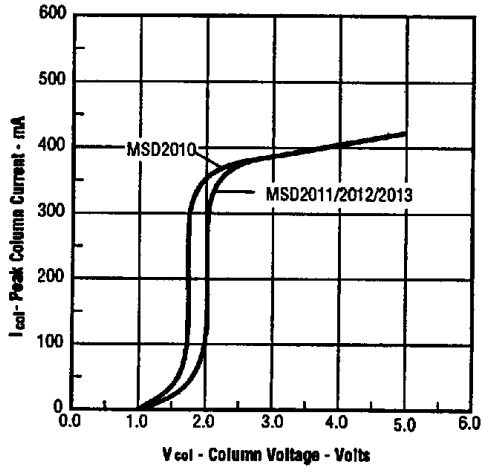
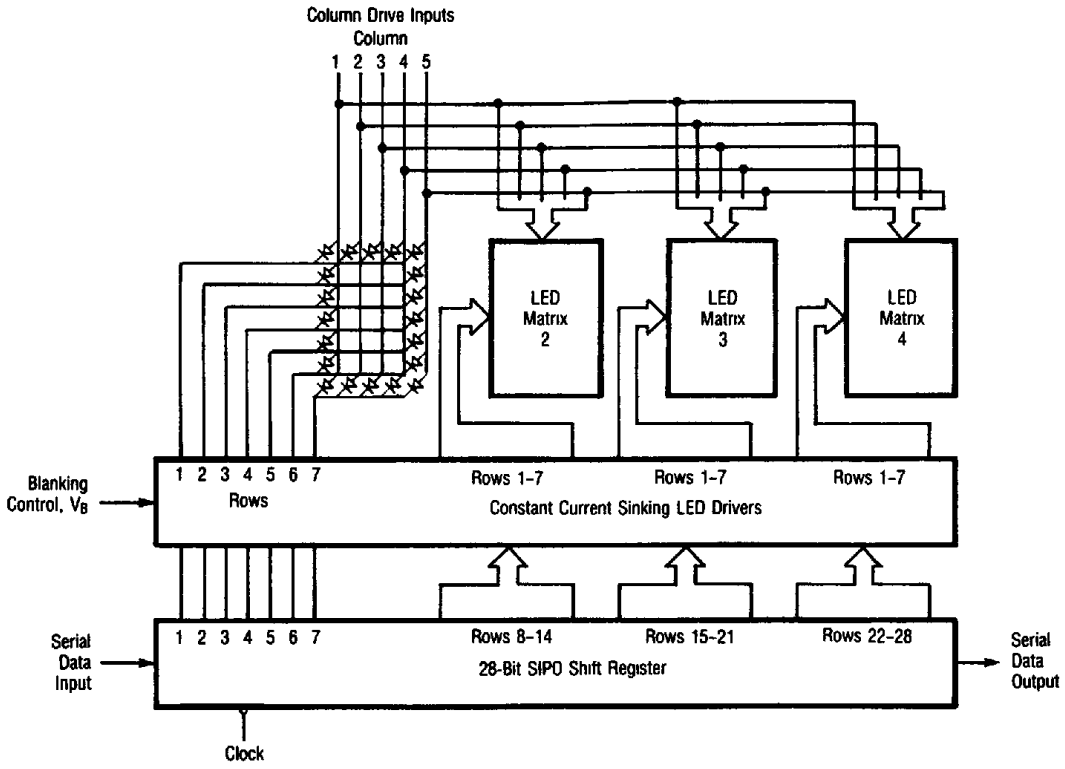


**FIGURE 4. BLOCK DIAGRAM**






**CONTRAST ENHANCEMENT FILTERS FOR SUNLIGHT READABILITY**

| Display Color Part No. | Filter Color | Marks Polarized Corp.* Filter Series | Optical Characteristics of Filter | |
|---|---|---|---|---|
| Red, HER MSD2010, 2012 | Red | MPC 20-15C | 25% @ 635 nm | Circular Polarizer |
| Yellow MSD2011 | Amber | MPC 30-25C | 25% @ 583 nm | |
| Green MSD2013 | Yellow/Green | MPC 50-22C | 22% @ 568 nm | |
| Multiple Colors High Ambient Light | Neutral Gray | MPC 80-10C | 10% Neutral | |
| Multiple Colors | Neutral Gray | MPC 80-37C | 37% Neutral | |

