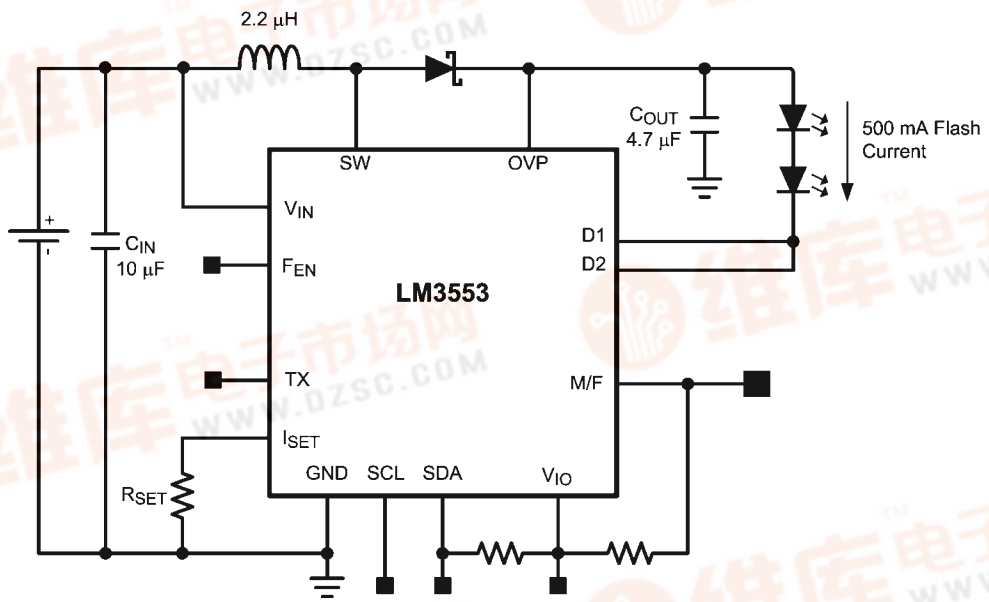
LM3553 1.2A Dual Flash LED Driver System with I2C Compatible Interface

National Semiconductor
Application Note 1780
March 12, 2008

Typical Application Drawing



Components:
L = Toko FDSE0312-2R2M
C_{IN} = Murata GRM188R60J106ME47D
C_{OUT} = Murata GRM21BR61E475KA12L
LEDs = Lumileds LXCL – PWF3
Or equivalent

