LM3530 Evaluation Kit

National Semiconductor
Application Note 1991
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Introduction

The LM3530 current mode boost converter supplies the power and controls the current in a series LED string of up to 40V. The 839 mA current limit and 2.7V to 5.5V input voltage range, makes the device a versatile backlight power source ideal for operation with Li+ batteries.

The LED current is adjustable from 0 to 29.5 mA via an I2C compatible interface. The 127 different current steps and 8 different maximum LED current levels (full scale LED current) gives a wide range of programmable LED currents. A PWM brightness control input allows for the backlight current to be a function of the brightness code and the PWM duty cycle. Two Ambient Light Sensor inputs are available to interface with two analog output ambient light sensors. These provide for the automatic adjustment of the LED current due to changes in the ambient light. Each ambient light sensor input has independently programmable internal voltage setting resistors which can be made high impedance to reduce power during shutdown.

The LM3530's 500 kHz switching frequency allows for high converter efficiency over a wide output voltage range accommodating from 2 to 11 series LEDs.
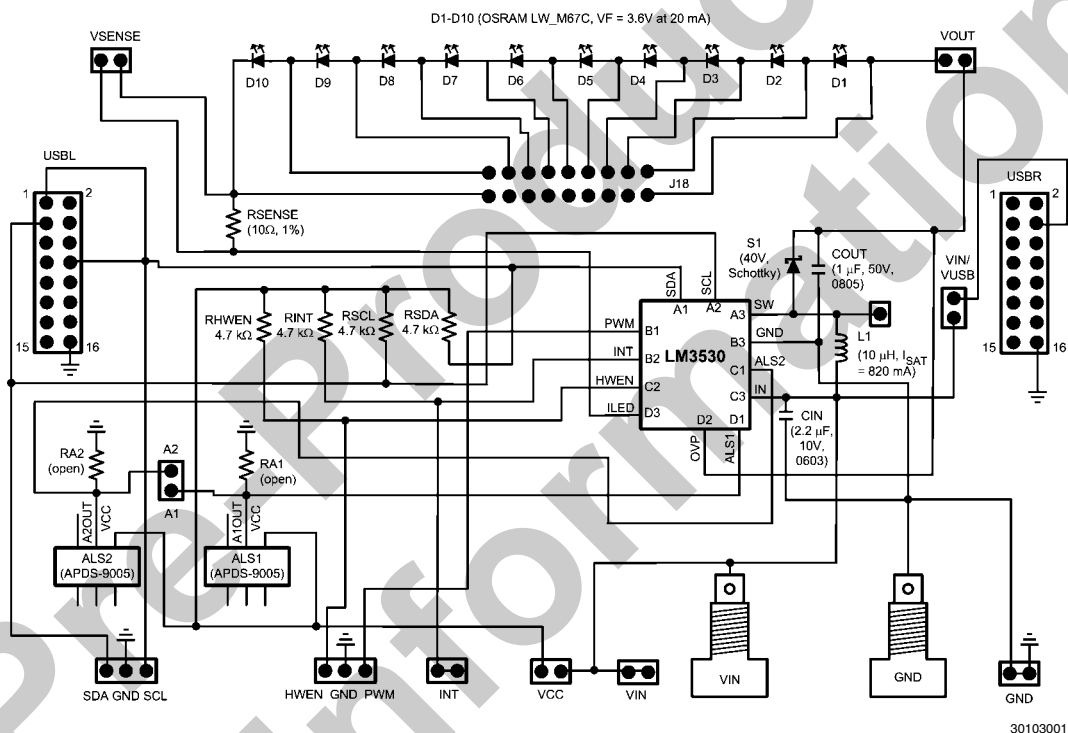

FIGURE 1. LM3530 Evaluation Board Schematic

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LM3530 Evaluation Board Bill of Materials

