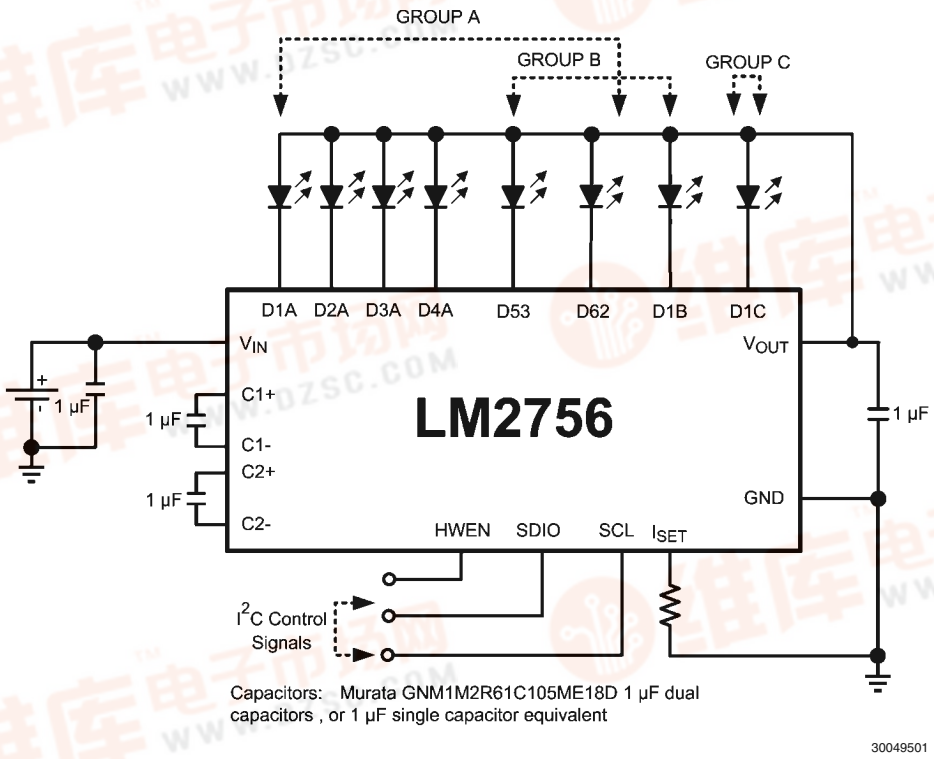
LM2756 Multi-Display Inductorless LED Driver with 32 Exponential Dimming Steps in µSMD

National Semiconductor
Application Note 1779
March 31, 2008

Typical Application



Capacitors: Murata GNM1M2R61C105ME18D 1 µF dual capacitors , or 1 µF single capacitor equivalent