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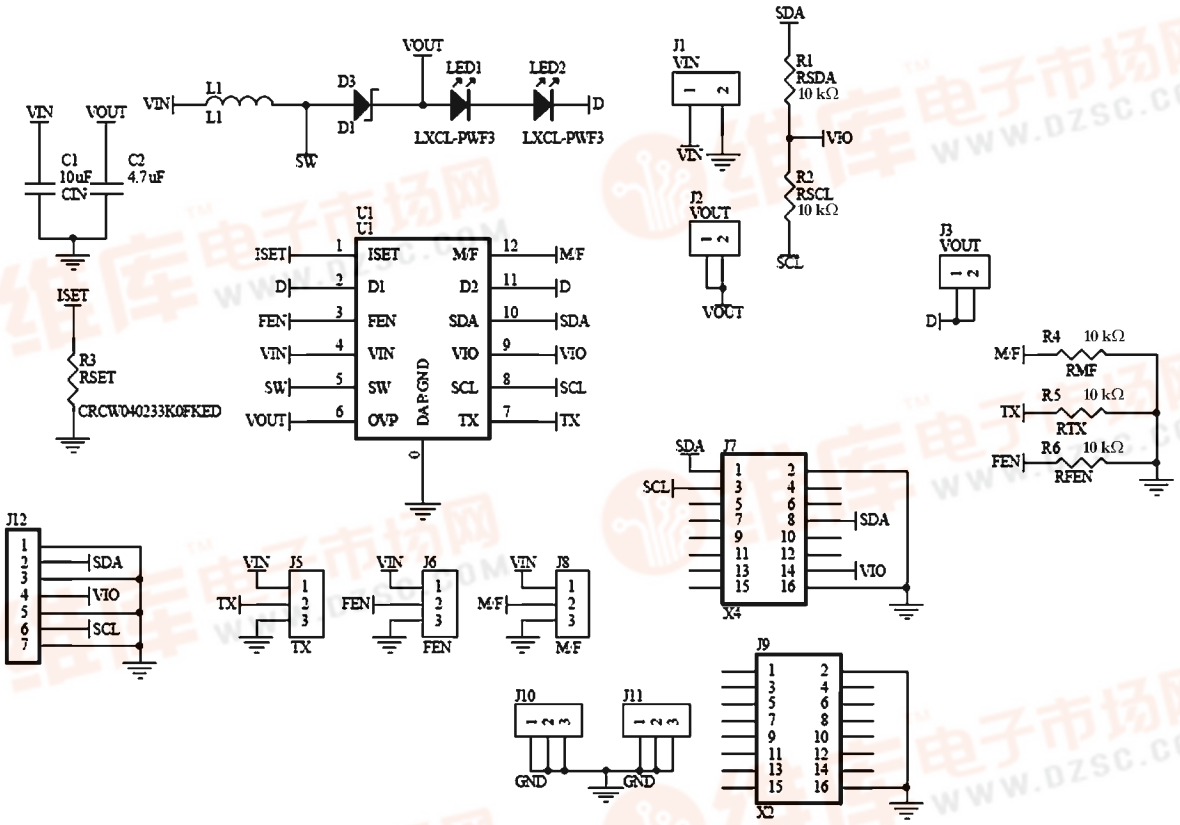
Bill of Materials

Component Symbol	Value	Package	Manufacturer	Part #
LM3553	--	SDF12A LLP12	National	LM3553SDX
LM3553 Evaluation Board	--	--	National	551600092-001 RevA
LED1,LED2	White LED	--	Philips Lumiled	LXCL-PWF3
CIN	10µF, 6.3V	0603	Murata	GRM188R60J106ME47D
COUT	4.7µF, 25V	0805	Murata	GRM21BR61E475KA12L
L1	2.2µH	3mm x 3mm x 1.2mm	Toko	FDSE0312-2R2M
RSET	33kΩ	0402	Vishay Dale	CRCW040233K0FKED
D1	1.5A, 30V		ROHM	RB070M-30
RSDA, RSCL, RFEN, RMF, RTX	10kΩ	0402	Vishay Dale	CRCW040210K0JNED

Schematic



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LM3553 Evaluation Board Layout

