

# AS1116

## 64 LED Driver with Detailed Error Detection

### 1 General Description

The AS1116 is a compact LED driver for 64 single LEDs or 8 digits of 7-segments. The devices can be programmed via an SPI compatible 3-wire interface.

Every segment can be individually addressed and updated separately. Only one external resistor ( $R_{SET}$ ) is required to set the current. LED brightness can be controlled by analog or digital means.

The devices include an integrated BCD code-B/HEX decoder, multiplex scan circuitry, segment and display drivers, and a 64-bit memory. Internal memory stores the shift register settings, eliminating the need for continuous device reprogramming.

Additionally the AS1116 offers a diagnostic mode for easy and fast production testing and allows the use of the AS1116 for critical applications. The diagnostic allows to detect individual open or shorted LEDs.

The AS1116 features a low shutdown current of typically 200nA, and an operational current of typically 350 $\mu$ A. The number of digits can be programmed, the devices can be reset by software, and an external clock is also supported.

The device is available in a QSOP-24 and TQFN(4x4)-24 package.

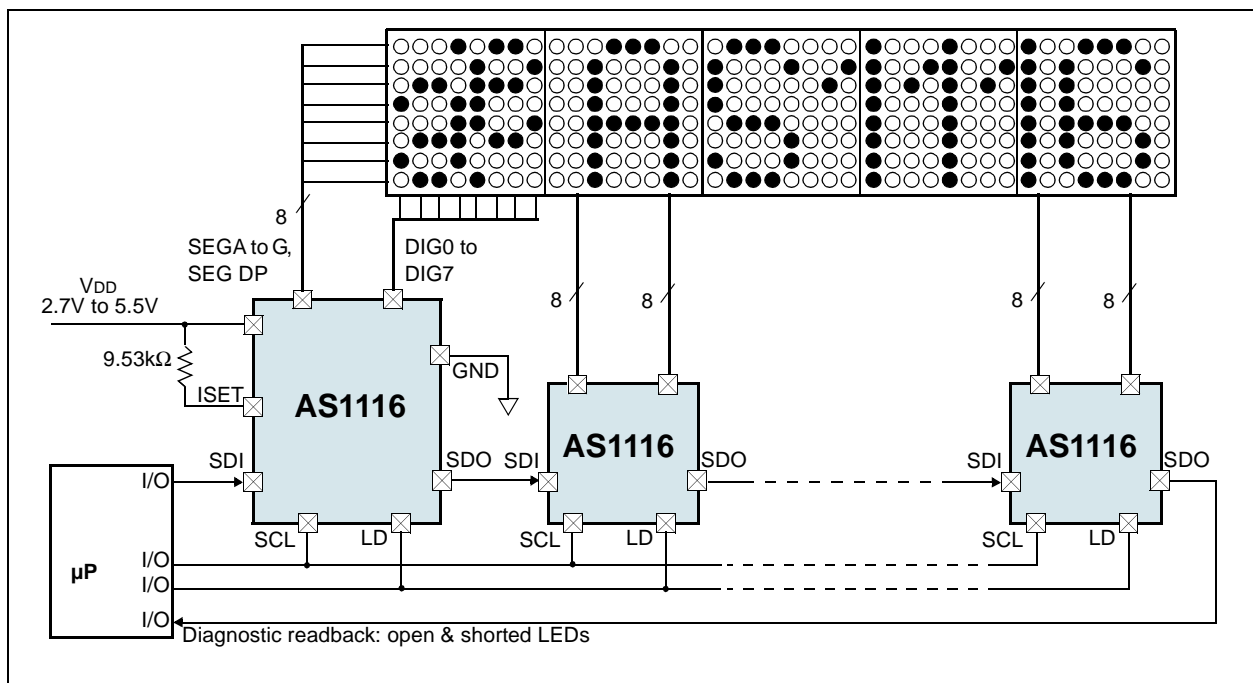
### 2 Key Features

- 10MHz SPI-Compatible Interface
- Open and Shorted LED Error Detection
  - Global or Individual Error Detection
- Hexadecimal- or BCD-Code for 7-Segment Displays
- 200nA Low-Power Shutdown Current (typ; data retained)
- Individual Digit Brightness Control
- Digital and Analog Brightness Control
- Display Blanked on Power-Up
- Drive Common-Cathode LED Displays
- Supply Voltage Range: 2.7 to 5.5V
- Software Reset
- Optional External Clock
- Package:
  - QSOP-24 and TQFN(4x4)-24

### 3 Applications

The AS1116 is ideal for seven-segment or dot matrix displays in public information displays at subway, train or bus stations, at airports and also at displays in public transportation like buses or trains mobile phones, personal electronic and toys.

Figure 1. AS1116 - Typical Application Diagram

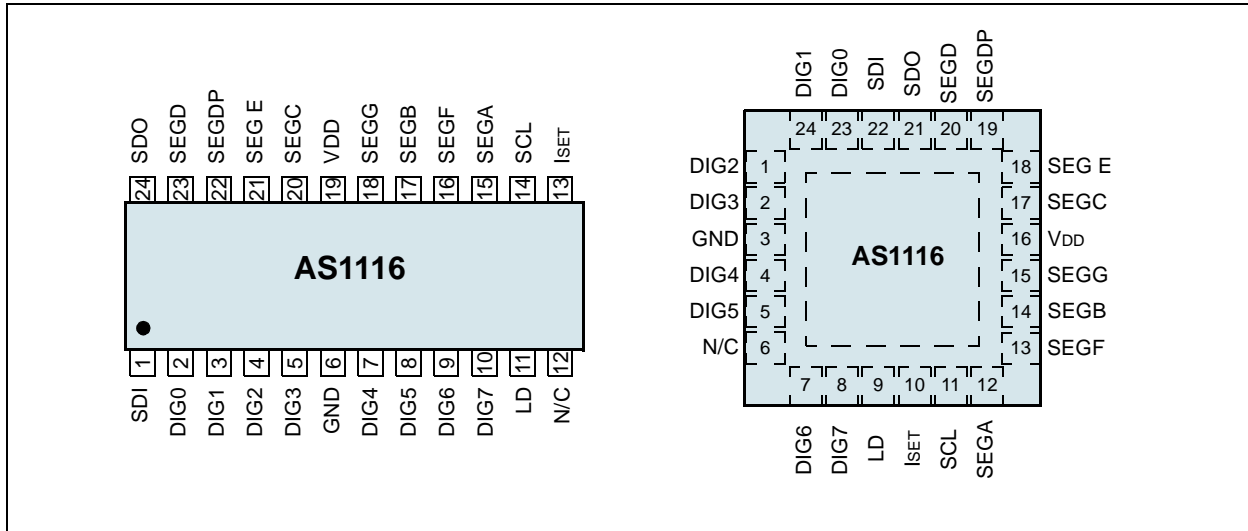




## 4 Pinout

### Pin Assignments

Figure 2. Pin Assignments (Top View)



### Pin Descriptions

Table 1. Pin Descriptions

| Pin Name         | QSOP-24      | TQFN(4x4)-24             | Description  |
|------------------|--------------|--------------------------|--|
| SDI              | 1            | 22                       | <b>Serial-Data Input.</b> Data is loaded into the internal 16-bit shift register on the rising edge of pin SCL.  |
| DIG0:DIG7        | 2-5, 7-10    | 1, 2, 4, 5, 7, 8, 23, 24 | <b>Digit Drive Lines.</b> Eight digit drive lines that sink current from the display cathode.  |
| GND              | 6            | 3                        | <b>Ground.</b>   |
| LD               | 11           | 9                        | <b>Load.</b> Serial Data is loaded into the shift register while this pin is low. The last 16 bits of serial data are latched on the rising edge of this pin.  |
| N/C              | 12           | 6                        | <b>Not Connected.</b>  |
| ISET             | 13           | 10                       | <b>Set Segment Current.</b> Connect to VDD or a reference voltage through RSET to set the peak segment current (see <a href="#">Selecting RSET Resistor Value and Using External Drivers on page 17</a> ). |
| SCL              | 14           | 11                       | <b>Serial-Clock Input.</b> 10MHz maximum rate. Data is shifted into the internal shift register on the rising edge of this pin. Data is clocked out of pin SDO on the rising edge of this pin.             |
| SEGA:SEGG, SEGDP | 15-18, 20-23 | 12-15, 17-20             | <b>Seven Segment and Decimal Point Drive Lines.</b> 8 seven-segment drives and decimal point drive that source current to the display.   |
| VDD              | 19           | 16                       | <b>Positive Supply Voltage.</b> Connect to +2.7 to +5.5V supply.   |
| SDO              | 24           | 21                       | <b>Serial-Data Output.</b> The data into pin SDI is valid at pin SDO 16 clock cycles later. This pin is used to daisy-chain several devices and is never high-impedance.                                   |
| -                | -            | Exposed Pad              | <b>Exposed Pad.</b> This pin also functions as a heat sink. Solder it to a large pad or to the circuit-board ground plane to maximize power dissipation.   |



## 5 Absolute Maximum Ratings

Stresses beyond those listed in [Table 2](#) may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in [Section 6 Electrical Characteristics on page 4](#) is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 2. Absolute Maximum Ratings

| Parameter  |                        | Min  | Max                        | Units | Notes   |
|--|------------------------|------|----------------------------|-------|---|
| <b>Electrical Parameters</b>                     |                        |      |                            |       |   |
| Input Voltage Range                              | V <sub>DD</sub> to GND | -0.3 | 7                          | V     |   |
|  | All other pins to GND  | -0.3 | 7 or V <sub>DD</sub> + 0.3 | V     |   |
| Current  | DIG0:DIG7 Sink Current |      | 500                        | mA    |   |
|  | SEGA:SEGG, SEGDP       |      | 100                        | mA    |   |
| Input Current (latch-up immunity)                |                        | ±100 |                            | mA    | Norm: JEDEC 78  |
| <b>Electrostatic Discharge</b>                   |                        |      |                            |       |   |
| Electrostatic Discharge                          | Digital outputs        |      | 1000                       | V     | Norm: MIL 833 E method 3015   |
|  | All other pins         |      | 1000                       | V     |   |
| <b>Thermal Information</b>                       |                        |      |                            |       |   |
| Thermal Resistance $\Theta_{JA}$                 |                        |      | 88                         | °C/W  | on PCB, QSOP-24 package   |
|  |                        |      | 30.5                       | °C/W  | on PCB, TQFN(4x4)-24 package  |
| <b>Temperature Ranges and Storage Conditions</b> |                        |      |                            |       |   |
| Junction Temperature                             |                        |      | +150                       | °C    |   |
| Storage Temperature                              |                        | -55  | +150                       | °C    |   |
| Package Body Temperature                         |                        |      | +260                       | °C    | The reflow peak soldering temperature (body temperature) specified is in accordance with <i>IPC/JEDEC J-STD-020 "Moisture/Reflow Sensitivity Classification for Non-Hermetic Solid State Surface Mount Devices"</i> . The lead finish for Pb-free leaded packages is matte tin (100% Sn). |
| Humidity non-condensing                          |                        | 5    | 85                         | %     |   |
| Moisture Sensitive Level                         | QSOP-24 package        | 1    |                            | %     | Represents a max. floor life time of unlimited  |
|  | TQFN(4x4)-24 package   | 3    |                            | %     | Represents a max. floor life time 168h  |



## 6 Electrical Characteristics

$V_{DD} = 2.7$  to  $5.5V$ ,  $R_{SET} = 9.53k\Omega$ , Typical values are at  $T_{AMB} = +25^{\circ}C$ ,  $V_{DD} = 5.0V$  (unless otherwise specified). All limits are guaranteed. The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods.

