

# ***AN-1582 LM27965 Dual Display White LED Driver with I2C Compatible Brightness Control***

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## **ABSTRACT**

This application note describes how to operate the LM27965 Evaluation Module.

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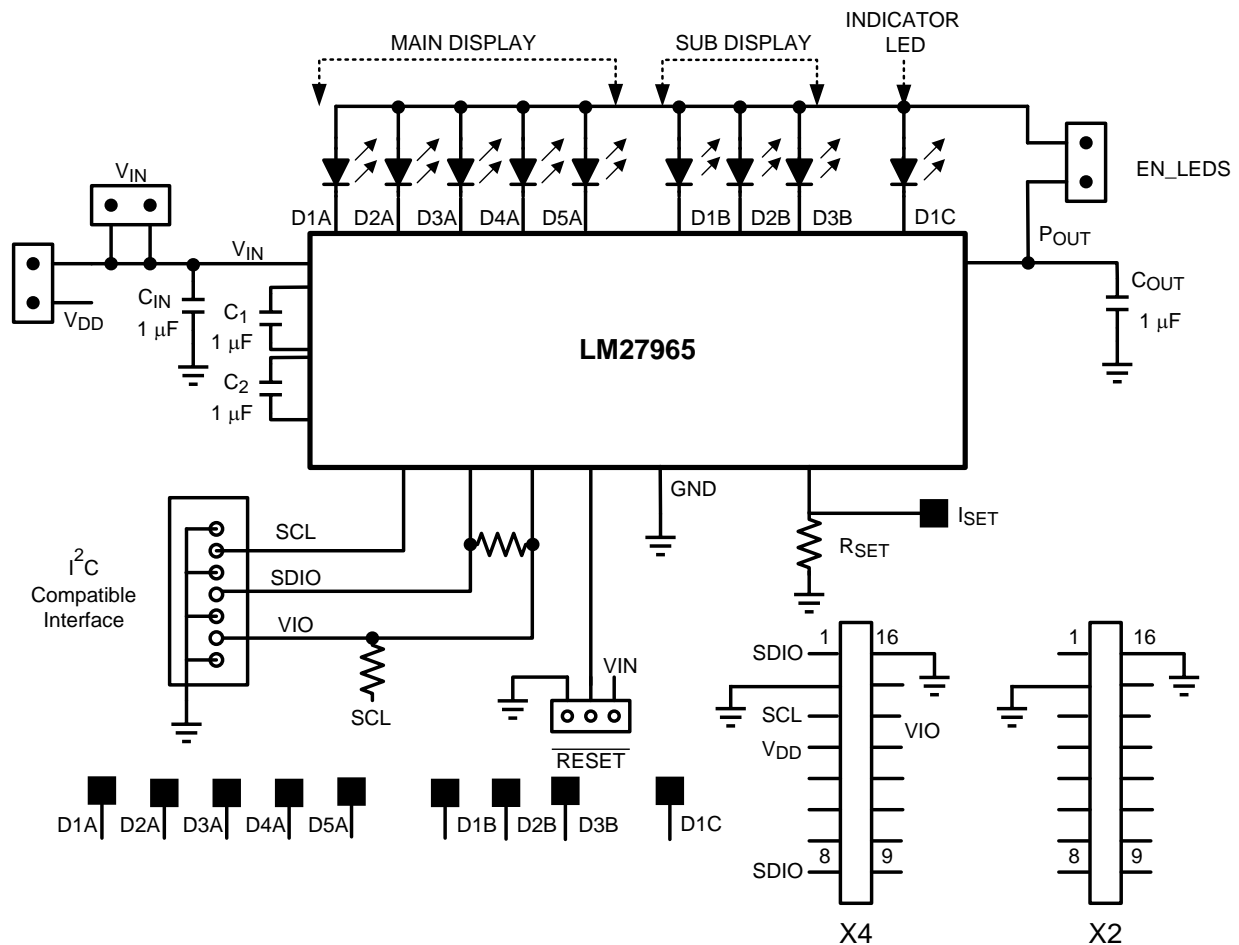
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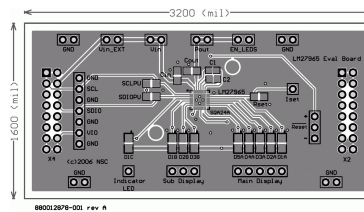
## 1 Schematic



