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

ABSTRACT

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

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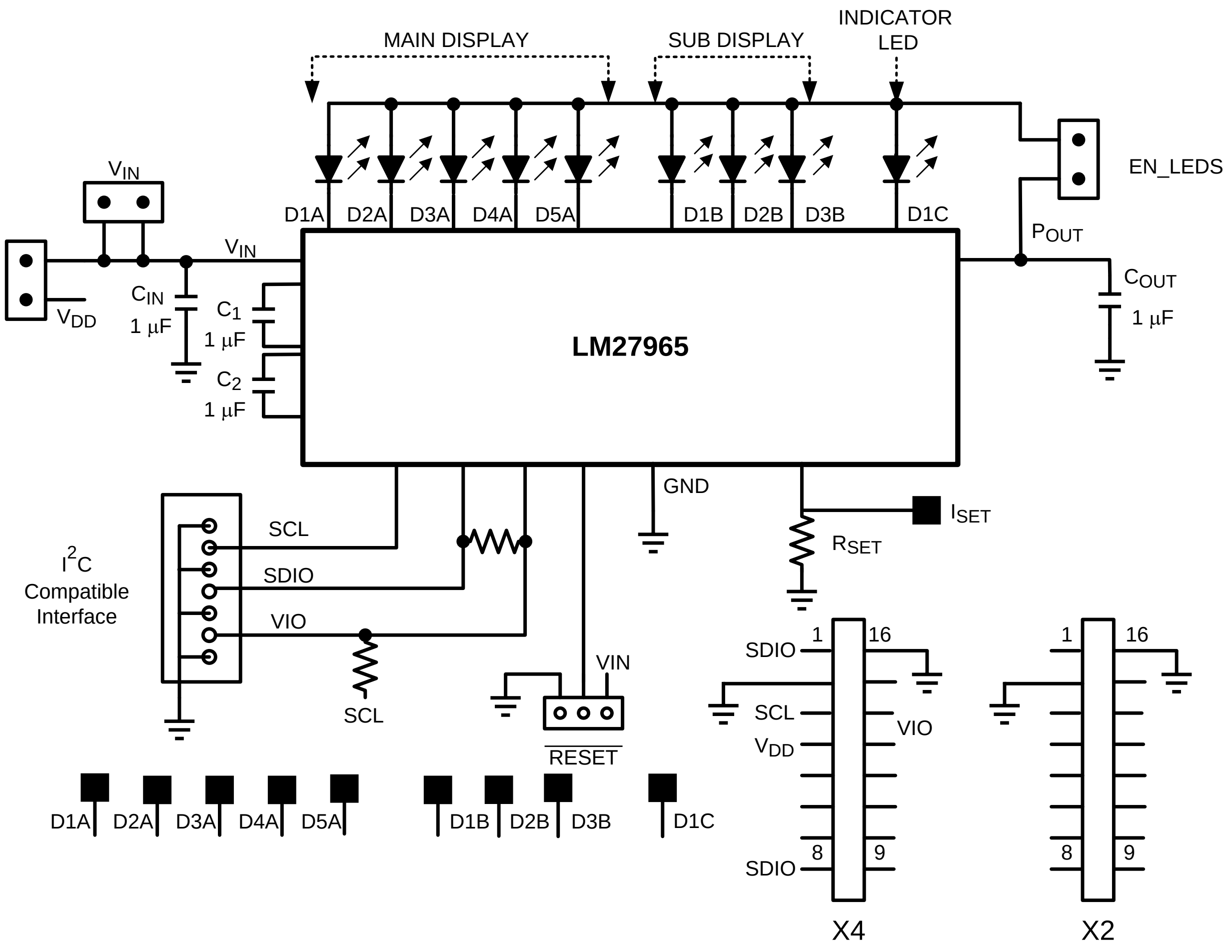
1 Schematic



2 Bill of Materials

Component Symbol	Value	Package	Manufacturer	Part #
LM27965	–	SQA24 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_{IN}	1µF, 10V	0603	TDK	C1608X5R1A105K
C_{OUT}	1µF, 10V	0603	TDK	C1608X5R1A105K
C_1,C_2	1µF, 10V	0603	TDK	C1608X5R1A105K
R_{SET}	16.9kΩ	0603	Vishay Dale	CRCW060316K9FKEA

3 LM27965 Evaluation Board Layout

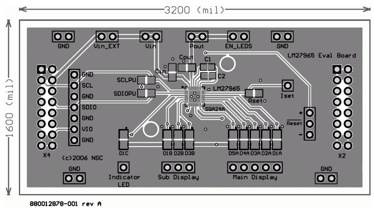


Figure 1. Top Layer

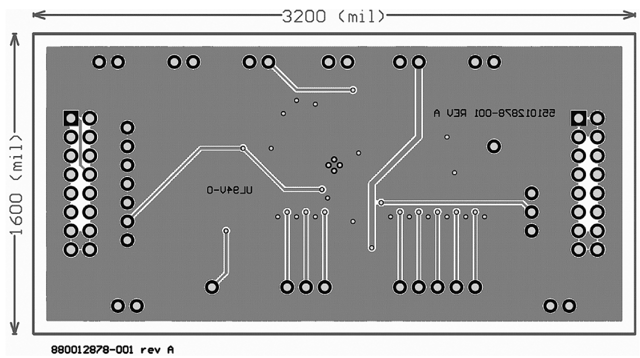


Figure 2. Bottom Layer (unmirrored)

4 Board Operation

4.1 Basic Connections

To operate the LM27965 Dual Display White LED Driver with I2C Compatible Brightness Control, connect a supply voltage (2.7V-5.5V) between board connectors VIN and GND and attach an I^2C interface using one of the methods described in the Section 4.2 of this document.