Table 3. Electrical Characteristics

| Symbol           | Parameter                      | Conditions   | Min | Typ  | Max  | Unit        |
|------------------|--------------------------------|--|-----|------|------|-------------|
| $T_{AMB}$        | Operating Temperature Range    |  | -40 |      | +85  | $^{\circ}C$ |
| $T_J$            | Operating Junction Temperature |  | -40 |      | +125 | $^{\circ}C$ |
| $V_{DD}$         | Operating Supply Voltage       |  | 2.7 |      | 5.5  | V           |
| $I_{DDSD}$       | Shutdown Supply Current        | All digital inputs at $V_{DD}$ or GND,<br>$T_{AMB} = +25^{\circ}C$ |     | 0.2  | 2    | $\mu A$     |
| $I_{DD}$         | Operating Supply Current       | $R_{SET} =$ open circuit.  |     | 0.35 | 0.6  | mA          |
|                  |                                | All segments and decimal point on;<br>$I_{SEG} = -40mA$ .          |     | 335  |      |             |
| $f_{OSC}$        | Display Scan Rate              | 8 digits scanned   | 0.6 | 0.8  | 1.2  | kHz         |
| $I_{DIGIT}$      | Digit Drive Sink Current       | $V_{OUT} = 0.65V$  | 320 |      |      | mA          |
| $I_{SEG}$        | Segment Drive Source Current   | $V_{DD} = 5.0V$ , $V_{OUT} = (V_{DD} - 1V)$                        | -37 | -42  | -47  | mA          |
| $\Delta I_{SEG}$ | Segment Drive Current Matching |  |     | 3    |      | %           |
| $I_{SEG}$        | Segment Drive Source Current   | Average Current  |     |      | 47   | mA          |

Table 4. Logic Inputs/Outputs Characteristics

| Symbol              | Parameter                       | Conditions                                    | Min                  | Typ                  | Max                  | Unit    |
|---------------------|---------------------------------|---|----------------------|----------------------|----------------------|---------|
| $I_{IH}$ , $I_{IL}$ | Input Current SDI, SCL, LD      | $V_{IN} = 0V$ or $V_{DD}$                     | -1                   |                      | 1                    | $\mu A$ |
| $V_{IH}$            | Logic High Input Voltage        | $4.5V < V_{DD} < 5.5V$                        | $0.6 \times V_{DD}$  |                      |                      | V       |
|                     |                                 | $2.7V < V_{DD} < 4.5V$                        | $0.7 \times V_{DD}$  |                      |                      | V       |
| $V_{IL}$            | Logic Low Input Voltage         | $V_{DD} = 5.0V$                               |                      |                      | 0.8                  | V       |
|                     |                                 | $V_{DD} = 3.0V$                               |                      |                      | 0.6                  |         |
| $V_{OH}$            | Output High Voltage             | SDO, $I_{SOURCE} = -1mA$ ,<br>$V_{DD} = 5.0V$ | $V_{DD} - 1$         |                      |                      | V       |
|                     |                                 | SDO, $I_{SOURCE} = -1mA$ ,<br>$V_{DD} = 3.0V$ | $V_{DD} - 0.5$       |                      |                      |         |
| $V_{OL}$            | Output Low Voltage              | SDO, $I_{SINK} = 1mA$                         |                      |                      | 0.4                  | V       |
| $\Delta V_I$        | Hysteresis Voltage              | SDI, SCL, LD                                  |                      | 1                    |                      | V       |
|                     | Open Detection Level Threshold  |   | $0.7 \times V_{DD}$  | $0.75 \times V_{DD}$ | $0.8 \times V_{DD}$  | V       |
|                     | Short Detection Level Threshold |   | $0.05 \times V_{DD}$ | $0.1 \times V_{DD}$  | $0.15 \times V_{DD}$ | V       |



Table 5. SPI Timing Characteristics

| Symbol | Parameter                         | Conditions   | Min | Typ | Max  | Unit |
|--------|-----------------------------------|--------------|-----|-----|------|------|
| tCP    | SCL Clock Period                  |              | 100 |     |      | ns   |
| tCH    | SCL Pulse Width High              |              | 20  |     |      | ns   |
| tCL    | SCL Pulse Width Low               |              | 20  |     |      | ns   |
| tcSS   | LD to SCL Rise Setup Time         |              | 25  |     |      | ns   |
| tCSH   | SCL Rise to LD Rise Hold Time     |              | 10  |     |      | ns   |
| tDS    | SDI Setup Time                    |              | 0   |     |      | ns   |
| tdH    | SDI Hold Time                     |              | 5   |     |      | ns   |
| tDO    | Output Data Propagation Delay     | CLOAD = 50pF |     |     | 25   | ns   |
| tLDCK  | LD Rising Edge to SCL Rising Edge |              | 20  |     |      | ns   |
| tCSW   | Minimum LD Pulse High             |              | 20  |     |      | ns   |
| tdSPD  | Data-to-Segment Delay             |              |     |     | 2.25 | ms   |

See [Figure 19 on page 10](#) for more information.



# 7 Typical Operating Characteristics

RSET = 9.53kΩ, VRset = VDD;

Figure 3. Display Scan Rate vs. Supply Voltage;

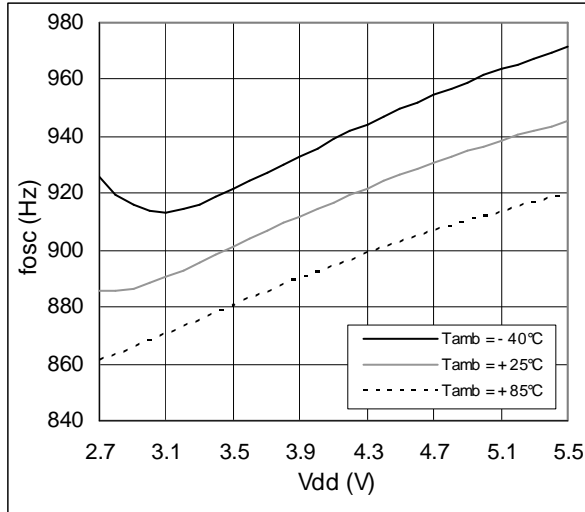


Figure 4. Display Scan Rate vs. Temperature;

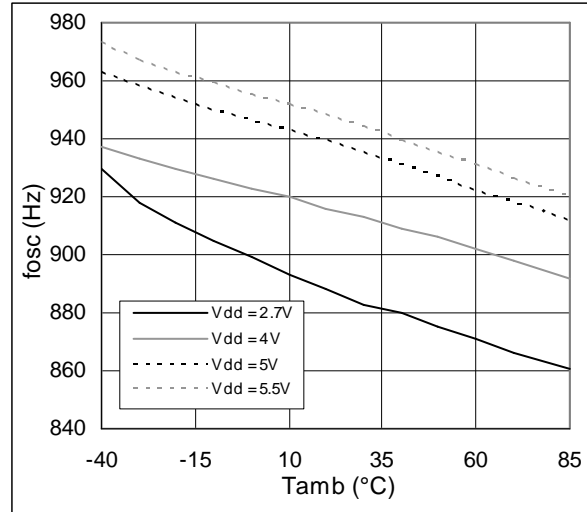


Figure 5. Segment Current vs. Temperature;

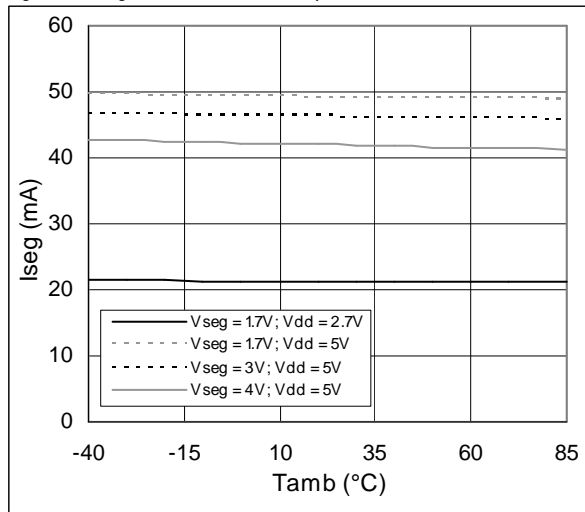


Figure 6. Segment Current vs. RSET;

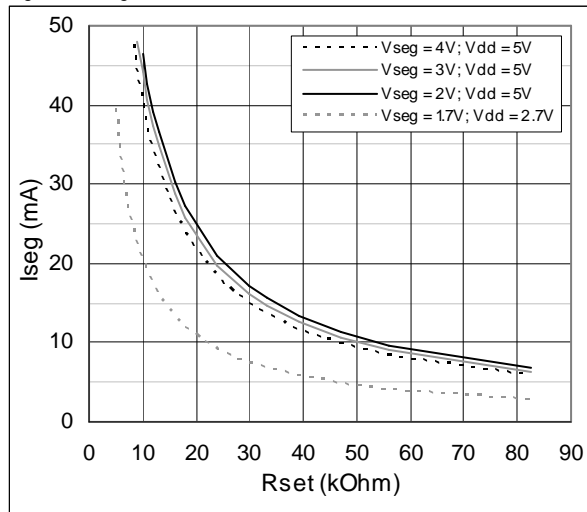


Figure 7. Segment Current vs. Supply Voltage;