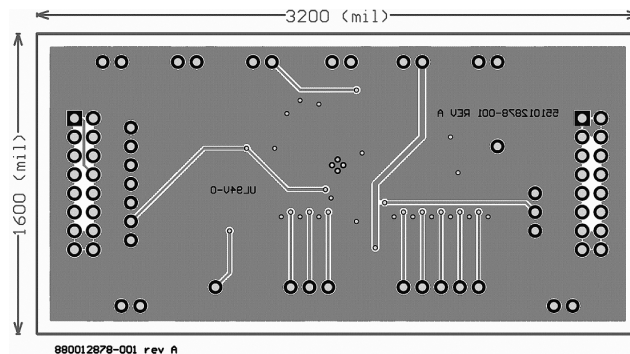
## 2 Bill of Materials

| Component Symbol                | Value     | Package        | Manufacturer | Part #             |
|---------------------------------|-----------|----------------|--------------|--------------------|
| LM27965                         | –         | SQA24<br>LLP24 | TI           | LM27965SDX         |
| LM27965 Evaluation Board        | –         | –              | –            | 551012878-001 RevA |
| D1A-D5A, D1B-D3B                | White LED | –              | Nichia       | LM_M67C            |
| D1c                             | Blue LED  | –              | Nichia       | LB_M573            |
| C <sub>IN</sub>                 | 1µF, 10V  | 0603           | TDK          | C1608X5R1A105K     |
| C <sub>OUT</sub>                | 1µF, 10V  | 0603           | TDK          | C1608X5R1A105K     |
| C <sub>1</sub> , C <sub>2</sub> | 1µF, 10V  | 0603           | TDK          | C1608X5R1A105K     |
| R <sub>SET</sub>                | 16.9kΩ    | 0603           | Vishay Dale  | CRCW060316K9FKEA   |

### 3 LM27965 Evaluation Board Layout



**Figure 1. Top Layer**



**Figure 2. Bottom Layer (unmirrored)**

## 4 Board Operation

### 4.1 Basic Connections

To operate the LM27965 Dual Display White LED Driver with I<sup>2</sup>C Compatible Brightness Control, connect a supply voltage (2.7V-5.5V) between board connectors VIN and GND and attach an I<sup>2</sup>C interface using one of the methods described in the [Section 4.2](#) of this document.

#### Default Jumper Connections:

- **RESET:** Connects the “+” post to the middle post of the RESET header strip. This connects VIN to the RESET pin of the LM27965, enabling the part.
- **EN\_LEDS:** This connects POUT to the anodes of the LEDs.
- **Vin\_EXT:** Connects the adjustable voltage supply of the USB Docking board to the VIN of the LM27965. If the USB board is not used, this jumper does not need to be placed. If the USB Docking board is going to be used for the I<sup>2</sup>C interface, but not for VIN, make sure the Vin\_EXT jumper is removed.

With the default jumper connections made, the board will be ready to operate once an input voltage and an I<sup>2</sup>C interface generator (external or USB docking board) are connected.

### 4.2 External Control Interface Connection

The LM27965 Evaluation Board provides two ways to connect an I<sup>2</sup>C compatible interface to the LM27965 IC. The first method to connect the interface is through a set of connectors on the bottom of the evaluation board that allow the board to plug into TI's USB interface board directly. The second method of interface connection is through a header strip located on the left hand side of the evaluation board. There are pins available to connect VIO (controller reference voltage), SCL (Interface Clock Line), and SDIO (Interface Data Line) each separated by a ground pin. The evaluation board has two external pull-ups that connect both SCL and SDIO to VIO to compliment the open drain inputs found on the LM27965. [Section 4.3.1.5](#) describes the internal registers and I<sup>2</sup>C compatible interface in greater detail.

### 4.3 Operation Description

#### 4.3.1 I<sup>2</sup>C Compatible Interface

##### 4.3.1.1 Data Validity

The data on SDIO line must be stable during the HIGH period of the clock signal (SCL). In other words, state of the data line can only be changed when CLK is LOW.