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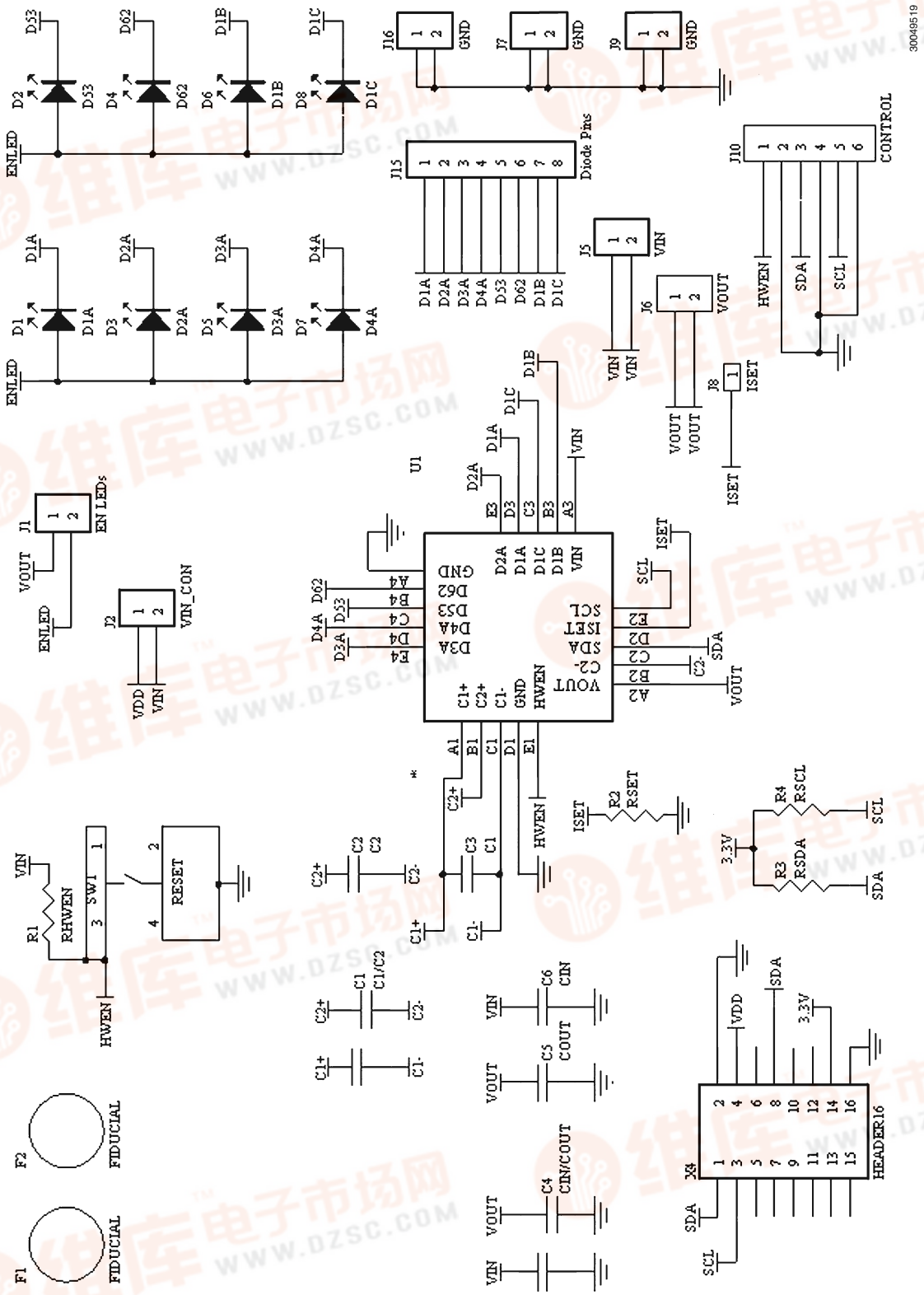
Basic Description

The LM2756 is a highly integrated, switched-capacitor, multi-display LED driver that can drive up to 8 LEDs in parallel. The regulated internal current sources on the evaluation boards are set-up to deliver 20mA to each LED delivering excellent current and brightness matching. Utilizing the I²C compatible interface, the user can configure the LM2756 evaluation board to drive the eight LEDs in any of the numerous LED group configurations (4:3:1. 5:2:1, 6:1:1, etc.).

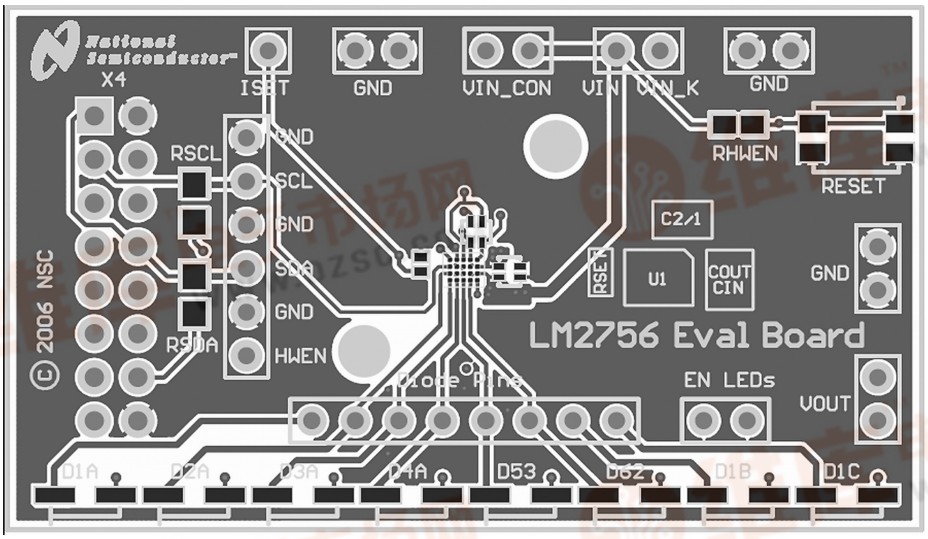
Bill of Materials

Component Symbol	Value	Manufacturer	Part #
LM2756	--	National	LM2756SDX
LM2756 Evaluation Board	--	National	551013004-002 RevA
D1A-D4A, D53B,D62,D1B,D1C	White LED	Nichia	NSSW020BT
C_{OUT}/C_{IN}	1µF, 16V Dual Capacitor	Murata	GNM1M2R61C105 ME18D
C_2/C_1	1µF, 16V Dual Capacitor	Murata	GNM1M2R61C105 ME18D
R_{SET}	11.8kΩ	Vishay Dale	CRCW04021182F
RSCL, RSDA,RHWEN	10kΩ	Vishay Dale	CRCW08051002F
RESET	Momentary Switch	Panasonic	EVQ-P2K02Q
X4	USB Dock Connector	3M	8516-4500JL