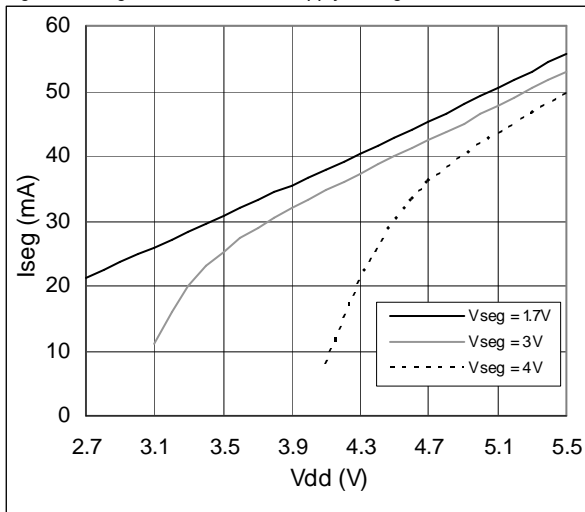


Figure 8. Segment Current vs. VDD; VRset = 2.8V

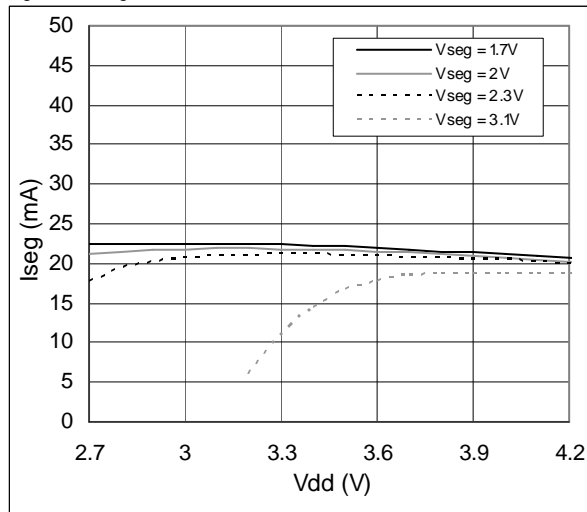




Figure 9. VD<sub>DIGIT</sub> vs. I<sub>DIGIT</sub>

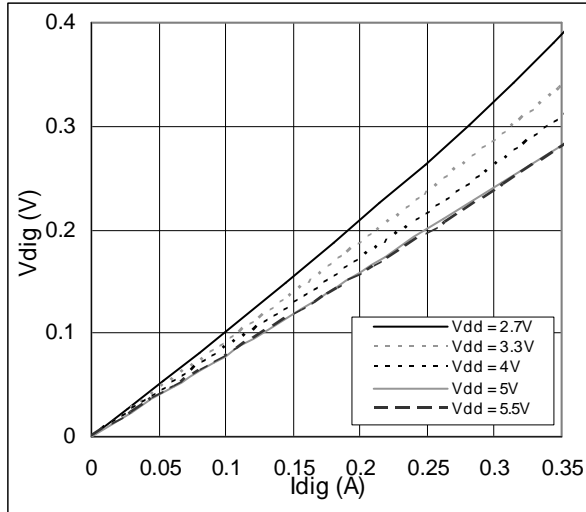


Figure 10. Input High Level vs. Supply Voltage

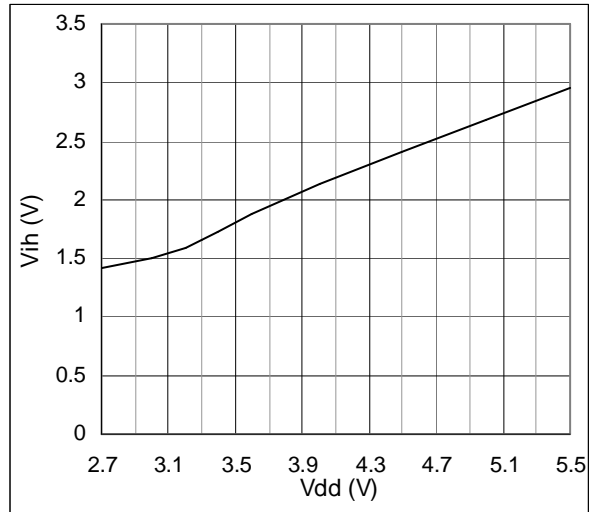


Figure 11. I<sub>SEG</sub> vs. V<sub>SEG</sub>; V<sub>DD</sub> = 5V

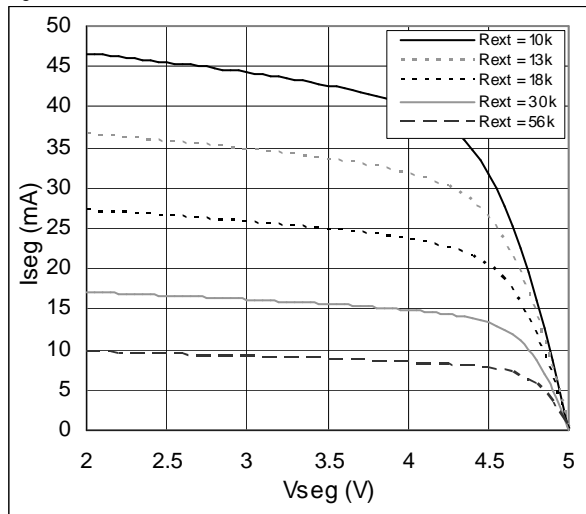


Figure 12. I<sub>SEG</sub> vs. V<sub>SEG</sub>; V<sub>DD</sub> = 4V

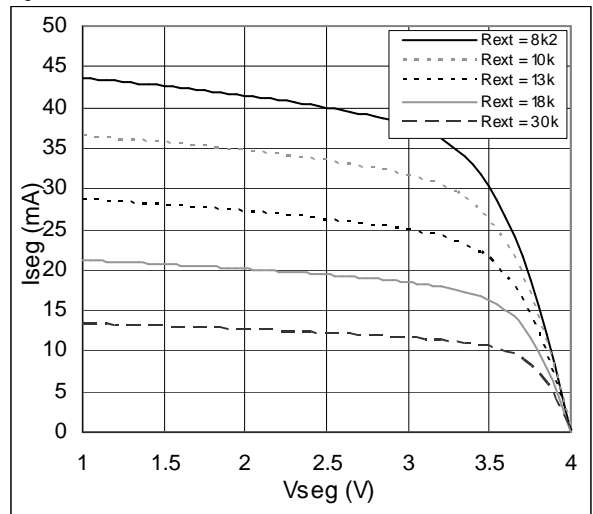


Figure 13. I<sub>SEG</sub> vs. V<sub>SEG</sub>; V<sub>DD</sub> = 3.3V

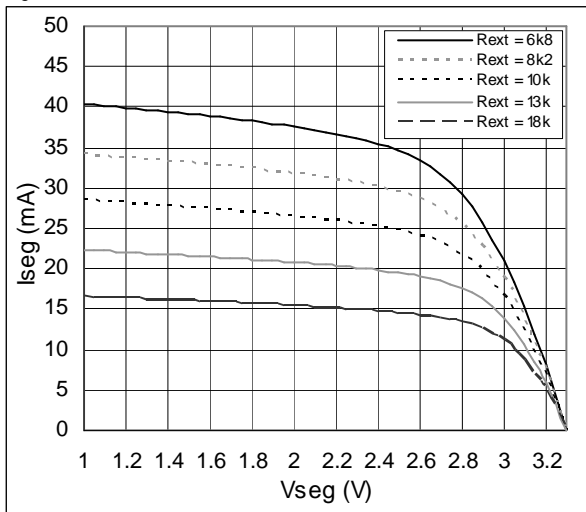
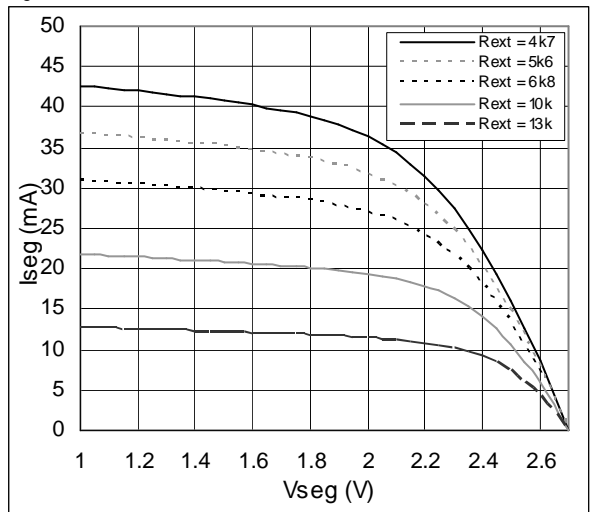


Figure 14. I<sub>SEG</sub> vs. V<sub>SEG</sub>; V<sub>DD</sub> = 2.7V





## 8 Detailed Description

### Block Diagram

Figure 15. Block Diagram (QSOP-24 Package)