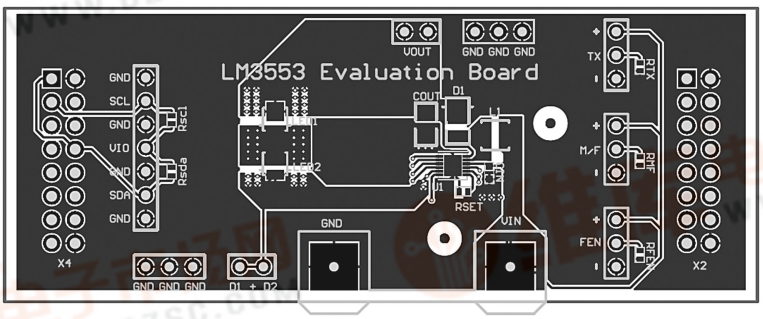

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FIGURE 1. Top Layer

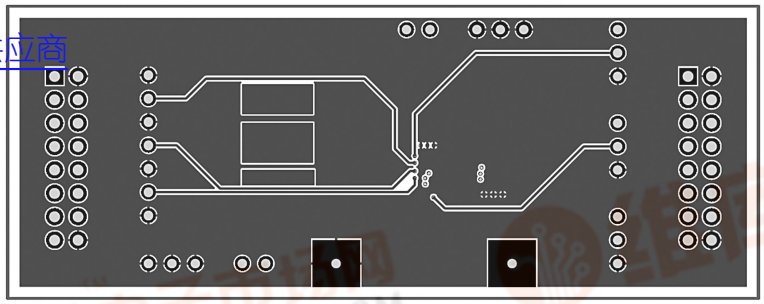

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FIGURE 2. Mid-Layer 1

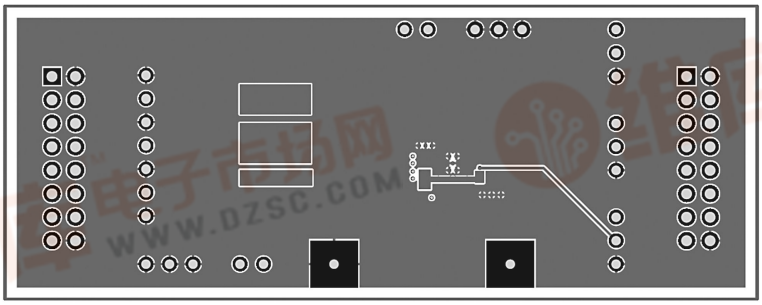

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FIGURE 3. Mid-Layer 2

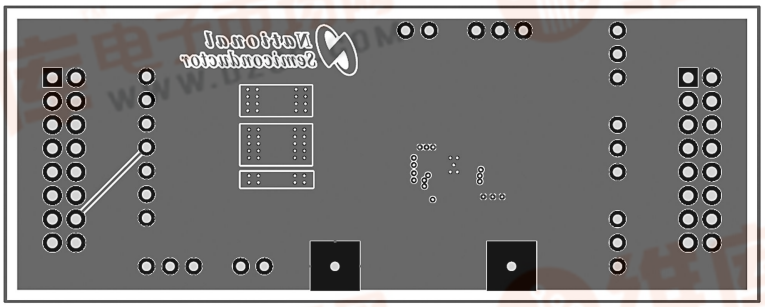

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FIGURE 4. Bottom Layer (unmirrored)

Board Operation

BASIC CONNECTIONS

To operate the LM3553 1.2A Dual Flash LED Driver System with I2C Compatible Interface, 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.

Default Jumper Connections:

- M/F: Connected to "-". To enable the LM3553 evaluation board, connect the M/F header to the '+' using the provided jumper. This will place the LM3553 evaluation board into normal operation mode and out of Hardware Reset
- TX: Connected to "-". By default, this setting will allow the full-scale flash to occur. Moving the TX jumper to the "+" position during a flash will force the LM3553 in a lower current TX mode. This TX mode level is equal to the level stored in the Torch Control Register.
- FEN: Connected to "-". By default, this setting will not allow an externally controlled flash even to occur. Moving the FEN jumper to the "+" position will start a flash event. The flash event will remain active until the FEN pin is driven back to the "-" position or the internal timeout time lapses, which ever occurs first.

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. **NOTE: For the evaluation board to work properly, the OVP bit in the Multi-Function/Options Register must be set to a 1 (18.9V OVP). If this bit is not enabled, the part**

will not boost to the required voltage and performance will be degraded.

EXTERNAL CONTROL INTERFACE CONNECTION

The LM3553 Evaluation Board provides two ways to connect an I²C compatible interface to the LM3553 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 (contoller 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 LM3553. 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 SDA line must be stable during the HIGH period of the clock signal (SCL). In other words, the state of the data line can only be changed when CLK is LOW.