*Marks Polarized Corp
25-B Jefryn Blvd W
Deer Park, NY 11729
516-242-1300
FAX (516) 242-1347
Marks Polarized Corp manufactures to MIL-I-45208 inspection system

## GENERAL QUALITY ASSURANCE LEVELS

The parts are tested in conformance with Quality Level A of MIL-D-87157 for hermetically sealed LED displays with 100% screening The product is tested to Tables I, II, IIIa and IVa

**Table I. Quality Level A of MIL-D-87157**

| Test Screen | Method | Conditions |
|---|---|---|
| 1 Precap Visual | 2072 MIL-STD-750 | |
| 2. High Temperature Storage | 1032 MIL-STD-750 | $T_{amb}$ = 125°C, Time = 24 hours |
| 3. Temperature Cycling | 1051 MIL-STD-750 | Condition B, 10 Cycles, 15 min. Dwell $T_{amb}$ = -65°C to +125°C |
| 4. Constant Acceleration | 2006 MIL-STD-750 | 10,000 G's at $Y_1$ Orientation |
| 5. Fine Leak | 1071 MIL-STD-750 | Condition H, Leak Rate $\leq 5 \times 10^{-7}$ cc/s |
| 6. Gross Leak | 1071 MIL-STD-750 | Condition C |
| 7 Interim Electrical/Optical Tests(2) | | $I_{CC}$ (at $V_B$ = 0 4 V and 2.4 V), $I_{COL}$ (at $V_B$ = 0.4 V and 2 4 V), $I_{IH}$ ($V_B$, Clock and Data In), $I_{IL}$ ($V_B$, Clock and Data In), $I_{OH}$, $I_{OL}$, Visual Function and $I_V$ Peak. $V_{IH}$ and $V_{IL}$ inputs are guaranteed by the electronic shift register test. $T_{amb}$ = 25°C. |
| 8 Burn-In(1) | 1015 MIL-STD-883 | Condition B at $V_{CC} = V_B$ = 5.25 V, $V_{COL}$ = 3 5 V, $T_{amb}$ = 100°C. LED On-Time Duty Factor = 5%, t = 160 hours |
| 9 Final Electrical Test (2) | | Same as Step 7. |
| 10 Delta Determinants | | $\Delta I_{CC}$ = +/-1 mA, $\Delta I_{IH}$ = +/-10 mA (Clock and Data In), $\Delta I_{OH}$ = +/-10% of initial value, $\Delta I_V$ = -20% |
| 11 External Visual | 2009 MIL-STD-883 | |

**Table II. Group A Electrical Tests – MIL-D-87157**

| Subgroup/Test | Parameters | LTPD |
|---|---|---|
| Subgroup 1<br>DC Electrical Tests at 25°C | $I_{CC}$ (at $V_B$ = 0 4 V and 2.4 V), $I_{COL}$ (at $V_B$ = 0.4 V and 2.4 V), $I_{IH}$ ($V_B$, Clock and Data In), $I_{IL}$ ($V_B$, Clock and Data In), $I_{OH}$, $I_{OL}$, Visual Function and $I_V$ Peak. $V_{IH}$ and $V_{IL}$ inputs are guaranteed by the electronic shift register test. | 5 |
| Subgroup 2<br>Selected DC Electrical Tests at High Temperatures(2) | Same as Subgroup 1, except delete $I_V$ and Visual Function, $T_{amb}$ = 100°C | 7 |
| Subgroup 3<br>Selected DC Electrical Tests at Low Temperatures(2) | Same as Subgroup 1, except delete $I_V$ and Visual Function, $T_{amb}$ = -55°C | 7 |
| Subgroup 4, 5 and 6 Not Tested | | |
| Subgroup 7<br>Optical and Functional Tests at 25°C | Satisfied by Subgroup 1 | 5 |
| Subgroup 8<br>External Visual | MIL-STD-883, Method 2009 | 7 |