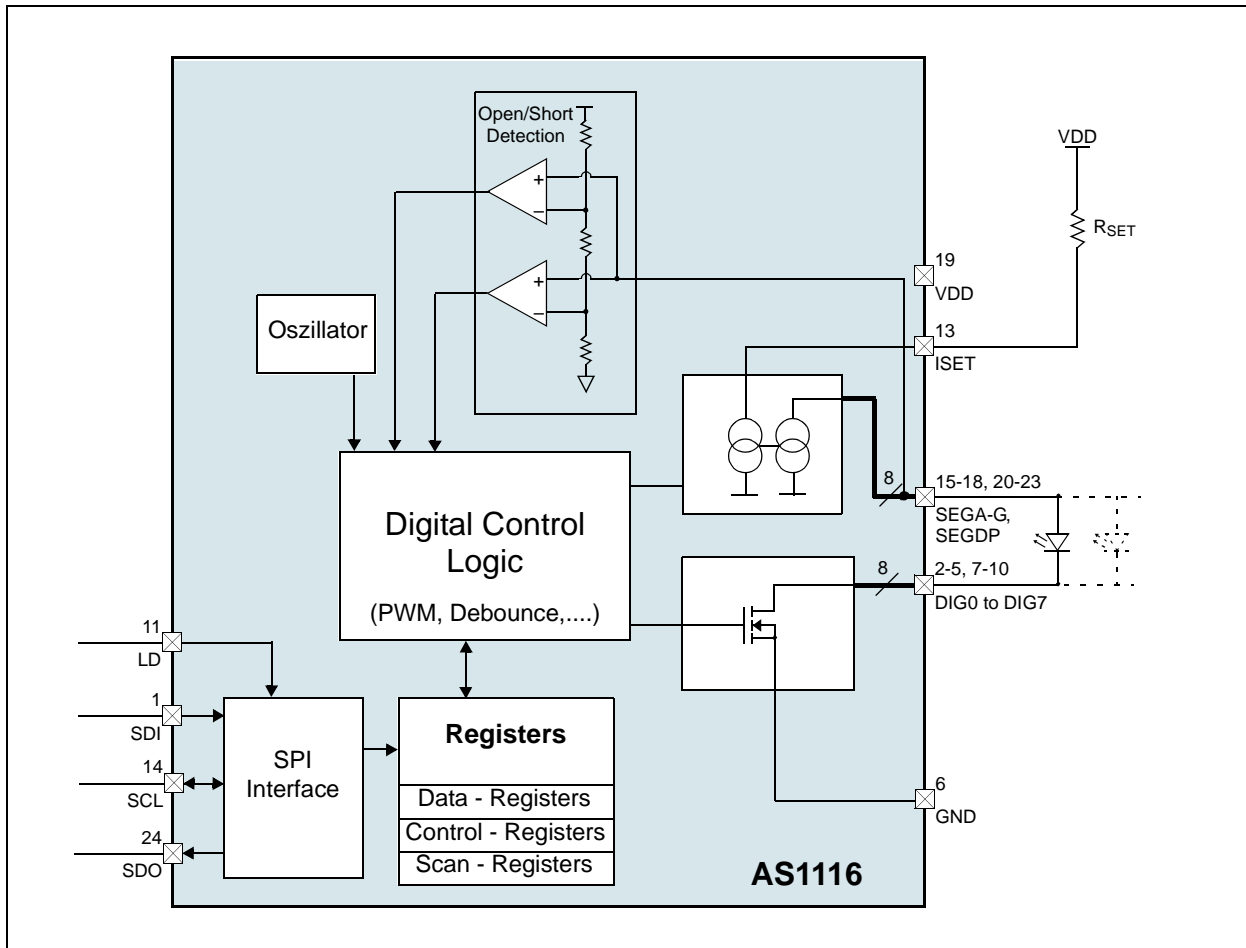
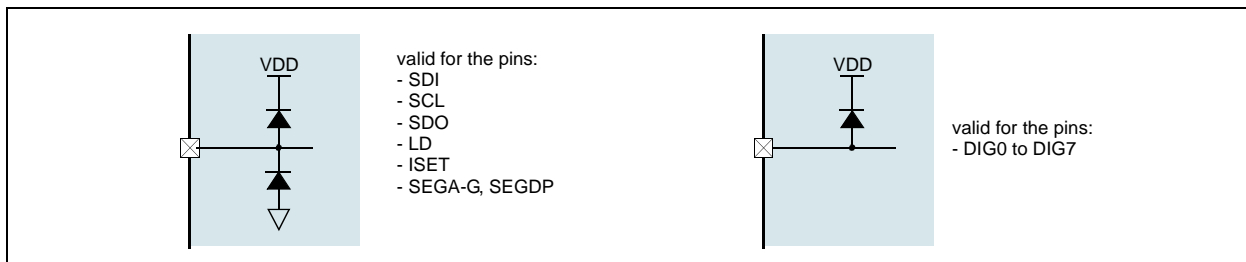


Figure 16. ESD Structure







## Serial Interface

The AS1116 contains a 16bit SPI interface to access the internal data and control registers of the device (see [Digit- and Control-Registers on page 11](#)). The SPI interface is driven with the rising edge of SCL. A falling edge on LD signal indicates the beginning of an access on the SPI interface, the rising edge on LD determines an access on SPI. An access must consist of exactly 16bits for write operation and 8bits for read operation. Timing restrictions on the SPI interface pins are defined in [Figure 19](#).

[Table 6](#) shows the structure of the 16bit command word for writing data. The bits D0 to D7 are the data information, bits D8 to D12 are the address bits, D13 is set to '0', bit D14 is defining the read (D14 = '1') or the write (D14 = '0') configuration and bit D15 is a don't care bit.

In [Table 7](#) on [page 11](#) the 8bit command word for the read operation can be found.

Bit D0 (write operation) or bit D8 (read operation) is the first bit to shift into the SPI interface after the falling edge of LD. Bit D15 is the last bit to write to SPI before rising edge of LD.

At a read operation an 8bit operation is executed (see [Figure 18](#)). At the first rising edge of SCL after the rising edge of LD D7 of addressed register is written to SDO pin. At the next rising edge of SCL D6 is written to SDO pin. LD must be kept high during reading data from a internal data or control register of AS1116.

Table 6. 16-Bit Serial Data Format

| D0  | D1 | D2 | D3 | D4 | D5 | D6 | D7   | D8 | D9 | D10 | D11 | D12 | D13 | D14 | D15   |  |  |  |   |     |   |
|-----|----|----|----|----|----|----|------|----|----|-----|-----|-----|-----|-----|---|--|--|--|---|-----|---|
| LSB |    |    |    |    |    |    | Data |    |    |     |     | MSB |     |     | Register Address (see <a href="#">Table 7</a> ) |  |  |  | 0 | R/W | X |

Figure 17. Write operation

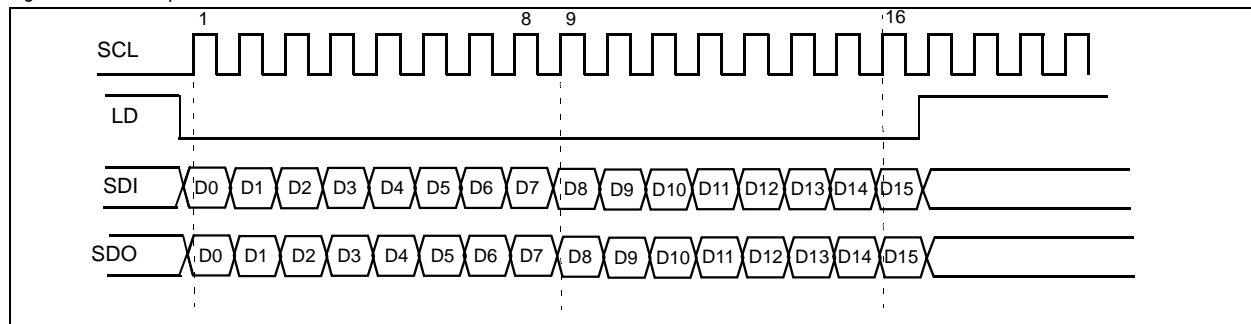


Figure 18. Read operation

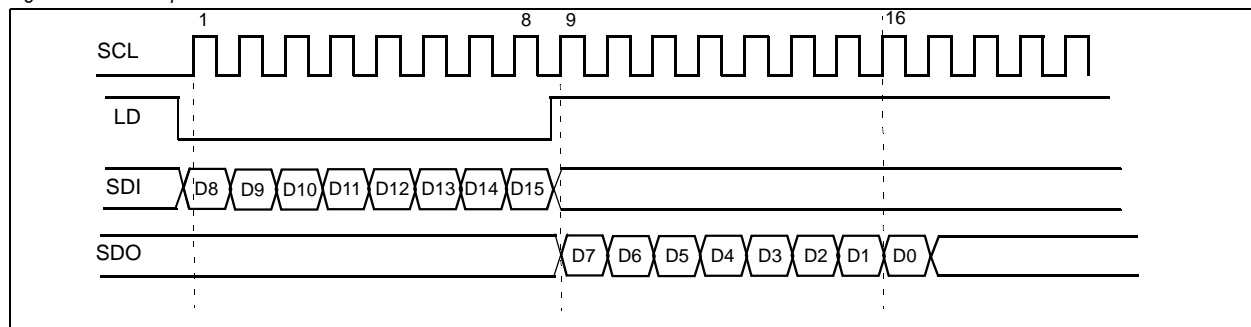
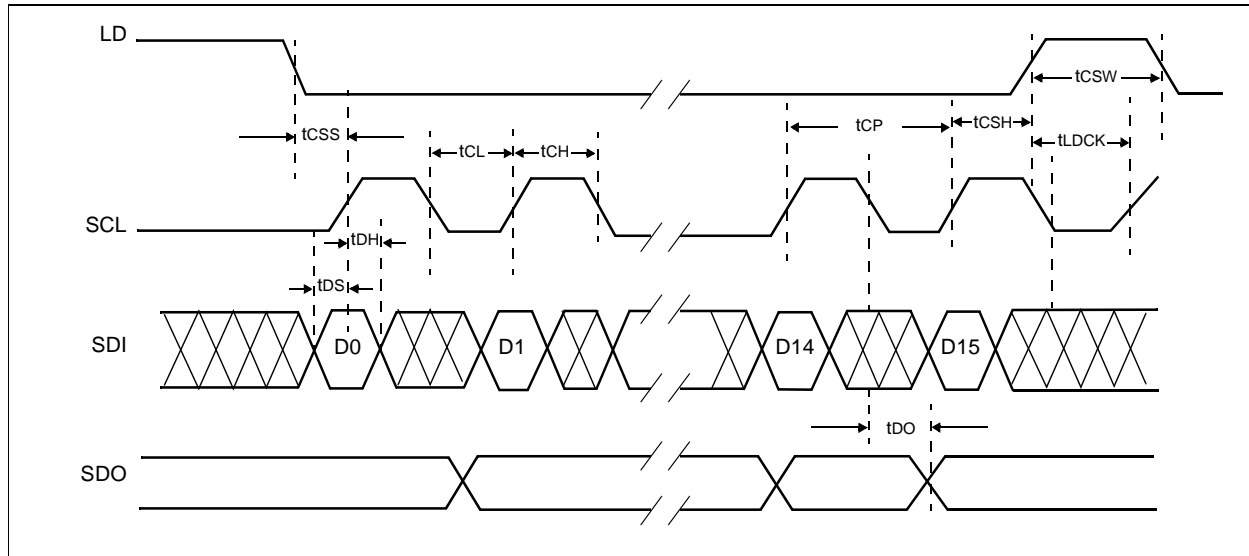




Figure 19. Interface Timing



## Initial Power-Up

On initial power-up, the AS1116 registers are reset to their default values, the display is blanked, and the device goes into shutdown mode. At this time, all registers should be programmed for normal operation.

**Note:** The default settings enable only scanning of one digit; the internal decoder is disabled and the Intensity Control Register (see page 15) is set to the minimum values.

## Shutdown Mode

The AS1116 devices feature a shutdown mode, where they consume only 200nA (typ) current. Shutdown mode is entered via a write to the Shutdown Register (see Table 8). For the AS1116, at that point, all segment current sources and digital drivers are switched off, so that all segments are blanked.

**Note:** During shutdown mode the Digit-Registers maintain their data.

Shutdown mode can either be used as a means to reduce power consumption or for generating a flashing display (repeatedly entering and leaving shutdown mode). For minimum supply current in shutdown mode, logic input should be at GND or VDD (CMOS logic level).

When entering or leaving shutdown mode, the Feature Register is reset to its default values (all 0s) when Shutdown Register bit D7 (page 12) = 0.