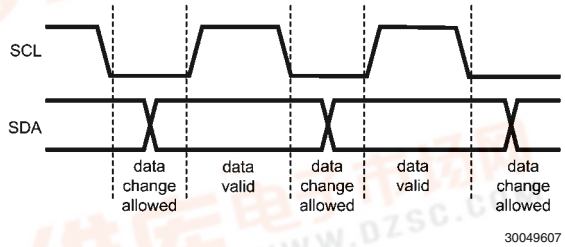


FIGURE 5. Data Validity Diagram

A pull-up resistor between VIO and SDA must be greater than [**(VIO-V_{OL}) / 3.7mA**] to meet the V_{OL} requirement on SDA. 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 SDA signal transitioning from HIGH to LOW while SCL line is HIGH. A STOP condition is defined as the SDA 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. The data on SDA line must be stable during the HIGH period of the clock signal (SCL). In other words, the state of the data line can only be changed when CLK is LOW.

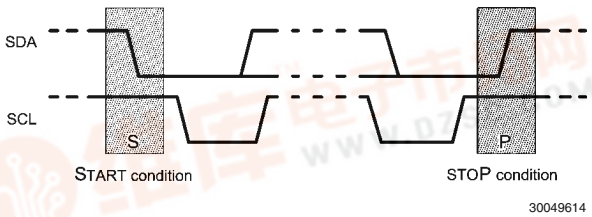


FIGURE 6. Start and Stop Conditions

TRANSFERRING DATA

Every byte put on the SDA line must be eight bits long, with the most significant bit (MSB) being 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 SDA line (HIGH) during the acknowledge clock pulse. The LM3553 pulls down the SDA line during the 9th clock pulse, signifying an acknowledge. The LM3553 generates an acknowledge after each byte has been 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 LM3553 address is 53h. 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.

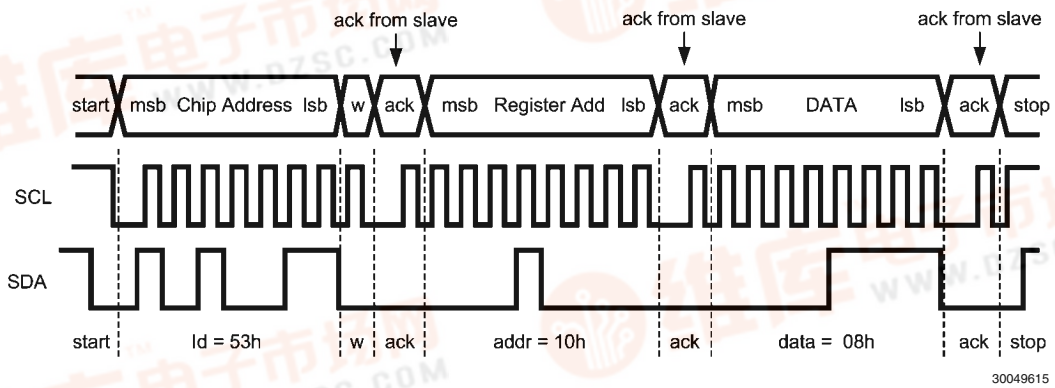


FIGURE 7. Write Cycle
w = write (SDA = "0")
ack = acknowledge (SDA pulled down by the slave)
id = chip address, 53h for LM3553

I²C COMPATIBLE CHIP ADDRESS

The chip address for LM3553 is 1010011, or 53hex.

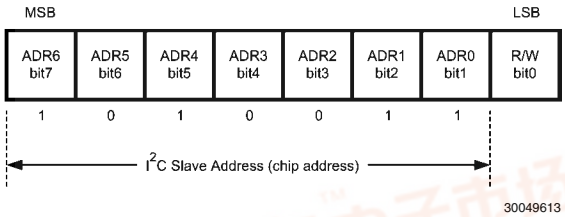


FIGURE 8.