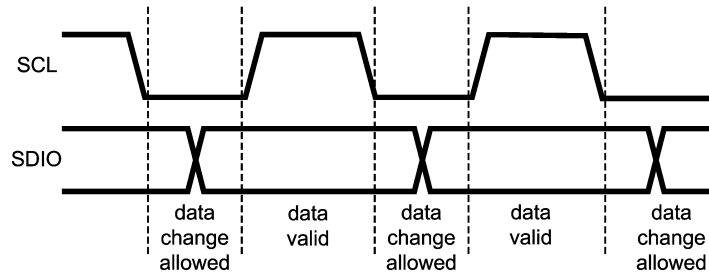


Figure 3. Data Validity Diagram

A pull-up resistor between VIO and SDIO must be greater than  $[(VIO - V_{OL}) / 3mA]$  to meet the  $V_{OL}$  requirement on SDIO. Using a larger pull-up resistor results in lower switching current with slower edges, while using a smaller pull-up results in higher switching currents with faster edges.

##### 4.3.1.2 Start and Stop Conditions

START and STOP conditions classify the beginning and the end of the I<sup>2</sup>C session. A START condition is defined as SDIO signal transitioning from HIGH to LOW while SCL line is HIGH. A STOP condition is defined as the SDIO transitioning from LOW to HIGH while SCL is HIGH. The I<sup>2</sup>C master always generates START and STOP conditions. The I<sup>2</sup>C bus is considered to be busy after a START condition and free after a STOP condition. During data transmission, the I<sup>2</sup>C master can generate repeated START conditions. First START and repeated START conditions are equivalent, function-wise.

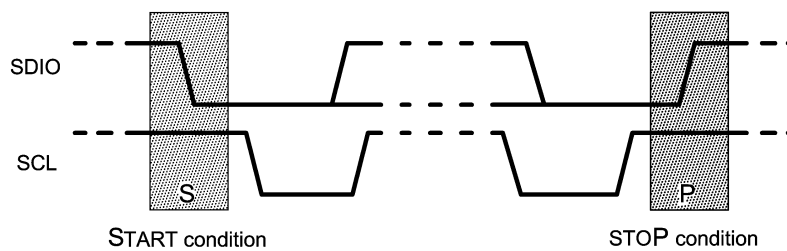
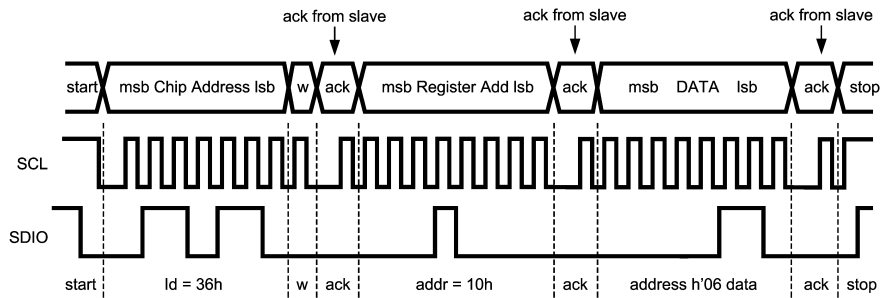


Figure 4. Start and Stop Conditions

##### 4.3.1.3 Transferring Data

Every byte put on the SDIO line must be eight bits long, with the most significant bit (MSB) transferred first. Each byte of data has to be followed by an acknowledge bit. The acknowledge related clock pulse is generated by the master. The master releases the SDIO line (HIGH) during the acknowledge clock pulse. The LM27965 pulls down the SDIO line during the 9th clock pulse, signifying an acknowledge. The LM27965 generates an acknowledge after each byte is received.

After the START condition, the I<sup>2</sup>C master sends a chip address. This address is seven bits long followed by an eighth bit which is a data direction bit (R/W). The LM27965 address is 36h. For the eighth bit, a “0” indicates a WRITE and a “1” indicates a READ. The second byte selects the register to which the data will be written. The third byte contains data to write to the selected register.



NOTE: w = write (SDIO = "0"); r = read (SDIO = "1"); ack = acknowledge (SDIO pulled down by either master or slave); id = chip address, 36h for LM27965

Figure 5. Write Cycle

#### 4.3.1.4 I<sup>2</sup>C Compatible Chip Address

The chip address for LM27965 is 0110110, or 36h.