Component Symbol	Value	Manufacturer	Part #	Size
U1	LED Driver	National Semiconductor	LM3530	(0.4mm × 1.215mm × 1.615mm)
L1	10 µH, I_{SAT} = 820mA, R_L = 0.25Ω	TDK	VLF34014ST-100MR82	(2.8mm x 3mmx 1.4mm)
CIN	2.2 µF, 10V	TDK	GRM188B31A225KE33	0603 (1.6mm x 0.8mm x 0.8mm)
COUT	1 µF, 50V	TDK	GRM21BR71H105KA12	0805 (2mm x 1.25mm x 1.25mm)
D1-D10	White LED	Osram	LW M67C	0805
RHWEN	4.7 kΩ	YAEGO	RC0603FR-074K7L	0603
RSDA	4.7 kΩ	YAEGO	RC0603FR-074K7L	0603
RSCL	4.7 kΩ	YAEGO	RC0603FR-074K7L	0603
RINT	4.7 kΩ	YAEGO	RC0603FR-074K7L	0603
S1	Schottky, 40V, 500 mA	Diodes Incorporated	B0540WS	SOD-323 (1.7mm x 1.3mm x 1.05mm)
RSENSE	10Ω, 1%	Vishay	CRCW080510R0 FKEA	0805
ALS1	0 - 1100 LUX Ambioent Light Sensor	Avago	APDS-9005	(1.6mm x 1.5mm x 0.55mm)
ALS2	0 - 1100 LUX Ambioent Light Sensor	Avago	APDS-9005	(1.6mm x 1.5mm x 0.55mm)
RA1	not installed			0603
RA2	not installed			0603
CBYP	not installed (bottom layer)			0805

LM3530 Evaluation Board Layout

FIGURE 2. Top Layer

FIGURE 3. Mid Layer 1

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3060.00
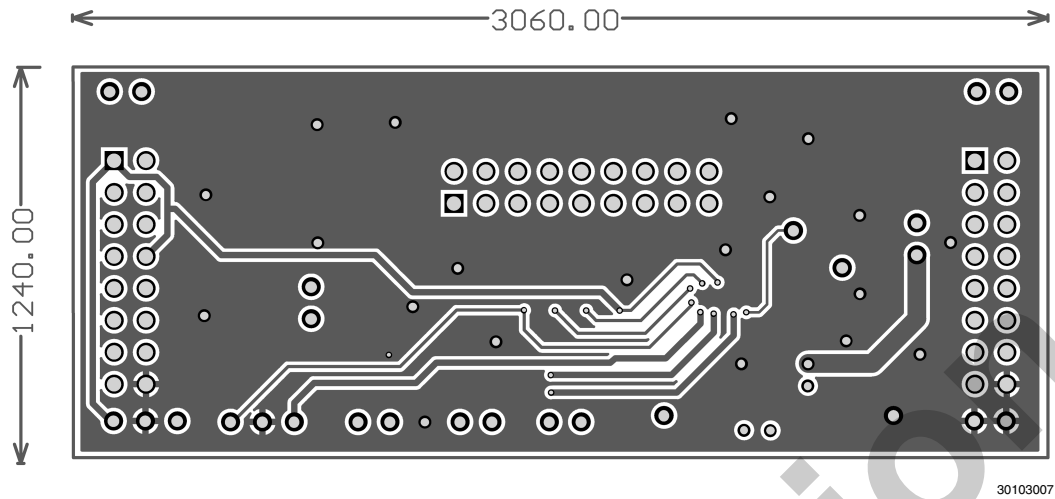
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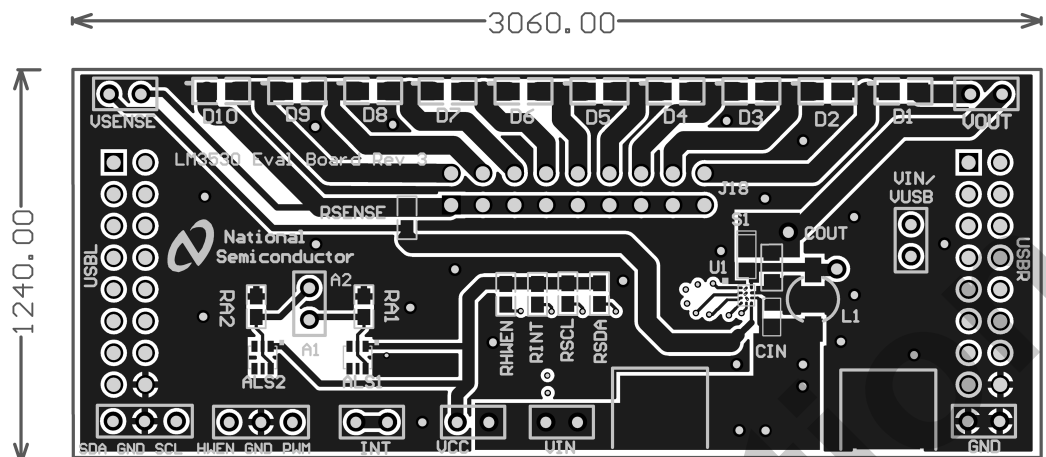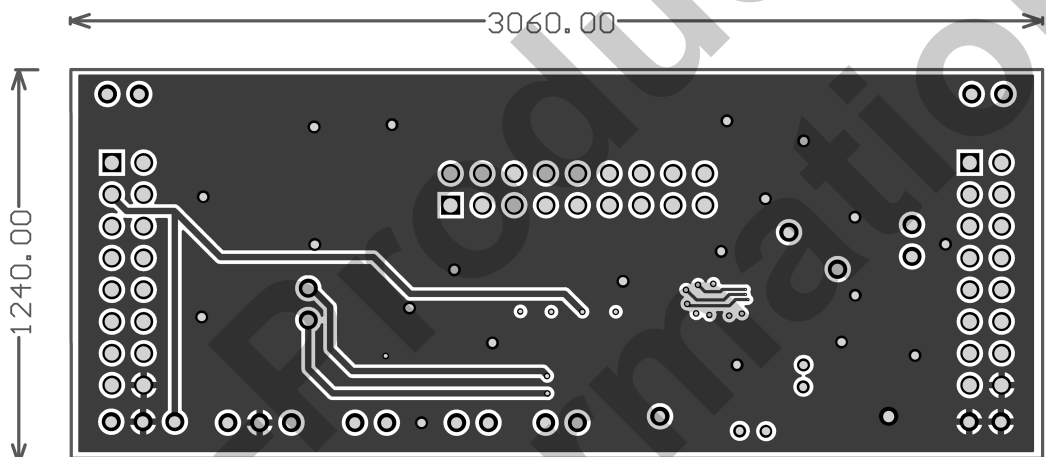
30103007