INTERNAL REGISTERS OF LM3553

Register	Internal Hex Address	Power On Value
General Purpose Register	0x10	0001 1000
Multi-Function Pin Control Register	0x20	1110 0000
Current Step Time Register	0x50	1111 1100
Torch Current Control Register	0xA0	1000 0000
Flash Current Control Register	0xB0	1000 0000
Flash Duration Control Register	0xC0	1111 0000

General Purpose Register

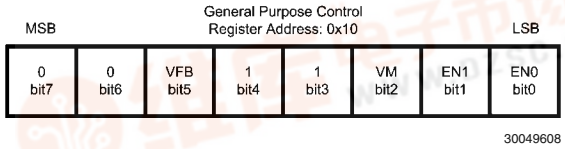


FIGURE 9.

EN0-EN1: Set Flash LED mode

Indicator Mode sets I_{LED} = 20mA. In this mode, D1 is enabled and D2 is disabled.

VM: Enables Voltage Mode. Current sinks D1 and D2 are turned off and the LM3553 will operate in a regulated voltage boost mode. Setting the VM bit to a '1' does not override the EN0 and EN1 bits stored in the general purpose register. The default setting is '0'. If the LM3553 is in Voltage Mode and an indicator, torch or flash command is issued, the LM3553 will turn on the D1 and D2 current sources and begin regulating the output voltage to a value equal to VFB (350mV or 450mV) + VLED.

VM	EN1	EN0	Function
0	0	0	Shutdown
0	0	1	Indicator Mode
0	1	0	Torch Mode
0	1	1	Flash Mode
1	0	0	Voltage Mode
1	0	1	Indicator Mode
1	1	0	Torch Mode
1	1	1	Flash Mode

VFB: Selects the regulation voltage for the LM3553. Setting this VFB bit to a '0' sets the regulation voltage to 450mV while setting the VFB bit to a '1' sets the regulation voltage to 350mV. Setting the VFB bit to a '1' during torch mode and/or lower current flash modes (I_{LED} < 1A) will help improve the LED efficiency of the LM3553.

M/F Pin Control Register

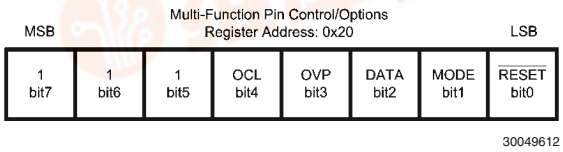


FIGURE 10.

$\overline{\text{RESET}}$: Enables M/F as hardware RESET. '0' = Hardware RESET, .'1' = GPIO or current sink depending on the MODE bit. Default = '0'

MODE: Sets M/F mode. Default for M0DE = '0'. '0' = GPI, and'1' = GPO

Note: When M/F is configured as an input, data is transfered from GPI to DATA whenever an I²C write command is issued to the LM3553. When configuring M/F as a GPO, the first write needs to take the LM3553 out of RESET mode and a second write can then set the pin to the GPO.

DATA: GPIO Data. When the M/F is configured as an output (GPO), DATA sets the GPO level. Example: DATA = '1', M/F is set high or logic '1'. When the M/F pin is configured as an input (GPI), DATA stores the GPI level. Example: M/F = '1', DATA will be set to a '1'. Default for DATA = '0'.

OVP: Enables high-voltage OVP (OVP Bit ='1') or low-voltage OVP (OVP Bit ='0'). Default = low-voltage mode '0'

OCL: SW Pin Current Limit Selector Bit: If OCL = '0', the inductor current limit is 2.5A typ. If OCL = '1', the inductor current limit is 1.7A typ.

M/F Functionality Configuration Table

$\overline{\text{RESET}}$	MODE	M/F Function
0	X	$\overline{\text{RESET}}$
1	0	GPI
1	1	GPO

Current Step Time Register

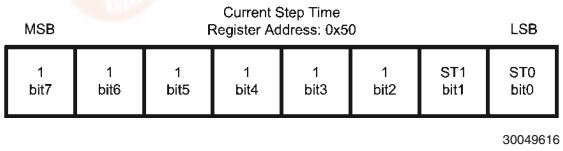


FIGURE 11.