**Notes:**
1 MIL-STD-883 test method applies
2 Limits and conditions are per the Electrical/Optical Characteristics The $I_{OH}$ and $I_{OL}$ tests are the inverse of $V_{OH}$ and $V_{OL}$ specified in the Electrical Characteristics

**Table IIIa. Group B, Classes A and B of MIL-D-87157**

| Subgroup/Test | MIL-STD-750 Method | Conditions | Sample Size |
|---|---|---|---|
| Subgroup 1<br>Resistance to Solvents | 1022 | | 4 Devices/0 Failures |
| Internal Visual and Mechanical | 2075 | Inspection may be performed through glass cover, includes front and back cavities | 1 Device/0 Failures |
| Subgroup 2[1 2]<br>Solderability | 2026 | $T_{amb}$ = 245°C for 5 seconds | LTPD = 15 |
| Subgroup 3<br>Thermal Shock (Temp Cycle) | 1051 | Condition B1, 15 min. Dwell | LTPD = 15 |
| Moisture Resistance[3]<br>Visual Inspection Endpoints | 1021 | Within 24 hours after completion of moisture resistance test | |
| Hermetic Seal | 1071 | | |
| Fine Leak | 1071 | Condition G or H | |
| Gross Leak | 1071 | Condition C | |
| Electrical/Optical Endpoints[4] | | $I_{CC}$ (at $V_B$ = 0.4 V and 2 4 V),<br>$I_{COL}$ (at $V_B$ = 0.4 V and 2 4 V),<br>$I_{IH}$ ($V_B$, Clock and Data In),<br>$I_{IL}$ ($V_B$, Clock and Data In),<br>$I_{OH}$, $I_{OL}$, Visual Function and $I_V$ Peak.<br>$V_{IH}$ and $V_{IL}$ inputs are guaranteed by the electronic shift register test.<br>$T_{amb}$ = 25°C. | |
| Subgroup 4<br>Operating Life Test (340 Hours) | 1027 | $T_{amb}$ = +100°C at $V_{CC}$ = $V_B$ = 5.25 V,<br>$V_{COL}$ = 3.5 V, LED on time DF = 5% | LTPD = 10 |
| Electrical/Optical Endpoints[4] | | Same as Subgroup 3 | |
| Subgroup 5<br>Non-Operating (Storage)<br>Life Test (340 hours) | 1032 | $T_{amb}$ = +125°C | LTPD = 10 |
| Electrical/Optical Endpoints[4] | | Same as Subgroup 3 | |

**Notes:**
1 Whenever electrical/optical tests are not required as endpoints, electrical rejects may be used
2 The LTPD applies to the number of leads inspected except in no case shall less than 3 displays be used to provide the number of leads required
3 Initial conditioning shall be a 15 degree inward bend and back to original position one cycle
4 Limits and conditions are per the Electrical/Optical Characteristics The $I_{OH}$ and $I_{OL}$ tests are the inverse of $V_{OH}$ and $V_{OL}$ specified in the Electrical Characteristics

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**Table IVa. Group C, Classes A and B of MIL-D-87157**