LM2756 Evaluation Board Schematic



LM2756 Evaluation Board Layout



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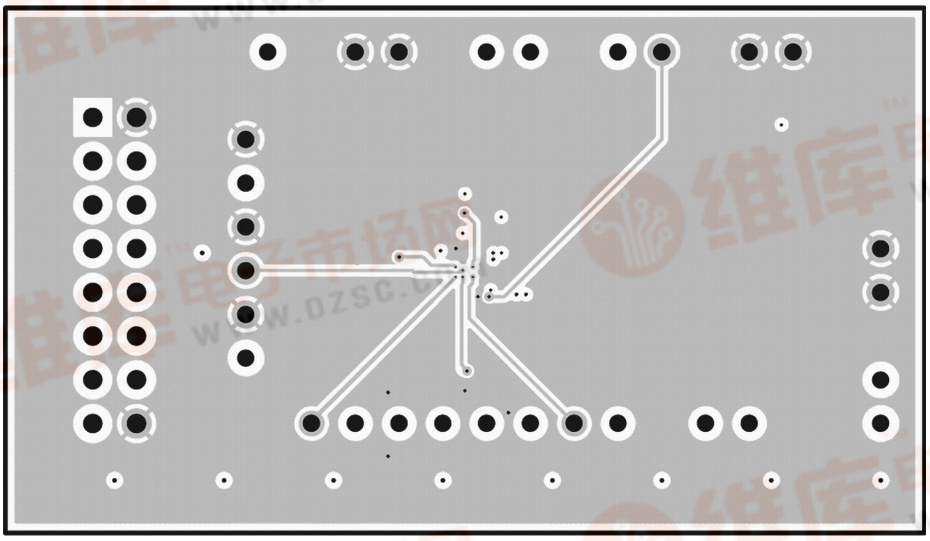
Top Layer



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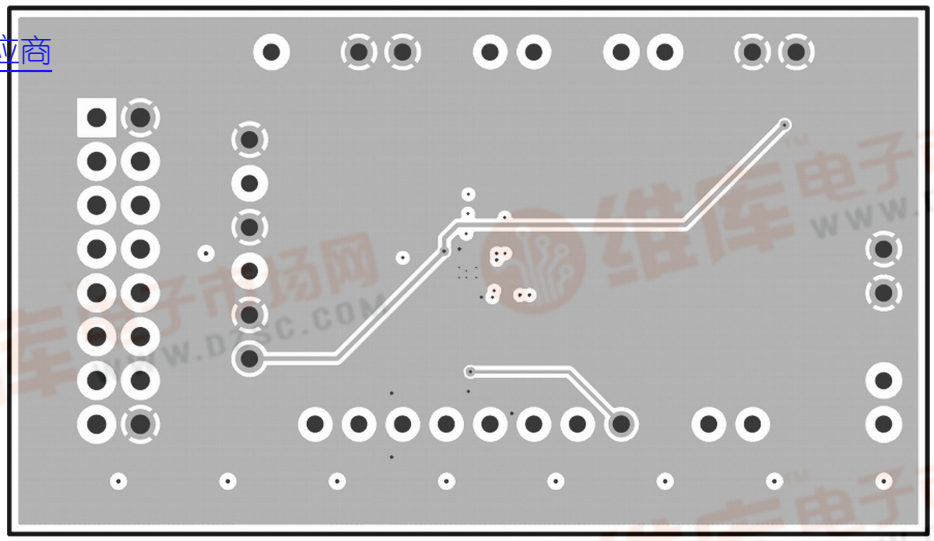
Middle Layer 1