Default Jumper Connections:

- $\overline{RESET}$: Connects the “+” post to the middle post of the $\overline{RESET}$ header strip. This connects VIN to the $\overline{RESET}$ 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 I2C 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 I2C 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^2C 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 (contoller 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^2C compatible interface in greater detail.

4.3 Operation Description

4.3.1 I²C 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.

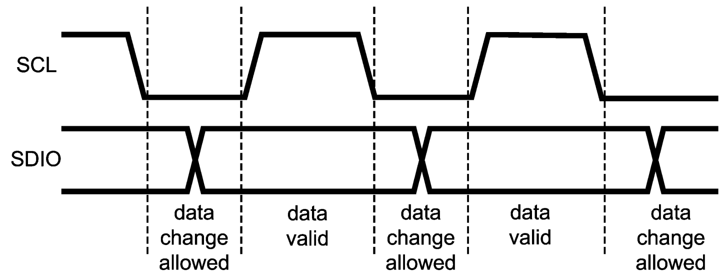


Figure 3. Data Validity Diagram

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 I²C 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 I²C master always generates START and STOP conditions. The I²C bus is considered to be busy after a START condition and free after a STOP condition. During data transmission, the I²C master can generate repeated START conditions. First START and repeated START conditions are equivalent, function-wise.

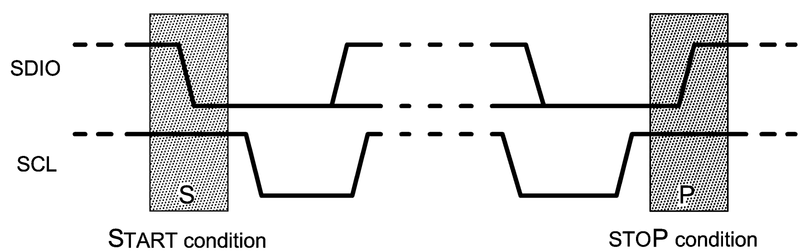
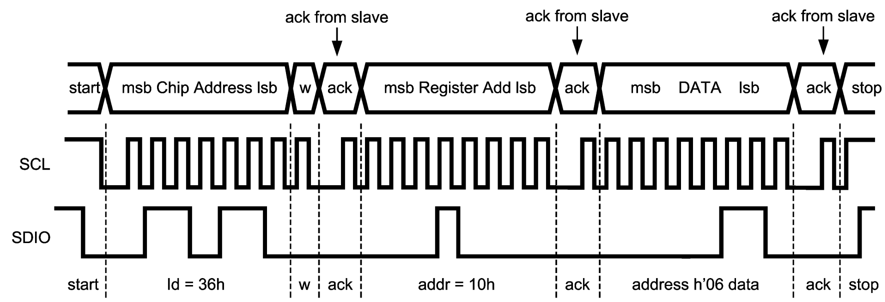


Figure 4. Start and Stop Conditions

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 I²C 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 I²C Compatible Chip Address

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

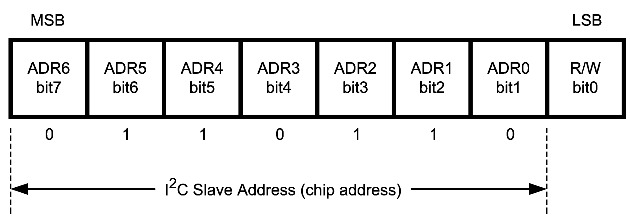


Figure 6. Chip Address

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

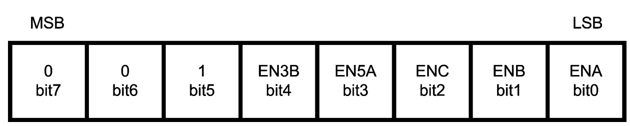


Figure 7. General Purpose Register Description Internal Hex Address: 10h

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

DxA Brightness Control
Register Address: 0xA0

MSB							LSB
1 bit7	1 bit6	1 bit5	DxA4 bit4	DxA3 bit3	DxA2 bit2	DxA1 bit1	DxA0 bit0

DxB Brightness Control
Register Address: 0xB0

MSB							LSB
1 bit7	1 bit6	1 bit5	DxB4 bit4	DxB3 bit3	DxB2 bit2	DxB1 bit1	DxB0 bit0

DxC Brightness Control
Register Address: 0xC0

MSB							LSB
1 bit7	1 bit6	1 bit5	1 bit4	1 bit3	1 bit2	D1C1 bit1	D1C0 bit0

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

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

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:

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

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^2C 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} = 16.9kΩ).

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 ($V_{DXX} = V_{POUT} – V_{LEDx}$). 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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