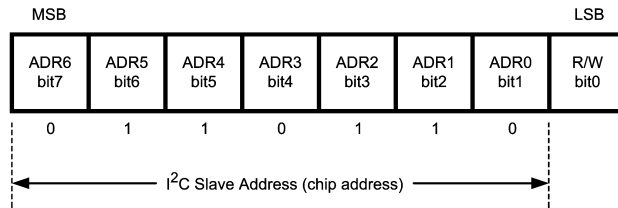


Figure 6. Chip Address

#### 4.3.1.5 Internal Registers of LM27965

| Register                           | Internal Hex Address | Power On Value |
|------------------------------------|----------------------|----------------|
| General Purpose Register           | 10h                  | 0010 0000      |
| Bank A Brightness Control Register | A0h                  | 1110 0000      |
| Bank B Brightness Control Register | B0h                  | 1110 0000      |
| Bank C Brightness Control Register | C0h                  | 1111 1100      |

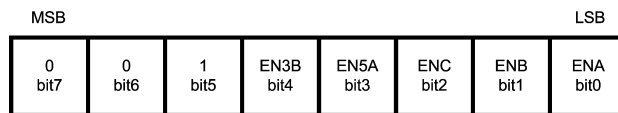
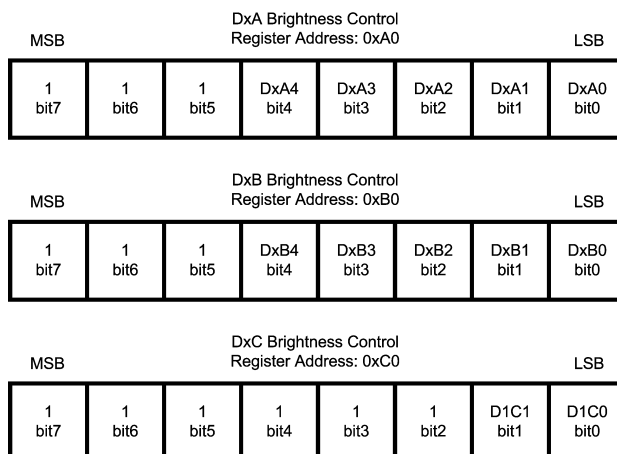


Figure 7. General Purpose Register Description  
Internal Hex Address: 10h

- NOTE:** ENA: Enables DxA LED drivers (Main Display)  
 ENB: Enables DxB LED drivers (Aux Lighting)  
 ENC: Enables D1C LED driver (Indicator Lighting)  
 EN5A: Enables D5A LED voltage sense  
 EN3B: Enables D3B LED driver and voltage sense



**Figure 8. Brightness Control Register Description**  
**Internal Hex Address: 0xA0 (BankA), 0xB0 (BankB), 0xC0 (BankC)**

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**NOTE:** DxA4-DxA0: Sets Brightness for DxA pins (BankA). 11111=Fullscale  
 DxB4-DxB0: Sets Brightness for DxB pins (BankB). 11111=Fullscale  
 Bit7 to Bit 5: Not Used  
 DxC1-DxC0: Sets Brightness for DxC pin. 11 = Full-scale  
 Bit7 to Bit2:Not Used

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### 4.3.2 Setting LED Current

The current through the LEDs connected to DxA and DxB can be set to a desired level simply by connecting an appropriately sized resistor ( $R_{SET}$ ) between the  $I_{SET}$  pin of the LM27965 and GND. The DxA and DxB LED currents are proportional to the current that flows out of the  $I_{SET}$  pin and are a factor of 200 times greater than the  $I_{SET}$  current. The feedback loops of the internal amplifiers set the voltage of the  $I_{SET}$  pin to 1.25V (typ.). The statements above are simplified in the equations below:

$$I_{DxA/B/C} (A) = 200 \times (V_{ISET} / R_{SET}) \quad R_{SET} (\Omega) = 200 \times (1.25V / I_{DxA/B/C}) \quad (1)$$

Once the desired  $R_{SET}$  value has been chosen, the LM27965 has the ability to internally dim the LEDs using a mix of Pulse Width Modulation (PWM) and analog current scaling. The PWM duty cycle is set through the I<sup>2</sup>C compatible interface. LEDs connected to BankA and BankB current sinks (DxA and DxB) can be dimmed to 32 different levels/duty-cycles. The internal PWM frequency for BankA and BankB is fixed at 20kHz. BankC(D1C) has 4 analog current levels.