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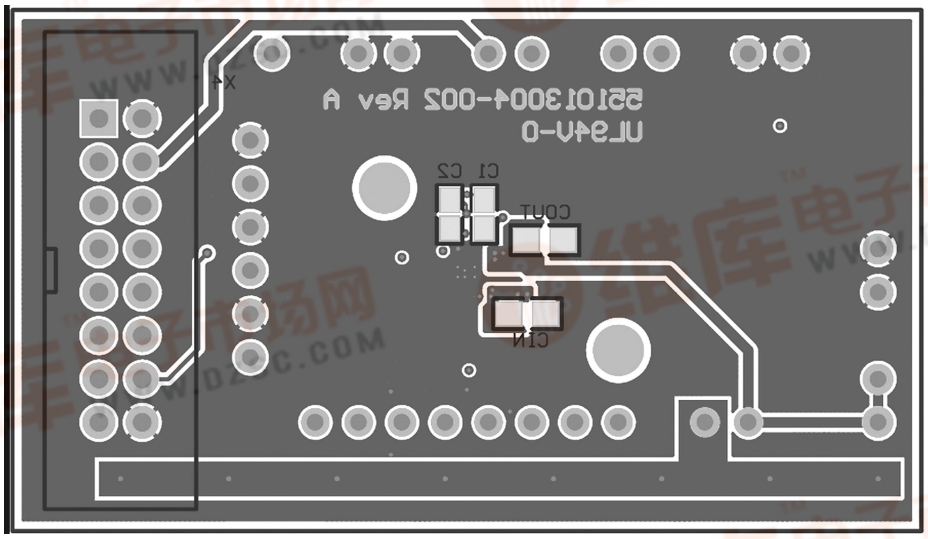
Middle Layer 2



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Bottom Layer (unmirrored)

Board Operation

BASIC CONNECTIONS

To operate the LM2756 Multi-Display Inductorless LED Driver with 32 Exponential Dimming Steps in µSMD, connect a supply voltage (2.7V-5.5V) between board connectors VIN and GND and attach an I²C interface using one of the methods described in the *EXTERNAL CONTROL INTERFACE SECTION* of this document. There is a RESET button provided on the board to exercise the RESET pin on the LM2756. By default, this pins is pulled high through a resistor to allow normal operation. Depressing this button during board operation will shutdown the LM2756 and will clear all of the internal registers resetting them to their default values.

Default Jumper Connections:

- EN_LEDS: This connects VOUT to the anodes of the LEDs. Removing the jumper disconnects the on-board LED power and allows external diodes / measurement equipment to be connected between VOUT and the Dx Pins
- VIN_CON: Connects the adjustable voltage supply of the USB Docking board to the VIN of the LM2756. 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_CON 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.

EXTERNAL CONTROL INTERFACE CONNECTION

The LM2756 Evaluation Board provides two ways to connect an I²C compatible interface to the LM2756 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 National'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 SDA (Interface Data Line) each separated by a ground pin. The evaluation board has two external pull-ups that connect both SCL and SDA to VIO to compliment the open drain inputs found on the LM2756. The *OPERATION DESCRIPTION* section of this application note describes the internal registers and I²C compatible interface in greater detail.

OPERATION DESCRIPTION

I²C Compatible Interface

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 SCL is LOW.

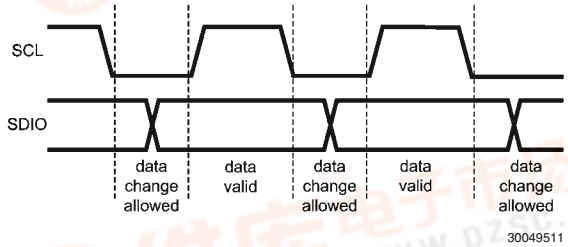


FIGURE 1. Data Validity Diagram

A pull-up resistor between the controller's VIO line and SDIO must be greater than [**(VIO-V_{OL}) / 3.5mA**] 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.

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.

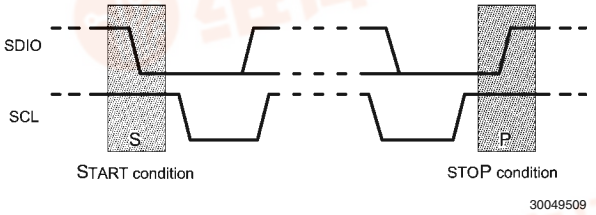


FIGURE 2. Start and Stop Conditions

TRANSFERING 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 LM2756 pulls down the SDIO line during the 9th clock pulse, signifying an acknowledge. The LM2756 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 LM2756 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.