ST1-ST0: Sets current level stepping time for D1 and D2 during the beginning and end of the flash or torch current waveform. '00' = 25µs, '01' = 50µs, '10' = 100µs, '11' = 200µs.

The current ramp-up/ramp-down times can be approximated by the following equation:

$T_{RAMPUP/RAMPDOWN} = (N_{FLASH} - N_{START} + 1) \times t_{STEP}$ where N is equal to the decimal value of the brightness level ($0 \leq N_{FLASH} \leq 127$ and $0 \leq N_{START} \leq 31$). $N_{START} = N_{TORCH}$ if Torch is enabled before going into a flash. If going straight into a flash from an off-state, $N_{START} = 0$

Torch Current Control Register

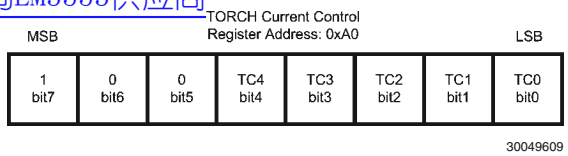


FIGURE 12.

TC6-TC0: Sets Torch current level for D1 and D2. xxx1 1111 = Full-scale

Flash Current Control Register

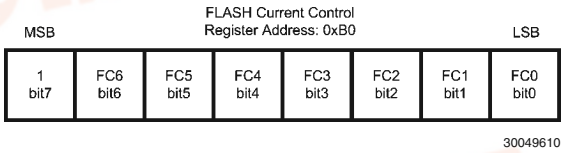


FIGURE 13.

FC6-FC0: Sets Flash current level for D1 and D2. x111 1111 = Full-scale

Current Level Equation

The Full-Scale Flash Current Level is set through the use of an external resistor (R_{SET}) connected to the I_{SET} pin. The R_{SET} selection equation can be used to set the current through each of the two current sinks, D1 and D2.

$$R_{SET} = 6770 \times 1.24V \div I_{Dx}$$

R_{SET} Selection Table

I_{Flash} = ID1 + ID2	R_{SET}
500mA	33.6kΩ
600mA	28kΩ
1A	16.8kΩ
1.2A	14kΩ

The current through each current sink, D1 and D2, can be approximated by the following equation using the values stored in either the Torch or Flash Current Control registers.

$$I_{FLASH} \cong (N + 1) \times I_{LED\_TOTAL} \div 128$$

where N is the decimal equivalent number ($0 \le N \le 127$ for Flash and $0 \le N \le 31$ for Torch) stored in the Torch or Flash Current control registers and $I_{LED\_TOTAL} = I_{D1} + I_{D2}$ @ Full-scale. Brightness codes 0 through 4 are repeated and each sets the total LED current to approximately 40mA.

Flash Safety Timer Control Register

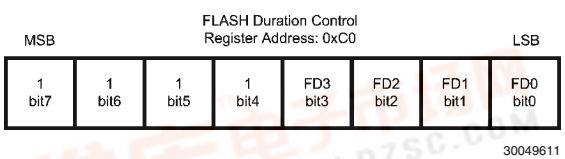


FIGURE 14.

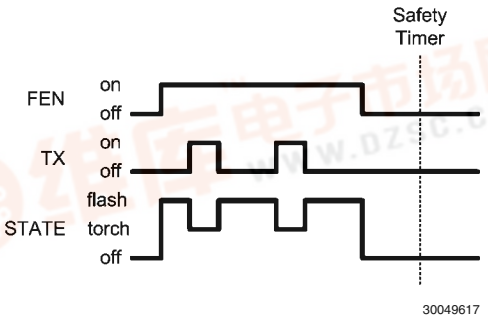
FD3-FD0: Sets Flash Duration for D1 and D2. 1111 = Full-scale