**For the LM27965 evaluation board, the diode current is set to 15mA per output ( $R_{SET} = 16.9k\Omega$ ).**

**Table 1. Brightness Level Control Table (BankA and BankB)**

| Brightness Code (hex) | Analog Current (% of Full-Scale) | Duty Cycle (%) | Perceived Brightness Level (%) |
|-----------------------|----------------------------------|----------------|--------------------------------|
| 00                    | 20                               | 1/16           | 1.25                           |
| 01                    | 20                               | 2/16           | 2.5                            |
| 02                    | 20                               | 3/16           | 3.75                           |
| 03                    | 20                               | 4/16           | 5                              |
| 04                    | 20                               | 5/16           | 6.25                           |
| 05                    | 20                               | 6/16           | 7.5                            |
| 06                    | 20                               | 7/16           | 8.75                           |
| 07                    | 20                               | 8/16           | 10                             |

**Table 1. Brightness Level Control Table (BankA and BankB) (continued)**

| Brightness Code (hex) | Analog Current (% of Full-Scale) | Duty Cycle (%) | Perceived Brightness Level (%) |
|-----------------------|----------------------------------|----------------|--------------------------------|
| 08                    | 20                               | 9/16           | 11.25                          |
| 09                    | 20                               | 10/16          | 12.5                           |
| 0A                    | 20                               | 11/16          | 13.75                          |
| 0B                    | 20                               | 12/16          | 15                             |
| 0C                    | 20                               | 13/16          | 16.25                          |
| 0D                    | 20                               | 14/16          | 17.5                           |
| 0E                    | 20                               | 15/16          | 18.75                          |
| 0F                    | 20                               | 16/16          | 20                             |
| 10                    | 40                               | 10/16          | 25                             |
| 11                    | 40                               | 11/16          | 27.5                           |
| 12                    | 40                               | 12/16          | 30                             |
| 13                    | 40                               | 13/16          | 32.5                           |
| 14                    | 40                               | 14/16          | 35                             |
| 15                    | 40                               | 15/16          | 37.5                           |
| 16                    | 40                               | 16/16          | 40                             |
| 17                    | 70                               | 11/16          | 48.125                         |
| 18                    | 70                               | 12/16          | 52.5                           |
| 19                    | 70                               | 13/16          | 56.875                         |
| 1A                    | 70                               | 14/16          | 61.25                          |
| 1B                    | 70                               | 15/16          | 65.625                         |
| 1C                    | 70                               | 16/16          | 70                             |
| 1D                    | 100                              | 13/16          | 81.25                          |
| 1E                    | 100                              | 15/16          | 93.75                          |
| 1F                    | 100                              | 16/16          | 100                            |

BankC Brightness Levels (%of Full-Scale) = 20%, 40%, 70%, 100%

### 4.3.3 LED Forward Voltage Monitoring

The LM27965 has the ability to switch converter gains (1x or 3/2x) based on the forward voltage of the LED load. This ability to switch gains maximizes efficiency for a given load. Forward voltage monitoring occurs on all diode pins within BankA and BankB. At higher input voltages, the LM27965 will operate in pass mode, allowing the  $P_{OUT}$  voltage to track the input voltage. As the input voltage drops, the voltage on the Dxx pins will also drop ( $V_{DXX} = V_{P_{OUT}} - V_{LEDX}$ ). Once any of the active Dxx pins reaches a voltage approximately equal to 175mV, the charge pump will switch to the gain of 3/2. This switch-over ensures that the current through the LEDs never becomes pinched off due to a lack of headroom across the current sinks.

Only active Dxx pins will be monitored. For example, if only BankA is enabled, the LEDs in BankB will not affect the gain transition point. If both banks are enabled, all diodes will be monitored, and the gain transition will be based upon the diode with the highest forward voltage. Diode pins D5A and D3B can have the diode sensing circuitry disabled through the general purpose register if those drivers are not going to be used.

BankC (D1C) is not a monitored LED current sink.

## 4.4 Additional Information

For more information regarding the operation of the LM27965, please refer to the LM27965 datasheet. If a USB Docking Board is required for the creation of the I2C interface, please contact your local TI sales representative.

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