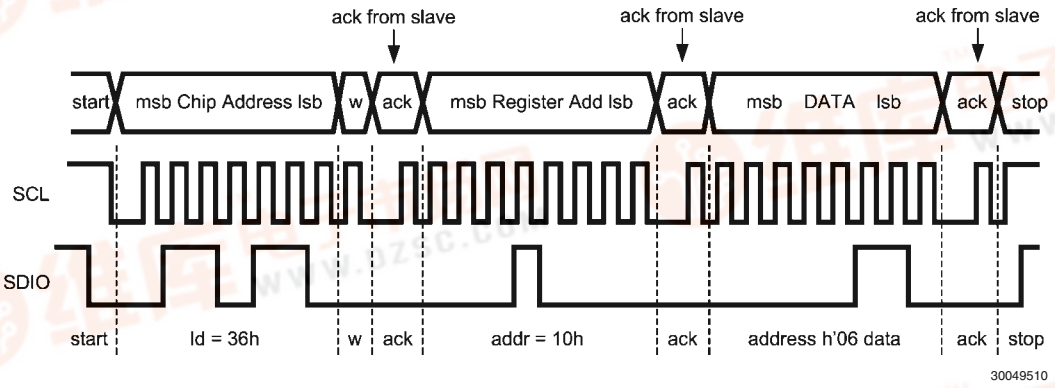


FIGURE 3. Write Cycle
w = write (SDIO = "0")
r = read (SDIO = "1")
ack = acknowledge (SDIO pulled down by either master or slave)
id = chip address, 36h for LM2756

I²C COMPATIBLE CHIP ADDRESS

The I2C address for LM2756 is 0110110, or 36h.

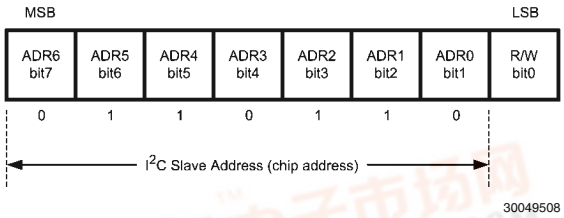


FIGURE 4. Chip Address

INTERNAL REGISTERS OF LM2756

Register	Internal Hex Address	Power On Value
General Purpose Register	10h	0000 0000
Group A Brightness Control Register	A0h	1110 0000
Group B Brightness Control Register	B0h	1111 1000
Group C Brightness Control Register	C0h	1111 1000
Ramp Step Time Register	20h	1111 0000
VF Monitor Delay Ragister	60h	1111 1100

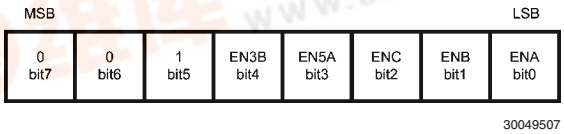
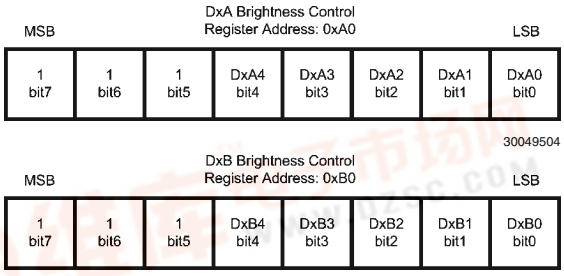


FIGURE 5. General Purpose Register Description Internal Hex Address: 10h

Note: ENA: Enables DxA LED drivers (Main Display)
ENB: Enables DxB LED drivers (Aux Lighting)
ENC: Enables D1C LED driver (Indicator Lighting)
SD53: Shuts down driver D53
SD62: Shuts down driver D62
53A: Configures D53 to GroupA
62A: Configures D62 to GroupA



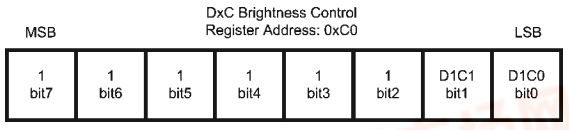


FIGURE 6. Brightness Control Register Description Internal Hex Address: 0xA0 (GroupA), 0xB0 (GroupB), 0xC0 (GroupC)

Note: DxA4-DxA0, D53, D62: Sets Brightness for DxA pins (GroupA). 11111=Fullscale
DxB2-DxB0: Sets Brightness for DxB pins (GroupB). 111=Fullscale
DxC2-DxC0: Sets Brightness for D1C pin. 111 = Fullscale
Full-Scale Current set externally by the following equation:
$I_{Dxx} = 189 \times 1.25V / R_{SET}$

Brightness Level Control Table (GroupA)

Brightness Code (hex)	Perceived Brightness Level (%)
00	0.125
01	0.313
02	0.625
03	1
04	1.125
05	1.313
06	1.688
07	2.063
08	2.438
09	2.813
0A	3.125
0B	3.75
0C	4.375
0D	5.25
0E	6.25
0F	7.5
10	8.75
11	10
12	12.5
13	15
14	16.875
15	18.75
16	22.5
17	26.25
18	31.25
19	37.5
1A	43.75
1B	52.5
1C	61.25
1D	70
1E	87.5
1F	100

GroupB and GroupC Brightness Levels (% of Full-Scale) = 10%, 20%, 30%, 40%, 50%, 60%, 70%, 100%

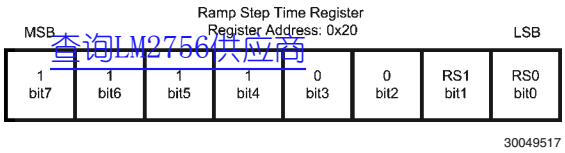


FIGURE 7. Ramp Step Time Register Description Internal Hex Address: 20h

Note: RS1-RS0: Sets Brightness Ramp Step Time. The Brightness ramp settings only affect GroupA current sinks. ('00' = 100µs, '01' = 25ms, '10' = 50ms, '11' = 100ms).