**Note:** When Shutdown Register bit D7 = 1, the Feature Register is left unchanged when entering or leaving shutdown mode. If the AS1116 is used with an external clock, Shutdown Register bit D7 should be set to 1 when writing to the Shutdown Register.



## Digit- and Control-Registers

The AS1116 devices contain 8 Digit-Registers, 11 control-registers and 8 diagnostic-registers, which are listed in [Table 7](#). All registers are selected using a 8-bit address word, and communication is done via the serial interface.

- Digit Registers – These registers are realized with an on-chip 64-bit memory. Each digit can be controlled directly without rewriting the whole register contents.
- Control Registers – These registers consist of decode mode, display intensity, number of scanned digits, shutdown, display test and features selection registers.

Table 7. Register Address Map

| Type                | Register            | Address |     |     |     |     |     |    |   |  | Page               |
|---------------------|---------------------|---------|-----|-----|-----|-----|-----|----|---|--|--------------------|
|                     |                     | D15     | D14 | D13 | D12 | D11 | D10 | D9 | D8  | D7:D0  |                    |
|                     | No-Op               | X       | 0   | 0   | 0   | 0   | 0   | 0  | 0   |  | <a href="#">16</a> |
| Digit Register      | Digit 0             | X       | 0   | 0   | 0   | 0   | 0   | 0  | 1   | (see <a href="#">Table 10</a> on page 12, <a href="#">Table 11</a> on page 13 and <a href="#">Table 12</a> on page 13) | N/A                |
|                     | Digit 1             | X       | 0   | 0   | 0   | 0   | 0   | 1  | 0   |  | N/A                |
|                     | Digit 2             | X       | 0   | 0   | 0   | 0   | 0   | 1  | 1   |  | N/A                |
|                     | Digit 3             | X       | 0   | 0   | 0   | 0   | 1   | 0  | 0   |  | N/A                |
|                     | Digit 4             | X       | 0   | 0   | 0   | 0   | 1   | 0  | 1   |  | N/A                |
|                     | Digit 5             | X       | 0   | 0   | 0   | 0   | 1   | 1  | 0   |  | N/A                |
|                     | Digit 6             | X       | 0   | 0   | 0   | 0   | 1   | 1  | 1   |  | N/A                |
|                     | Digit 7             | X       | 0   | 0   | 0   | 1   | 0   | 0  | 0   |  | N/A                |
| Control Register    | Decode-Mode         | X       | 0   | 0   | 0   | 1   | 0   | 0  | 1   | (see <a href="#">Table 9</a> on page 12)   | <a href="#">12</a> |
|                     | Global Intensity    | X       | 0   | 0   | 0   | 1   | 0   | 1  | 0   | (see <a href="#">Table 16</a> on page 15)  | <a href="#">15</a> |
|                     | Scan Limit          | X       | 0   | 0   | 0   | 1   | 0   | 1  | 1   | (see <a href="#">Table 18</a> on page 15)  | <a href="#">15</a> |
|                     | Shutdown            | X       | 0   | 0   | 0   | 1   | 1   | 0  | 0   | (see <a href="#">Table 8</a> on page 12)   | <a href="#">12</a> |
|                     | Not Used            | X       | 0   | 0   | 0   | 1   | 1   | 0  | 1   |  | N/A                |
|                     | Feature             | X       | 0/1 | 0   | 0   | 1   | 1   | 1  | 0   | (see <a href="#">Table 19</a> on page 16)  | <a href="#">16</a> |
|                     | Display Test Mode   | X       | 0   | 0   | 0   | 1   | 1   | 1  | 1   | (see <a href="#">Table 13</a> on page 14)  | <a href="#">12</a> |
|                     | DIG0:DIG1 Intensity | X       | 0   | 0   | 1   | 0   | 0   | 0  | 0   | (see <a href="#">Table 17</a> on page 15)  |                    |
|                     | DIG2:DIG3 Intensity | X       | 0   | 0   | 1   | 0   | 0   | 0  | 1   | (see <a href="#">Table 17</a> on page 15)  |                    |
|                     | DIG4:DIG5 Intensity | X       | 0   | 0   | 1   | 0   | 0   | 1  | 0   | (see <a href="#">Table 17</a> on page 15)  |                    |
| DIG6:DIG7 Intensity | X                   | 0       | 0   | 1   | 0   | 0   | 1   | 1  | (see <a href="#">Table 17</a> on page 15) |  |                    |
| Diagnostic Register | Diagnostic Digit 0  | X       | 1   | 0   | 1   | 0   | 1   | 0  | 0   |  | N/A                |
|                     | Diagnostic Digit 1  | X       | 1   | 0   | 1   | 0   | 1   | 0  | 1   |  | N/A                |
|                     | Diagnostic Digit 2  | X       | 1   | 0   | 1   | 0   | 1   | 1  | 0   |  | N/A                |
|                     | Diagnostic Digit 3  | X       | 1   | 0   | 1   | 0   | 1   | 1  | 1   |  | N/A                |
|                     | Diagnostic Digit 4  | X       | 1   | 0   | 1   | 1   | 0   | 0  | 0   |  | N/A                |
|                     | Diagnostic Digit 5  | X       | 1   | 0   | 1   | 1   | 0   | 0  | 1   |  | N/A                |
|                     | Diagnostic Digit 6  | X       | 1   | 0   | 1   | 1   | 0   | 1  | 0   |  | N/A                |
|                     | Diagnostic Digit 7  | X       | 1   | 0   | 1   | 1   | 0   | 1  | 1   |  | N/A                |

**Note:** Write operation: D14=0; Read operation: D14=1.



The Shutdown Register controls AS1116 shutdown mode.

Table 8. Shutdown Register Format (Address (HEX) = 0x0C)

| Mode   | HEX Code | Register Data |    |    |    |    |    |    |    |
|--|----------|---------------|----|----|----|----|----|----|----|
|  |          | D7            | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| Shutdown Mode, Reset Feature Register to Default Settings    | 0x00     | 0             | X  | X  | X  | X  | X  | X  | 0  |
| Shutdown Mode, Feature Register Unchanged                    | 0x80     | 1             | X  | X  | X  | X  | X  | X  | 0  |
| Normal Operation, Reset Feature Register to Default Settings | 0x01     | 0             | X  | X  | X  | X  | X  | X  | 1  |
| Normal Operation, Feature Register Unchanged                 | 0x81     | 1             | X  | X  | X  | X  | X  | X  | 1  |

### Decode Enable Register (0x09)

The Decode Enable Register sets the decode mode. BCD/HEX decoding (either BCD code – characters 0:9, E, H, L, P, and -, or HEX code – characters 0:9 and A:F) is selected by bit D2 (page 16) of the Feature Register. The Decode Enable Register is used to select the decode mode or no-decode for each digit. Each bit in the Decode Enable Register corresponds to its respective display digit (i.e., bit D0 corresponds to digit 0, bit D1 corresponds to digit 1 and so on). Table 10 lists some examples of the possible settings for the Decode Enable Register bits.

**Note:** A logic high enables decoding and a logic low bypasses the decoder altogether.

When decode mode is used, the decoder looks only at the lower-nibble (bits D3:D0) of the data in the Digit-Registers, disregarding bits D6:D4. Bit D7 sets the decimal point (SEG DP) independent of the decoder and is positive logic (bit D7 = 1 turns the decimal point on). Table 10 lists the code-B font; Table 11 lists the HEX font.

When no-decode mode is selected, data bits D7:D0 of the Digit-Registers correspond to the segment lines of the AS1116. Table 12 shows the 1:1 pairing of each data bit to the appropriate segment line.

Table 9. Decode Enable Register Format Examples

| Decode Mode  | HEX Code | Register Data |    |    |    |    |    |    |    |
|--|----------|---------------|----|----|----|----|----|----|----|
|  |          | D7            | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| No decode for digits 7:0   | 0x00     | 0             | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Code-B/HEX decode for digit 0. No decode for digits 7:1                | 0x01     | 0             | 0  | 0  | 0  | 0  | 0  | 0  | 1  |
| Code-B/HEX decode for digit 0:2. No decode for digits 7:3              | 0x07     | 0             | 0  | 0  | 0  | 0  | 1  | 1  | 1  |
| Code-B/HEX decode for digits 0:5. No decode for digits 7:6             | 0x3F     | 0             | 0  | 1  | 1  | 1  | 1  | 1  | 1  |
| Code-B/HEX decode for digits 0,2,5. No decode for digits 1, 3, 4, 6, 7 | 0x25     | 0             | 0  | 1  | 0  | 0  | 1  | 0  | 1  |

Table 10. Code-B Font

| Char-acter | Register Data |       |    |    |    |    | Char-acter | Register Data |        |    |    |    |    | Char-acter | Register Data |       |    |    |    |    |
|------------|---------------|-------|----|----|----|----|------------|---------------|--------|----|----|----|----|------------|---------------|-------|----|----|----|----|
|            | D7            | D6:D4 | D3 | D2 | D1 | D0 |            | D7            | D6: D4 | D3 | D2 | D1 | D0 |            | D7            | D6:D4 | D3 | D2 | D1 | D0 |
|            |               | X     | 0  | 0  | 0  | 0  |            |               | X      | 0  | 1  | 1  | 0  |            |               | X     | 1  | 1  | 0  | 0  |
|            |               | X     | 0  | 0  | 0  | 1  |            |               | X      | 0  | 1  | 1  | 1  |            |               | X     | 1  | 1  | 0  | 1  |
|            |               | X     | 0  | 0  | 1  | 0  |            |               | X      | 1  | 0  | 0  | 0  |            |               | X     | 1  | 1  | 1  | 0  |
|            |               | X     | 0  | 0  | 1  | 1  |            |               | X      | 1  | 0  | 0  | 1  |            |               | X     | 1  | 1  | 1  | 1  |
|            |               | X     | 0  | 1  | 0  | 0  |            |               | X      | 1  | 0  | 1  | 0  |            | 1*            | X     | X  | X  | X  | X  |
|            |               | X     | 0  | 1  | 0  | 1  |            |               | X      | 1  | 0  | 1  | 1  |            |               |       |    |    |    |    |

\* The decimal point can be enabled with every character by setting bit D7 = 1.