Safety Timer Duration Code (Binary)	Typical Safety Timer Duration (milliseconds)
0000	50
0001	100
0010	200
0011	300
0100	400
0101	500
0110	600
0111	700
1000	800
1001	900
1010	1000
1011	1100
1100	1200
1101	1300
1110	1400
1111	3200

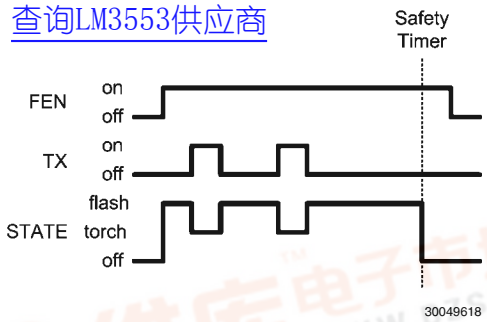
LM3553 Functionality Truth Table

EN1	EN0	F_{EN}	T_X	Result
0	0	0	0	Shutdown
0	0	0	1	Shutdown
0	0	1	0	Flash
0	0	1	1	Torch
0	1	0	0	Indicator
0	1	0	1	Indicator
0	1	1	0	Flash
0	1	1	1	Torch
1	0	0	0	Torch
1	0	0	1	Torch
1	0	1	0	Flash
1	0	1	1	Torch
1	1	0	0	Flash
1	1	0	1	Torch
1	1	1	0	Flash
1	1	1	1	Torch