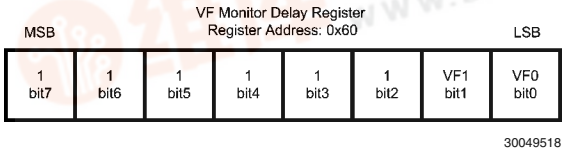


FIGURE 8. VF Monitor Delay Register Description Internal Hex Address: 60h

Note: VF1-VF0: Sets the Gain Transition Delay Time. The VF Monitor Delay can be set to four different delay times. ('00' (Default) = 3-6msec., '01' = 1.5-3msec., '10' = 0.4msec., '11' = 60-90µsec.).

LED Configurations

The LM2756 has a total of 8 current sinks capable of sinking 180mA of total diode current. These 8 current sinks are configured to operate in three independently controlled lighting regions. GroupA has four dedicated current sinks, while GroupB and GroupC each have one. To add greater lighting flexibility, the LM2756 has two additional drivers (D53 and D62) that can be assigned to either GroupA or GroupB through a setting in the general purpose register.

At start-up, the default condition is four LEDs in GroupA, three LEDs in GroupB and a single LED in GroupC (NOTE: GroupC only consists of a single current sink (D1C) under any configuration). Bits 53A and 62A in the general purpose register control where current sinks D53 and D62 are assigned. By writing a '1' to the 53A or 62A bits, D53 and D62 become assigned to the GroupA lighting region. Writing a '0' to these bits assigns D53 and D62 to the GroupB lighting region. With this added flexibility, the LM2756 is capable of supporting applications requiring 4, 5, or 6 LEDs for main display lighting, while still providing additional current sinks that can be used for a wide variety of lighting functions.

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 LM2756 and GND. The DxA, DxB and D1C LED currents are proportional to the current that flows out of the I_{SET} pin and are a factor of 189 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:

$$I_{DxA/B/C}\ (A) = 189 \times (V_{ISET} / R_{SET})$$
$$R_{SET}\ (\Omega) = 189 \times (1.25V / I_{DxA/B/C})$$

Once the desired R_{SET} value has been chosen, the LM2756 has the ability to internally dim the LEDs using analog current scaling. The analog current level is set through the I²C compatible interface. LEDs connected to GroupA can be dimmed to 32 different levels. GroupB and GroupC(D1C) have 8 analog current levels.

Please refer to the I²C Compatible Interface section of this datasheet for detailed instructions on how to adjust the brightness control registers.

LED Current Ramping

The LM2756 provides an internal LED current ramping function that allows the GroupA LEDs to turn on and turn off gradually over time. The target current level is set in the GroupA Brightness Control Register (0xA0). The total ramp-up/ramp-down time is determind by the GroupA brightness level (0-31) and the user configurable ramp step time.

Bits RS1 and RS2 in the Ramp Step Time Register (0x20) set the ramp step time to the following four times: **'00' = 100µsec., '01' = 25msec., '10' = 50msec., '11' = 100msec**.

The LM2756 will always ramp-up (upon enable) and ramp-down (upon disable) through the brightness levels until the target level is reached. At the default setting of '00', the LM2756's current ramping feature looks more like a current step rather than a current ramp. The following table gives the approximate ramp-up/ramp-down times if the GroupA brightness register is set to full-scale, or brightness code 31.

Brightness Ramp-Up/Ramp-Down Times

Ramp Code RS1-RS0	Ramp Step Time	Total Ramp Time
00	100µs	3.2ms
01	25ms	0.8s
10	50ms	1.6s
11	100ms	3.2s