Table 11. HEX Font

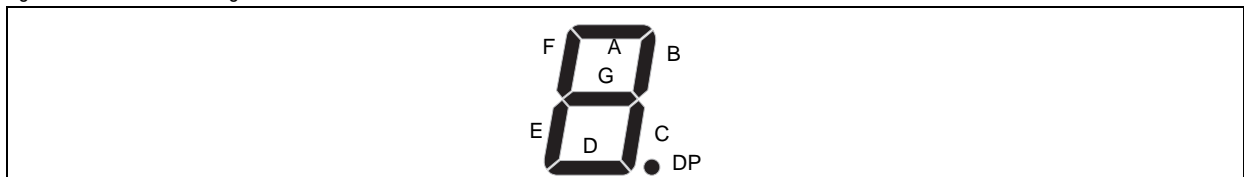
| Char-acter | Register Data |       |    |    |    |    | Char-acter | Register Data |        |    |    |    |    | Char-acter | Register Data |       |    |    |    |    |
|------------|---------------|-------|----|----|----|----|------------|---------------|--------|----|----|----|----|------------|---------------|-------|----|----|----|----|
|            | D7            | D6:D4 | D3 | D2 | D1 | D0 |            | D7            | D6: D4 | D3 | D2 | D1 | D0 |            | D7            | D6:D4 | D3 | D2 | D1 | D0 |
|            |               | X     | 0  | 0  | 0  | 0  |            |               | X      | 0  | 1  | 1  | 0  |            |               | X     | 1  | 1  | 0  | 0  |
|            |               | X     | 0  | 0  | 0  | 1  |            |               | X      | 0  | 1  | 1  | 1  |            |               | X     | 1  | 1  | 0  | 1  |
|            |               | X     | 0  | 0  | 1  | 0  |            |               | X      | 1  | 0  | 0  | 0  |            |               | X     | 1  | 1  | 1  | 0  |
|            |               | X     | 0  | 0  | 1  | 1  |            |               | X      | 1  | 0  | 0  | 1  |            |               | X     | 1  | 1  | 1  | 1  |
|            |               | X     | 0  | 1  | 0  | 0  |            |               | X      | 1  | 0  | 1  | 0  |            | 1*            | X     | X  | X  | X  | X  |
|            |               | X     | 0  | 1  | 0  | 1  |            |               | X      | 1  | 0  | 1  | 1  |            |               |       |    |    |    |    |

\* The decimal point can be enabled with every character by setting bit D7 = 1.

Table 12. No-Decode Mode Data Bits and Corresponding Segment Lines

|                            | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----------------------------|----|----|----|----|----|----|----|----|
| Corresponding Segment Line | DP | A  | B  | C  | D  | E  | F  | G  |

Figure 20. Standard 7-Segment LED





## Display-Test Mode

The AS1116 can detect open or shorted LEDs. Readout of either open LEDs (D2=1) or short LEDs (D1=1) is possible, as well as a OR relation of open and short (D1=D2=1). After a diagnostic run bit D4 can be read to clarify if an error occurred before reading out detailed diagnostic data.

**Note:** All settings of the digit- and control-registers are maintained.

Table 13. Testmode Register Summary

| D7 | D6         | D5        | D4         | D3       | D2       | D1        | D0        |
|----|------------|-----------|------------|----------|----------|-----------|-----------|
| X  | REXT_short | REXT_open | LED_global | LED_test | LED_open | LED_short | DISP_test |

Table 14. Testmode Register Bit Description (Address (HEX) = 0x0F)

| Addr: 0x0F |            | Address |        |   |  |
|------------|------------|---------|--------|---|--|
| Bit        | Bit Name   | Default | Access | D7:D0   |  |
| D0         | DISP_test  | 0       | W      | Optical display test. (Testmode for external visual test.)<br>0: Normal operation; 1: Run display test (All digits are tested independently from scan limit & shutdown register.) |  |
| D1         | LED_short  | 0       | W      | Starts a test for shorted LEDs. (Can be set together with D2)<br>0: Normal operation; 1: Activate testmode  |  |
| D2         | LED_open   | 0       | W      | Starts a test for open LEDs. (Can be set together with D1)<br>0: Normal operation; 1: Activate testmode   |  |
| D3         | LED_test   | 0       | R      | Indicates an ongoing open/short LED test<br>0: No ongoing LED test; 1: LED test in progress   |  |
| D4         | LED_global | 0       | R      | Indicates that the last open/short LED test has detected an error<br>0: No error detected; 1: Error detected  |  |
| D5         | REXT_open  | 0       | R      | Checks if external resistor REXT is open<br>0: REXT correct; 1: REXT is open  |  |
| D6         | REXT_short | 0       | R      | Checks if external resistor REXT is shorted<br>0: REXT correct; 1: REXT is shorted  |  |
| D7         |            | 0       | -      | Not used  |  |

## LED Diagnostic Registers

These eight registers contain the result of the LED open/short test for the individual LED of each digit.

Table 15. LED Diagnostic Register Address

| Register<br>HEX<br>Address | Digit | Segment |    |    |    |    |    |    |    | Register<br>HEX<br>Address | Digit | Segment |    |    |    |    |    |    |    |
|----------------------------|-------|---------|----|----|----|----|----|----|----|----------------------------|-------|---------|----|----|----|----|----|----|----|
|                            |       | D7      | D6 | D5 | D4 | D3 | D2 | D1 | D0 |                            |       | D7      | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| 0x14                       | DIG0  | DP      | A  | B  | C  | D  | E  | F  | G  | 0x18                       | DIG4  | DP      | A  | B  | C  | D  | E  | F  | G  |
| 0x15                       | DIG1  |         |    |    |    |    |    |    |    | 0x19                       | DIG5  |         |    |    |    |    |    |    |    |
| 0x16                       | DIG2  |         |    |    |    |    |    |    |    | 0x1A                       | DIG6  |         |    |    |    |    |    |    |    |
| 0x17                       | DIG3  |         |    |    |    |    |    |    |    | 0x1B                       | DIG7  |         |    |    |    |    |    |    |    |
|                            |       |         |    |    |    |    |    |    |    |                            |       |         |    |    |    |    |    |    |    |

**Note:** If more than 2 shorts occur in the LED array, detection of individual LED fault could become limited to blocs.



### Intensity Control Register (0x0A)

The brightness of the display can be controlled by digital means using the Intensity Control Registers and by analog means using RSET (see [Selecting RSET Resistor Value and Using External Drivers on page 17](#)). The intensity can be controlled globally for all digits, or for each digit individually. The global intensity command will write intensity data to all four individual brightness registers, while the individual intensity command will only write to the associated individual intensity register.

Display brightness is controlled by an integrated pulse-width modulator which is controlled by the lower-nibble of the Intensity Control Register. The modulator scales the average segment-current in 16 steps from a maximum of 15/16 down to 1/16 of the peak current set by RSET.

Table 16. Intensity Register Format

| Duty Cycle    | HEX Code | Register Data |    |    |     | Duty Cycle     | HEX Code | Register Data |    |    |     |
|---------------|----------|---------------|----|----|-----|----------------|----------|---------------|----|----|-----|
|               |          | MSB           | D2 | D1 | LSB |                |          | MSB           | D2 | D1 | LSB |
| 1/16 (min on) | 0xX0     | 0             | 0  | 0  | 0   | 9/16           | 0xX8     | 1             | 0  | 0  | 0   |
| 2/16          | 0xX1     | 0             | 0  | 0  | 1   | 10/16          | 0xX9     | 1             | 0  | 0  | 1   |
| 3/16          | 0xX2     | 0             | 0  | 1  | 0   | 11/16          | 0xXA     | 1             | 0  | 1  | 0   |
| 4/16          | 0xX3     | 0             | 0  | 1  | 1   | 12/16          | 0xXB     | 1             | 0  | 1  | 1   |
| 5/16          | 0xX4     | 0             | 1  | 0  | 0   | 13/16          | 0xXC     | 1             | 1  | 0  | 0   |
| 6/16          | 0xX5     | 0             | 1  | 0  | 1   | 14/16          | 0xDD     | 1             | 1  | 0  | 1   |
| 7/16          | 0xX6     | 0             | 1  | 1  | 0   | 15/16          | 0xXE     | 1             | 1  | 1  | 0   |
| 8/16          | 0xX7     | 0             | 1  | 1  | 1   | 15/16 (max on) | 0xFF     | 1             | 1  | 1  | 1   |

Table 17. Intensity Register Address

| Register HEX Address | Type   | Register Data     |                   |
|----------------------|--------|-------------------|-------------------|
|                      |        | D7:D4             | D3:D0             |
| 0x0A                 | Global | X                 | Global Intensity  |
| 0x10                 | Digit  | Digit 1 Intensity | Digit 0 Intensity |
| 0x11                 | Digit  | Digit 3 Intensity | Digit 2 Intensity |
| 0x12                 | Digit  | Digit 5 Intensity | Digit 4 Intensity |
| 0x13                 | Digit  | Digit 7 Intensity | Digit 6 Intensity |

### Scan-Limit Register (0x0B)

The Scan-Limit Register controls which of the digits are to be displayed. When all 8 digits are to be displayed, the update frequency is typically 0.8kHz. If the number of digits displayed is reduced, the update frequency is increased. The frequency can be calculated using  $8f_{OSC}/N$ , where N is the number of digits. Since the number of displayed digits influences the brightness, RSET should be adjusted accordingly.

**Note:** To avoid differences in brightness this register should not be used to blank parts of the display (leading zeros).

Table 18. Scan-Limit Register Format (Address (HEX) = 0x0B)

| Scan Limit           | HEX Code | Register Data |    |    |    | Scan Limit         | HEX Code | Register Data |    |    |    |
|----------------------|----------|---------------|----|----|----|--------------------|----------|---------------|----|----|----|
|                      |          | D7:D3         | D2 | D1 | D0 |                    |          | D7:D3         | D2 | D1 | D0 |
| Display digit 0 only | 0xX0     | X             | 0  | 0  | 0  | Display digits 0:4 | 0xX4     | X             | 1  | 0  | 0  |
| Display digits 0:1   | 0xX1     | X             | 0  | 0  | 1  | Display digits 0:5 | 0xX5     | X             | 1  | 0  | 1  |
| Display digits 0:2   | 0xX2     | X             | 0  | 1  | 0  | Display digits 0:6 | 0xX6     | X             | 1  | 1  | 0  |
| Display digits 0:3   | 0xX3     | X             | 0  | 1  | 1  | Display digits 0:7 | 0xX7     | X             | 1  | 1  | 1  |



### Feature Register (0x0E)

The Feature Register is used for enabling various features including switching the device into external clock mode, applying an external reset, selecting code-B or HEX decoding, enabling or disabling blinking, enabling or disabling the SPI-compatible interface, setting the blinking rate, and resetting the blink timing.