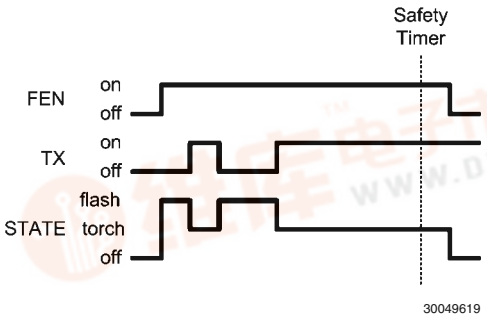
FEN Terminated Pulse



Safety Timer Terminated Pulse



TX Terminated Pulse



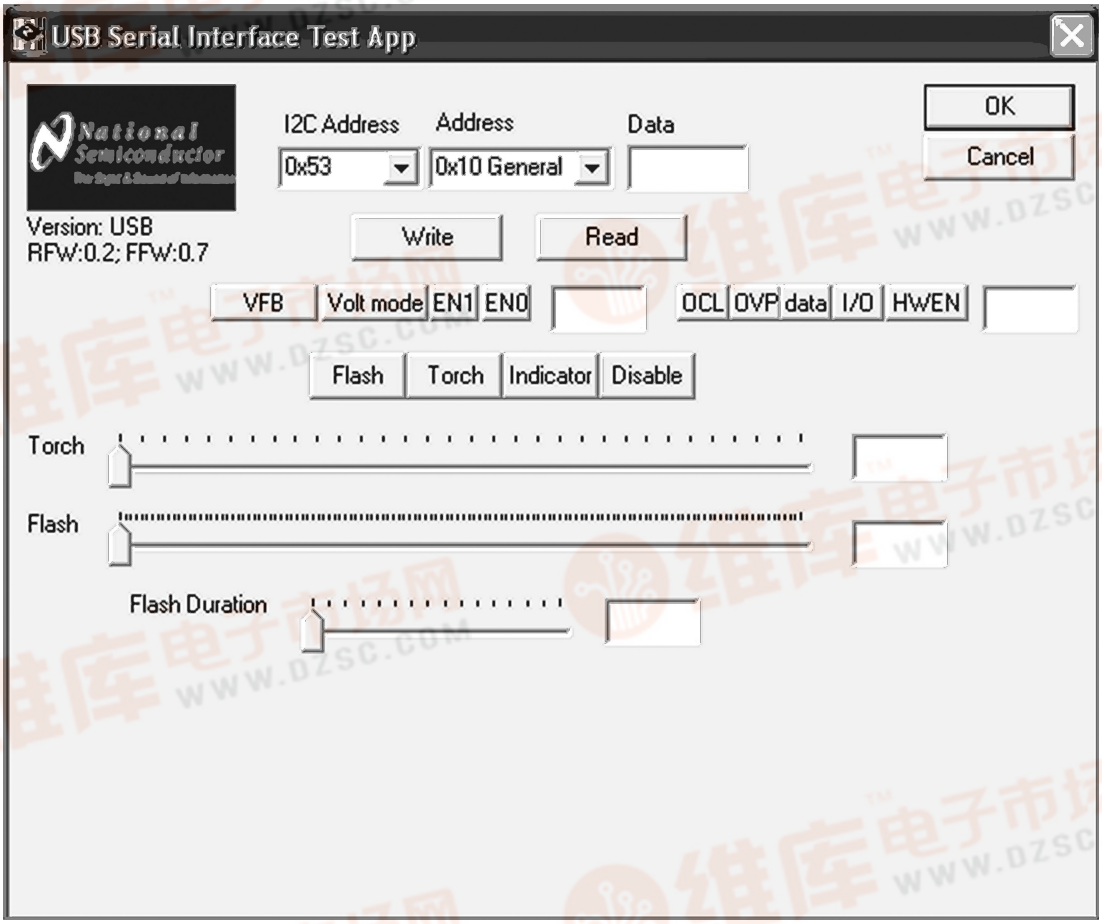
Software Interface Information

In order to fully evaluate the LM3553 part, an "I²C Compatible" interface must be used for any functionality to occur. A detailed description of the interface control is described in the LM3553 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 LM3553 evaluation board has the means to "plug into" the USB docking board. The USB docking board provides all of the control signals for the simple interface. Power to the part must be provided externally. 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 LM3553 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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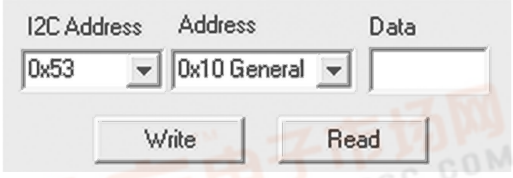
GUI Start-Up

At the top of the interface, the user can read or write to any of the data registers on the LM3553 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 Control Registers.

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- VFB: Toggles the Feedback voltage between 450mV (default) and 350mV. When depressed, the feedback voltage will be set to 350mV
- Volt Mode: Places the LM3553 into voltage output mode. When depressed, the part will output 4.98V.
- EN1 and EN0: These bits place the part into either shutdown, indicator, torch or flash. '00' = Shutdown, '01'=Indicator, '10'=Torch, '11'=Flash.

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- OCL: Toggles the inductor current limit between 2.5A (default) and 1.7A. When the OCL button is depressed, the current limit will be set to 1.7A
- OVP: Toggles the over-voltage protection level between 5.6V (default) and 18.9V. When the OVP button is depressed, the OVP level will be set to 18.9V
- Data, I/O, HWEN: These buttons control the functionality of the M/F pin. Please refer to the M/F pin description for a detailed description of the M/F pin operation.

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- Flash: Starts a Flash event by setting the EN1 and EN0 bits to 1's.
- Torch: Starts a Torch event by setting the EN1 bit to a '1' and EN 0 bit to a '0'.
- Indicator: Starts an Indicator event by setting the EN1 bit to a '0' and EN 0 bit to a '1'.
- Disable: Shuts down the LM3553 by setting the EN1 and EN0 bits to 0's.

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- Torch Slider: Sets the Torch brightness to any allowable brightness code (0 to 31)
- Flash Slider: Sets the Flash brightness to any allowable brightness code (0 to 127)
- Flash Duration: Sets the Flash duration to one of the 16 built-in time durations (0 to 15)

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 LM3553 part will remain in the last controlled state.

Notes

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