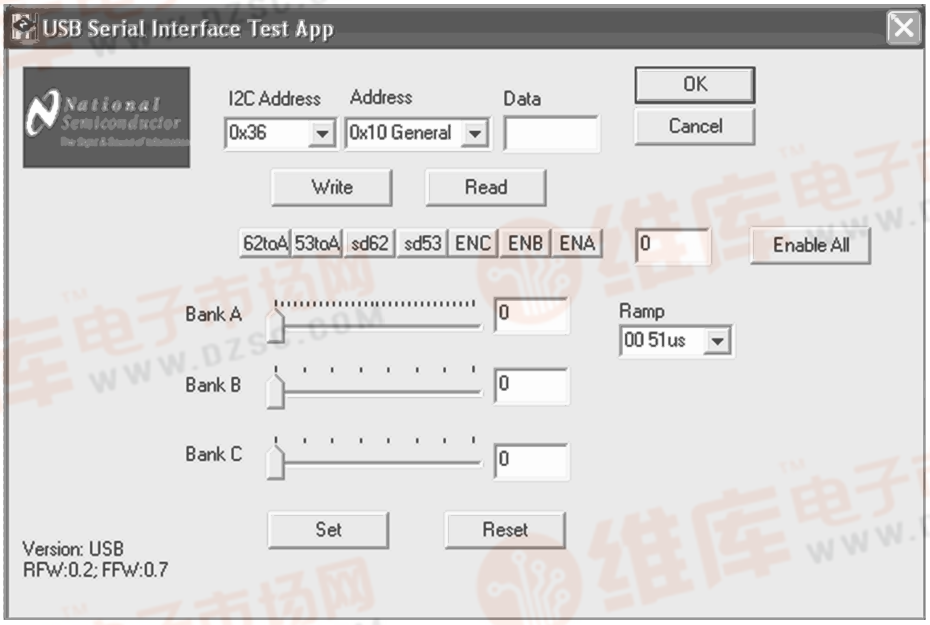
Software Interface Information

In order to fully evaluate the LM2756 part, an "I²C Compatible" interface must be used for any functionality to occur. A detailed description of the interface control is described in the LM2756 datasheet.

National has created an I²C compatible interface generation program and USB docking board that can help exercise the part in a simple way. Contained in this document is a description of how to use the USB docking board and interface software.

The LM2756 evaluation board has the means to "plug into" the USB docking board. The USB docking board can provide all of the control signals and power required to operate the evaluation board. A standard USB cable must be connected to the board from a PC.

The I²C compatible interface program provides all of the control that the LM2756 part requires. For proper operation, the USB docking board should be plugged into the PC before the interface program is opened. Once connected, and the program is executed, a basic interface window will open.



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GUI Start-Up

At the top of the interface, the user can read or write to any of the data registers on the LM2756 part using the two pull down menus (for the slave i.d. and the desired data address), the data field, and the read and write buttons.

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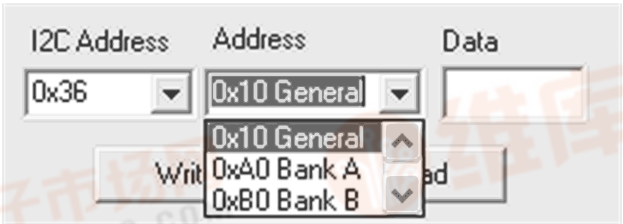
Generic Read/Write Field



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Drop Down Menu

Just below the pull down menus are convenient toggle buttons to set/reset the control bits in the General Purpose Register.

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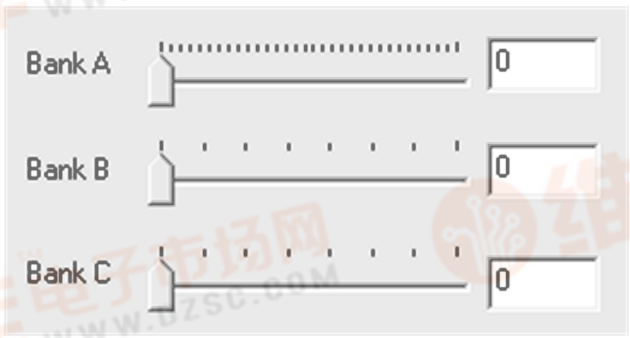
Control and Configuration Buttons

- 62toA and 53toA: Assigns D62 and D63 current sinks to BankA when depressed. By default, D62 and D53 are assigned to BankB
- SD62 and SD53: Disabled drivers D62 and D53 when depressed
- ENC, ENB and ENA: These bits, when depressed, enable BankA, BankB and BankC.