**Note:** At power-up the Feature Register is initialized to 0.

Table 19. Feature Register Summary

| D7          | D6   | D5             | D4       | D3 | D2         | D1      | D0     |
|-------------|------|----------------|----------|----|------------|---------|--------|
| blink_start | sync | blink_freq_sel | blink_en | NU | decode_sel | reg_res | clk_en |

Table 20. Feature Register Bit Descriptions (Address (HEX) = 0xXE)

| Addr: 0xXE                                    |                | Feature Register |        |   |
|---|----------------|------------------|--------|---|
| Enables and disables various device features. |                |                  |        |   |
| Bit   | Bit Name       | Default          | Access | Bit Description   |
| D0  | clk_en         | 0                | R/W    | External clock active.<br>0 = Internal oscillator is used for system clock.<br>1 = Pin CLK of the serial interface operates as system clock input.  |
| D1  | reg_res        | 0                | R/W    | Resets all control registers except the Feature Register.<br>0 = Reset Disabled. Normal operation.<br>1 = All control registers are reset to default state (except the Feature Register) identically after power-up.<br><b>Note:</b> The Digit Registers maintain their data. |
| D2  | decode_sel     | 0                | R/W    | Selects display decoding for the selected digits (Table 9 on page 12).<br>0 = Enable Code-B decoding (see Table 10 on page 12).<br>1 = Enable HEX decoding (see Table 11 on page 13).   |
| D3  | NU             |                  |        | Not used  |
| D4  | blink_en       | 0                | R/W    | Enables blinking.<br>0 = Disable blinking. 1 = Enable blinking.   |
| D5  | blink_freq_sel | 0                | R/W    | Sets blink with low frequency (with the internal oscillator enabled):<br>0 = Blink period typically is 1 second (0.5s on, 0.5s off).<br>1 = Blink period is 2 seconds (1s on, 1s off).  |
| D6  | sync           | 0                | R/W    | Synchronizes blinking on the rising edge of pin LD. The multiplex and blink timing counter is cleared on the rising edge of pin LD. By setting this bit in multiple devices, the blink timing can be synchronized across all the devices.                                     |
| D7  | blink_start    | 0                | R/W    | Start Blinking with display enabled phase. When bit D4 (blink_en) is set, bit D7 determines how blinking starts.<br>0 = Blinking starts with the display turned off.<br>1 = Blinking starts with the display turned on.   |

### No-Op Register (0xX0)

The No-Op Register is used when multiple AS1116 devices are cascaded in order to support displays with more than 8 digits. The cascading must be done in such a way that all SDO pins are connected to SDI of the next AS1116 (see Figure 21 on page 18). The LD and SCL signals are connected to all devices.

For example, if five devices are cascaded, in order to perform a write operation to the fifth device, the write-command must be followed by four no-operation commands. When the LD signal goes high, all shift registers are latched. The first four devices will receive no-operation commands and only the fifth device will receive the intended operation command, and subsequently update its register.





## 9 Typical Application

### Selecting R<sub>SET</sub> Resistor Value and Using External Drivers

Brightness of the display segments is controlled via R<sub>SET</sub>. The current that flows between V<sub>DD</sub> and I<sub>SET</sub> defines the current that flows through the LEDs.

Segment current is about 200 times the current in I<sub>SET</sub>. Typical values for R<sub>SET</sub> for different segment currents, operating voltages, and LED voltage drop (V<sub>LED</sub>) are given in [Table 21](#) & [Table 22](#). The maximum current the AS1116 can drive is 47mA. If higher currents are needed, external drivers must be used, in which case it is no longer necessary that the devices drive high currents.

**Note:** The display brightness can also be logically controlled ([see Intensity Control Register \(0x0A\) on page 15](#)).

Table 21. R<sub>SET</sub> vs. Segment Current and LED Forward Voltage, V<sub>DD</sub> = 2.7V & 3.3V & 3.6V

| I <sub>SEG</sub> (mA) | V <sub>LED</sub>       |        |                        | V <sub>LED</sub> |        |        |                        | V <sub>LED</sub> |         |       |        |        |
|-----------------------|------------------------|--------|------------------------|------------------|--------|--------|------------------------|------------------|---------|-------|--------|--------|
|                       | 1.5V                   | 2.0V   |                        | 1.5V             | 2.0V   | 2.5V   |                        | 1.5V             | 2.0V    | 2.5V  | 3.0V   |        |
| 40                    | V <sub>DD</sub> = 2.7V | 5kΩ    | V <sub>DD</sub> = 3.3V | 6.7kΩ            | 6.4kΩ  | 5.7kΩ  | V <sub>DD</sub> = 3.6V | 7.5kΩ            | 7.2kΩ   | 6.6kΩ | 5.5kΩ  |        |
| 30                    |                        | 6.9kΩ  |                        | 5.9kΩ            | 9.1kΩ  | 8.8kΩ  |                        | 8.1kΩ            | 10.18kΩ | 9.8kΩ | 9.2kΩ  | 7.5kΩ  |
| 20                    |                        | 10.7kΩ |                        | 9.6kΩ            | 13.9kΩ | 13.3kΩ |                        | 12.6kΩ           | 15.6kΩ  | 15kΩ  | 14.3kΩ | 13kΩ   |
| 10                    |                        | 22.2kΩ |                        | 20.7kΩ           | 28.8kΩ | 27.7kΩ |                        | 26kΩ             | 31.9kΩ  | 31kΩ  | 29.5kΩ | 27.3kΩ |

Table 22. R<sub>SET</sub> vs. Segment Current and LED Forward Voltage, V<sub>DD</sub> = 4.0V & 5.0V

| I <sub>SEG</sub> (mA) | V <sub>LED</sub>       |         |        |        |        |        | V <sub>LED</sub>       |         |         |         |         |        |        |
|-----------------------|------------------------|---------|--------|--------|--------|--------|------------------------|---------|---------|---------|---------|--------|--------|
|                       | 1.5V                   | 2.0V    | 2.5V   | 3.0V   | 3.5V   |        | 1.5V                   | 2.0V    | 2.5V    | 3.0V    | 3.5V    | 4.0V   |        |
| 40                    | V <sub>DD</sub> = 4.0V | 8.6kΩ   | 8.3kΩ  | 7.9kΩ  | 7.6kΩ  | 5.2kΩ  | V <sub>DD</sub> = 5.0V | 11.35kΩ | 11.12kΩ | 10.84kΩ | 10.49kΩ | 10.2kΩ | 9.9kΩ  |
| 30                    |                        | 11.6kΩ  | 11.2kΩ | 10.8kΩ | 9.9kΩ  | 7.8kΩ  |                        | 15.4kΩ  | 15.1kΩ  | 14.7kΩ  | 14.4kΩ  | 13.6kΩ | 13.1kΩ |
| 20                    |                        | 17.7kΩ  | 17.3kΩ | 16.6kΩ | 15.6kΩ | 13.6kΩ |                        | 23.6kΩ  | 23.1kΩ  | 22.6kΩ  | 22kΩ    | 21.1kΩ | 20.2kΩ |
| 10                    |                        | 36.89kΩ | 35.7kΩ | 34.5kΩ | 32.5kΩ | 29.1kΩ |                        | 48.9kΩ  | 47.8kΩ  | 46.9kΩ  | 45.4kΩ  | 43.8kΩ | 42kΩ   |

### Calculating Power Dissipation

The upper limit for power dissipation (PD) for the AS1116 is determined from the following equation:

$$PD = (V_{DD} \times 5mA) + (V_{DD} - V_{LED})(DUTY \times I_{SEG} \times N) \quad (EQ 1)$$

#### Where:

V<sub>DD</sub> is the supply voltage.

DUTY is the duty cycle set by intensity register ([page 15](#)).

N is the number of segments driven (worst case is 8)

V<sub>LED</sub> is the LED forward voltage

I<sub>SEG</sub> = segment current set by R<sub>SET</sub>

#### Dissipation Example:

$$I_{SEG} = 40mA, N = 8, DUTY = 15/16, V_{LED} = 2.2V \text{ at } 40mA, V_{DD} = 5V \quad (EQ 2)$$

$$PD = 5V(5mA) + (5V - 2.2V)(15/16 \times 40mA \times 8) = 0.865W \quad (EQ 3)$$

Thus, for a QSOP-24 package  $\Theta_{JA} = +88^\circ C/W$ , the maximum allowed T<sub>AMB</sub> is given by:

$$T_{J,MAX} = T_{AMB} + PD \times \Theta_{JA} = 150^\circ C = T_{AMB} + 0.865W \times 88^\circ C/W \quad (EQ 4)$$

In this example the maximum ambient temperature must stay below 73.88°C.



## 8x8 Dot Matrix Mode

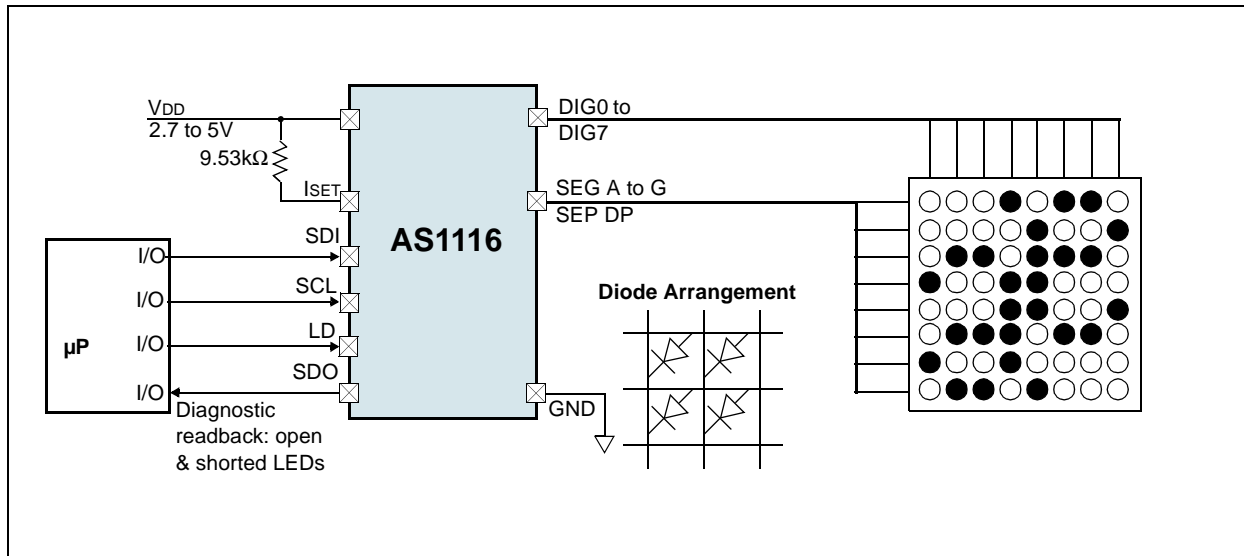
The application example in [Figure 21](#) shows the AS1116 in the 8x8 LED dot matrix mode.