| Subgroup/Test | MIL-STD-750 Method | Conditions | Sample Size |
|---|---|---|---|
| Subgroup 1(1) Physical Dimensions | 2066 | | 2 Devices/0 Failures |
| Subgroup 2(1 2) Lead Integrity | 2004 | Condition B2 | LTPD = 15 |
| Hermetic Seal | 1071 | | |
| Fine Leak | 1071 | Condition G or H | |
| Gross Leak | 1071 | Condition C | |
| Subgroup 3 Shock | 2016 | 1500G's, Time = 0 5 ms, 5 Blows in Each Orientation X1, Y1, Y2 | LTPD = 15 |
| Vibration, Variable Frequency | 2056 | | |
| Constant Acceleration | 2006 | 10,000G's at Y1 Orientation | |
| External Visual(3) | 1010 or 1011 | | |
| Electrical/Optical Endpoints | | $I_{CC}$ (at $V_B$ = 0.4 V and 2 4 V), $I_{COL}$ (at $V_B$ = 0.4 V and 2 4 V), $I_{IH}$ ($V_B$, Clock and Data In), $I_{OL}$ ($V_B$, Clock and Data In), $I_{OH}$, $I_{OL}$, Visual Function and $I_V$ Peak. $V_{IH}$ and $V_{IL}$ inputs are guaranteed by the electronic shift register test $T_{amb}$ = 25°C. | |
| Subgroup 4(5 6) Salt Atmosphere | 1041 | | LTPD = 15 |
| External Visual(3) | 1010 or 1011 | | |
| Subgroup 5 Bond Strength(7) | 2037 | Condition A | LTPD = 20 (C = 0) |
| Subgroup 6 Operating Life Test(8) | 1026 | $T_{amb}$ = + 100°C at $V_{CC} = V_B$ = 5.25 V, $V_{COL}$ = 3.5 V, LED on time DF = 5% | λ = 10 |
| Electrical/Optical Endpoints(4) | | Same as Subgroup 3 | |

**Notes:**

1 The LTPD applies to the number of leads inspected except in no case shall less than three displays be used to provide the number of leads required
2 MIL-STD 883 test method applies
3 Visual requirements shall be as specified in MIL-STD-883, Methods 1010 or 1011.
4 Limits and conditions are per the electrical/optical characteristics
5 Whenever electrical/optical tests are not required as endpoints, electrical rejects may be used
6 Solderability samples shall not be used
7 Displays may be selected prior to seal
8 If any given inspection lot undergoing Group B inspection has been selected to satisfy Group C inspection requirements, the 340-hour life tests may be continued on test to 1000 hours in order to satisfy the Group C Life Test requirements In such cases, either the 340-hour endpoint measurement shall be made a basis for Group B lot acceptance or the 1000-hour endpoint measurement shall be used as the basis for both Group B and Group C acceptance

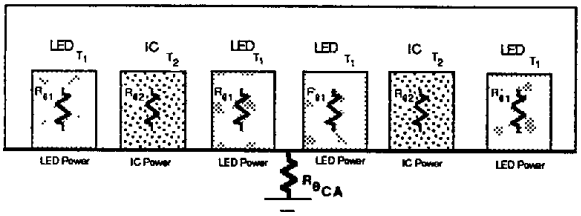
## THERMAL CONSIDERATIONS

The small alphanumeric displays are hybrid LED and CMOS assemblies that are designed for reliable operation in commercial, industrial, and military environments. Optimum reliability and optical performance will result when the junction temperature of the LEDs and CMOS ICs are kept as low as possible.

### THERMAL MODELING

MSD201X displays consist of two driver ICs and four 5 x 7 LED matrixes. A thermal model of the display is shown in Figure 5. It illustrates that the junction temperature of the semiconductor = junction self heating + the case temperature rise + the ambient temperature. Equation 1 shows this relationship.

**FIGURE 5. THERMAL MODEL**




**Equation 1.**

$$T_{J(LED)} = P_{LED}\, Z_{\theta JC} + P_{CASE}\, (R_{\theta JC} + R_{\theta CA}) + T_A$$

$$T_{J(LED)} = [(I_{COL}/28)\, V_{F(LED)}\, Z_{\theta JC}] + [(n/35)\, I_{COL}\, DF\, (5\, V_{COL}) + V_{CC}\, I_{CC}] \cdot [R_{\theta JC} + R_{\theta CA}] + T_A$$