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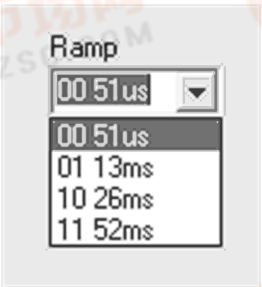
Brightness Control Sliders

- BankA Slider: Sets the BankA brightness to any allowable brightness code (0 to 31)
- BankB Slider: Sets the BankB brightness to any allowable brightness code (0 to 7)
- BankCSlider: Sets the BankC brightnessn to any allowable brightness code (0 to 7)



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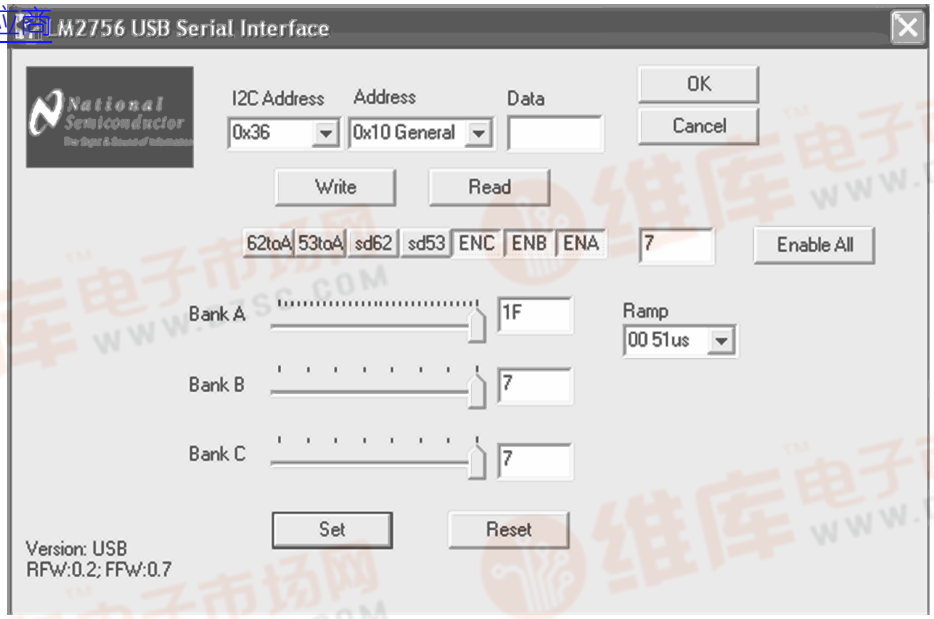
BankA Ramp Step Time

- Ramp Step Time: This field sets the BankA brightness control ramp-up/ramp-down times. The time shown in the field corresponds to the time the LM2756 remains at each brightness code.



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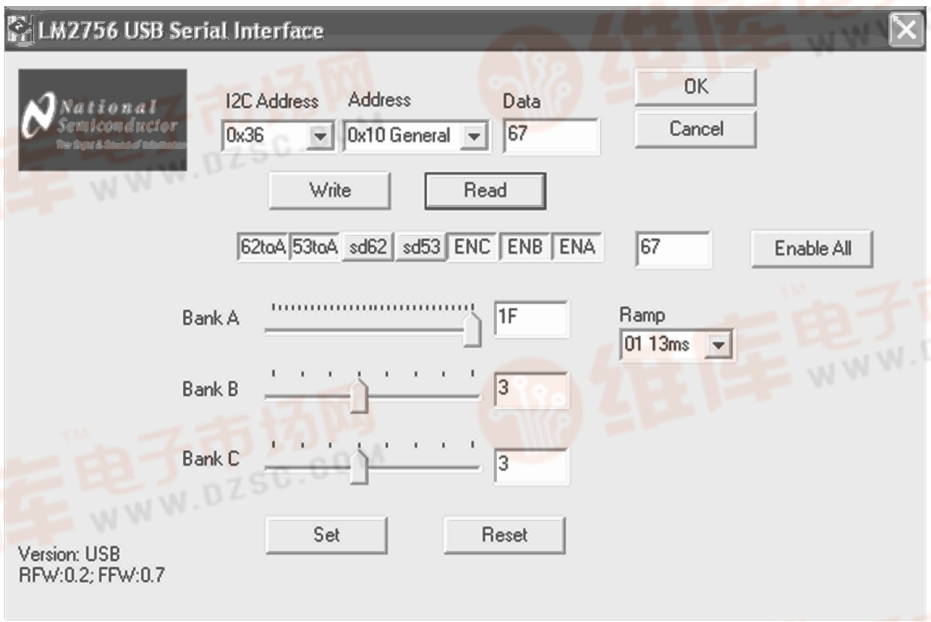
Results of Pressing the Set Button

Pressing the Set button places the LM2756 into the 4:3:1 configuration and sets the brightness levels in each bank to full-scale.



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Example Configuration

In this configuration, the LM2756 will have 6 LEDs in BankA set to the Full-Scale brightness with a ramp step time equal to 13ms. BankB and BankC are each set to brightness code3 and are both active.

Note: If the part is enabled to any level of brightness or state and the program is closed (by either hitting the OK or cancel buttons) , the LM2756 part will remain in the last controlled state.

Notes

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