The LED columns have common cathodes and are connected to the DIG0:7 outputs. The rows are connected to the segment drivers. Each of the 64 LEDs can be addressed separately. The columns are selected via the digits as listed in [Table 7 on page 11](#).

The Decode Enable Register ([see page 12](#)) must be set to '00000000' as described in [Table 9 on page 12](#). Single LEDs in a column can be addressed as described in [Table 12 on page 13](#), where bit D0 corresponds to segment G and bit D7 corresponds to segment DP.

**Note:** For a multiple-digit dot matrix, multiple AS1116 devices can be cascaded easily.

Figure 21. Application Example as LED Dot Matrix Driver



## Supply Bypassing and Wiring

In order to achieve optimal performance the AS1116 should be placed very close to the LED display to minimize effects of electromagnetic interference and wiring inductance.

Furthermore, it is recommended to connect a 10µF electrolytic and a 0.1µF ceramic capacitor between pins VDD and GND to avoid power supply ripple ([see Figure 21 on page 18](#)).



## 10 Package Drawings and Markings

Figure 22. QSOP-24 Marking

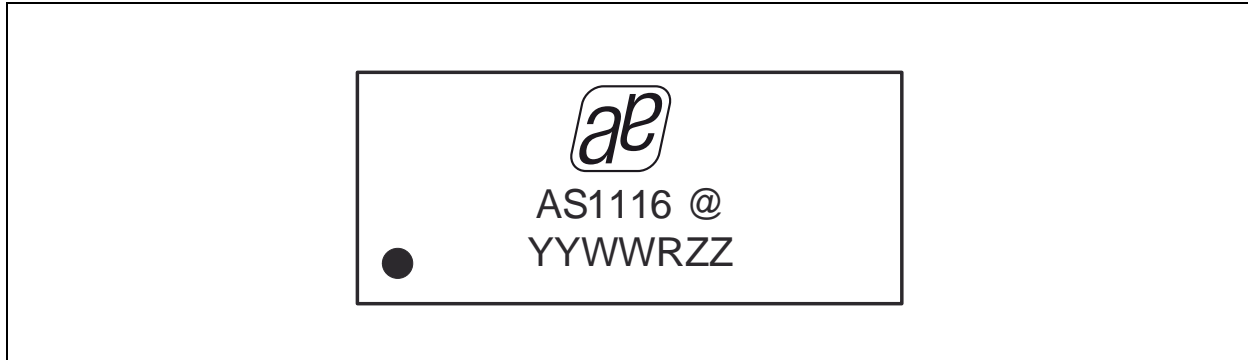


Figure 23. TQFN(4x4)-24 Marking

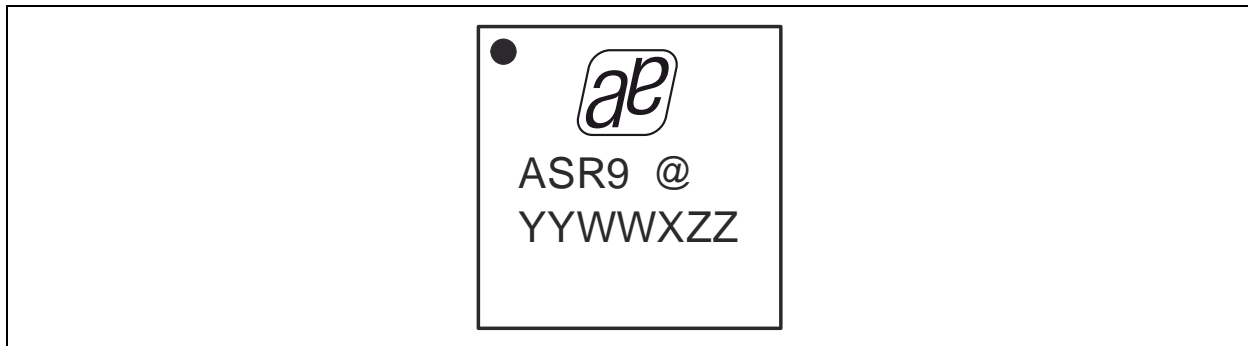
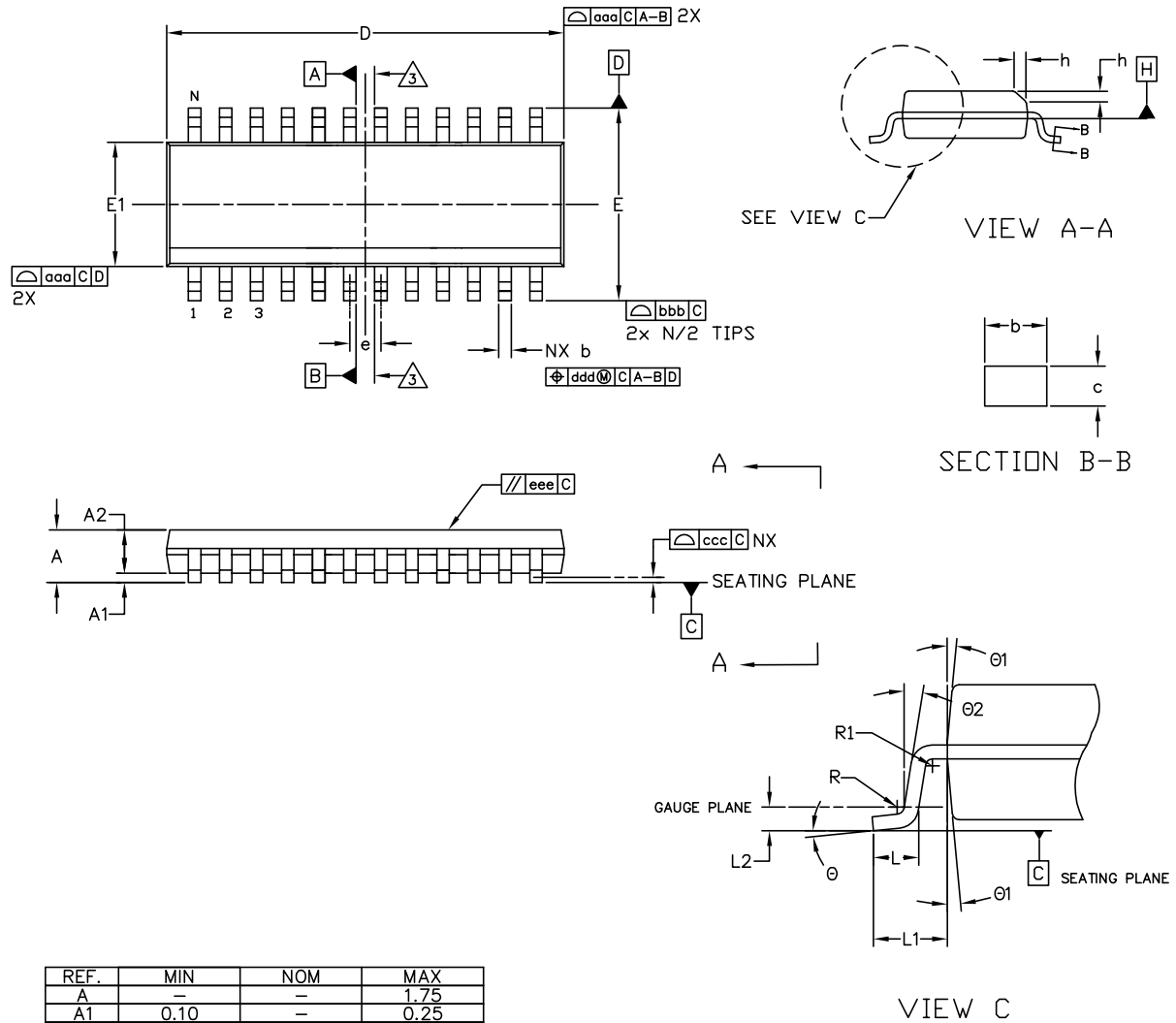


Table 23. Packaging Code

| YY                 | WW                 | R / X            | ZZ                              | AS1116 / ASR9  | @                 |
|--------------------|--------------------|------------------|---------------------------------|----------------|-------------------|
| manufacturing year | manufacturing week | plant identifier | free choice / traceability code | marketing code | sublot identifier |



Figure 24. QSOP-24 Package



| REF.   | MIN  | NOM       | MAX  |
|--------|------|-----------|------|
| A      | —    | —         | 1.75 |
| A1     | 0.10 | —         | 0.25 |
| A2     | 1.24 | —         | —    |
| b      | 0.20 | —         | 0.30 |
| c      | 0.15 | —         | 0.25 |
| D      | —    | 8.66 BSC  | —    |
| E      | —    | 6.00 BSC  | —    |
| E1     | —    | 3.91 BSC  | —    |
| e      | —    | 0.635 BSC | —    |
| L      | 0.41 | —         | 1.27 |
| L1     | —    | 1.04 REF  | —    |
| L2     | —    | 0.25 BSC  | —    |
| R      | 0.08 | —         | —    |
| R1     | 0.08 | —         | —    |
| h      | 0.25 | —         | 0.51 |
| theta  | 0°   | —         | 8°   |
| theta1 | 5°   | —         | 15°  |
| theta2 | 0°   | —         | —    |
| aaa    | —    | 0.10      | —    |
| bbb    | —    | 0.20      | —    |
| ccc    | —    | 0.10      | —    |
| ddd    | —    | 0.18      | —    |
| eee    | —    | 0.10      | —    |
| fff    | —    | 0.15      | —    |
| N      | —    | 24        | —    |

NOTE:

1. DIMENSIONS & TOLERANCEING CONFIRM TO ASME Y14.5M-1994.
  2. ALL DIMENSIONS ARE IN MILLIMETERS. ANGELS ARE IN DEGREES.
- △ DATUMS A & B TO BE DETERMINED AT DATUM H.







## 11 Ordering Information

The devices are available as the standard products shown in [Table 24](#).

Table 24. Ordering Information

| Ordering Code | Marking | Description                                 | Delivery Form | Package      |
|---------------|---------|---|---------------|--------------|
| AS1116-BSSST  | AS1116  | 64 LED Driver with Detailed Error Detection | Tape and Reel | QSOP-24      |
| AS1116-BQFT   | ASR9    | 64 LED Driver with Detailed Error Detection | Tape and Reel | TQFN(4x4)-24 |

**Note:** All products are RoHS compliant and ams green.  
Buy our products or get free samples online at ICdirect: <http://www.ams.com/ICdirect>

Technical Support is found at <http://www.ams.com/Technical-Support>

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