The junction rise within the LED is the product of the thermal impedance of an individual LED (37 °C/W, DF = 20%, F = 200 Hz), times the forward voltage, $V_{F(LED)}$, and forward current, $I_{F(LED)}$, of 13 – 14 5 mA. This rise averages $T_{J(LED)} = 1$ °C The table below shows the $V_{F(LED)}$ for the respective displays

| Part Number | $V_F$ | | |
|---|---|---|---|
| | Min. | Typ. | Max. |
| MSD2010 | 1.6 | 1 7 | 2.0 |
| MSD2011/2/3 | 1 9 | 2 2 | 3.0 |

The junction rise within the LED driver IC is the combination of the power dissipated by the IC quiescent current and the 28 row driver current sinks. The IC junction rise is given in Equation 2.

A thermal resistance of 28 °C/W results in a typical junction rise of 6 °C.

**Equation 2.**

$$T_{J(IC)} = P_{COL}\, (R_{\theta JC} + R_{\theta CA}) + T_A$$

$$T_{J(IC)} = [5\, (V_{COL} - V_{F(LED)}) \cdot (I_{COL}/2) \cdot (n/35)\, DF + V_{CC} \cdot I_{CC}] \cdot [R_{\theta JC} + R_{\theta CA}] + T_A$$

**THERMAL MODELING (Cont.)**

For ease of calculations the maximum allowable electrical operating condition is dependent upon the aggregate thermal resistance of the LED matrixes and the two driver ICs. All of the thermal management calculations are based upon the parallel combination of these two networks which is 15°C/W Maximum allowable power dissipation is given in Equation 3.

**Equation 3.**

$$P_{DISPLAY} = \frac{T_{J(MAX)} - T_A}{R_{\theta JC} + R_{\theta CA}}$$

$$P_{DISPLAY} = 5\ V_{COL}\ I_{COL}\ (n/35)\ DF + V_{CC}\ I_{CC}$$

For further reference see Figures 2, 7, 8, 9, 10 and 11.

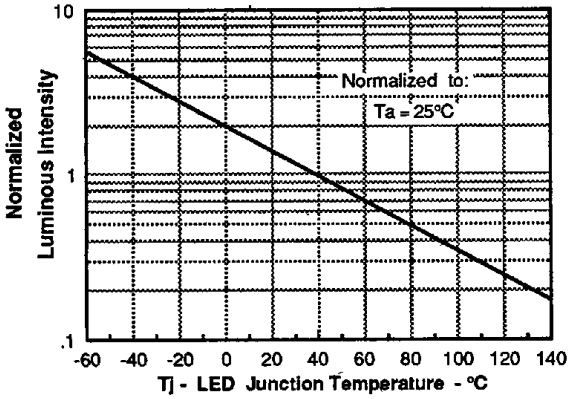
**KEY TO EQUATION SYMBOLS**

| | |
|---|---|
| DF | Duty factor |
| $I_{CC}$ | Quiescent IC current |
| $I_{COL}$ | Column current |
| n | Number of LEDs on in a 5 x 7 array |
| $P_{CASE}$ | Package power dissipation excluding LED under consideration |
| $P_{COL}$ | Power dissipation of a column |
| $P_{DISPLAY}$ | Power dissipation of the display |
| $P_{LED}$ | Power dissipation of an LED |
| $R_{\theta CA}$ | Thermal resistance case to ambient |
| $R_{\theta JC}$ | Thermal resistance junction to case |
| $T_A$ | Ambient temperature |
| $T_{J(IC)}$ | Junction temperature of an IC |
| $T_{J(LED)}$ | Junction temperature of a LED |
| $T_{J(MAX)}$ | Maximum junction temperature |
| $V_{CC}$ | IC voltage |
| $V_{COL}$ | Column voltage |
| $V_{F(LED)}$ | Forward voltage of LED |
| $Z_{\theta JC}$ | Thermal impedance junction to case |

## OPTICAL CONSIDERATIONS

The light output of the LEDs is inversely related to the LED diode's junction temperature as shown in Figure 6. For optimum light output, keep the thermal resistance of the socket or PC board as low as possible.

**FIGURE 6. NORMALIZED LUMINOUS INTENSITY VS. JUNCTION TEMPERATURE**




When mounted in a 10°C/W socket and operated at Absolute Maximum Electrical conditions, the MSD201X will show an LED junction rise of 17°C. If $T_A = 40°C$, then the LED's $T_J$ will be 57°C. Under these conditions Figure 7 shows that the $I_V$ will be 75% of its 25°C value.

**FIGURE 7. MAX. LED JUNCTION TEMPERATURE VS. SOCKET THERMAL RESISTANCE**

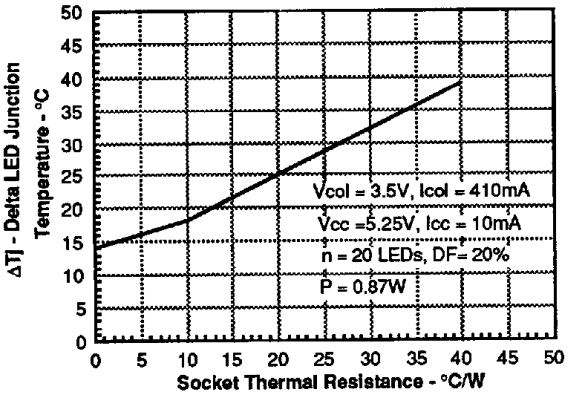



**FIGURE 8. MAX. PACKAGE POWER DISSIPATION**

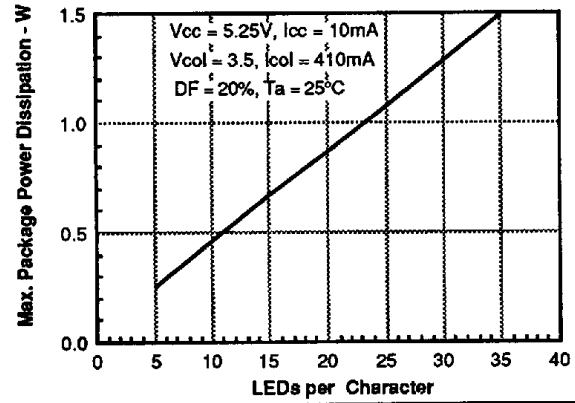



**FIGURE 9. PACKAGE POWER DISSIPATION**

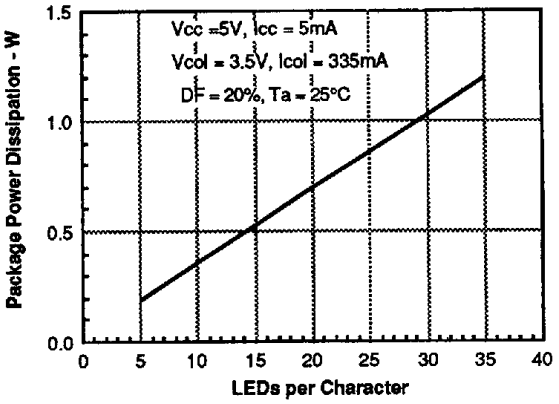



**FIGURE 10. MAX. CHARACTER POWER DISSIPATION**

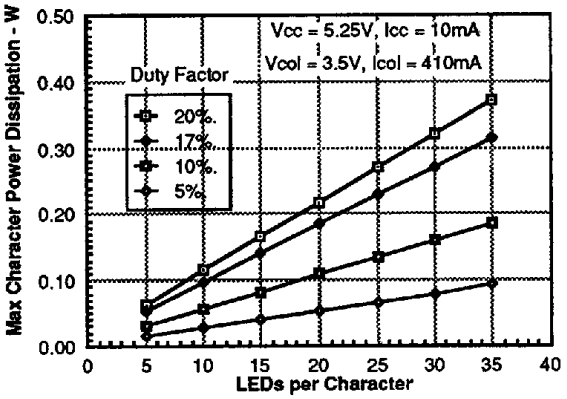



**FIGURE 11. CHARACTER POWER DISSIPATION**