FIGURE 4. Mid Layer 2
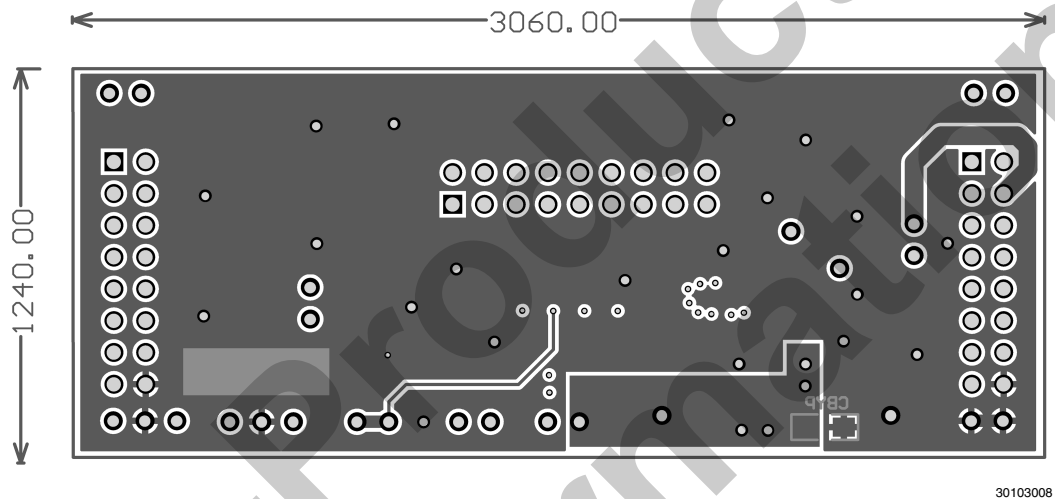
3060.00

1240.00

30103008

FIGURE 5. Bottom Layer

LM3530 Graphical User Interface (GUI) Instructions

The GUI for the LM3530 is designed to fully demonstrate all the features of the LM3530 High Voltage White LED Backlight Driver. The GUI provides the interface between the PC and the National Semiconductor USB Interface Board + LM3530 Evaluation Board. A picture of the interface program (LM3530.exe) is shown in *Figure 6*.
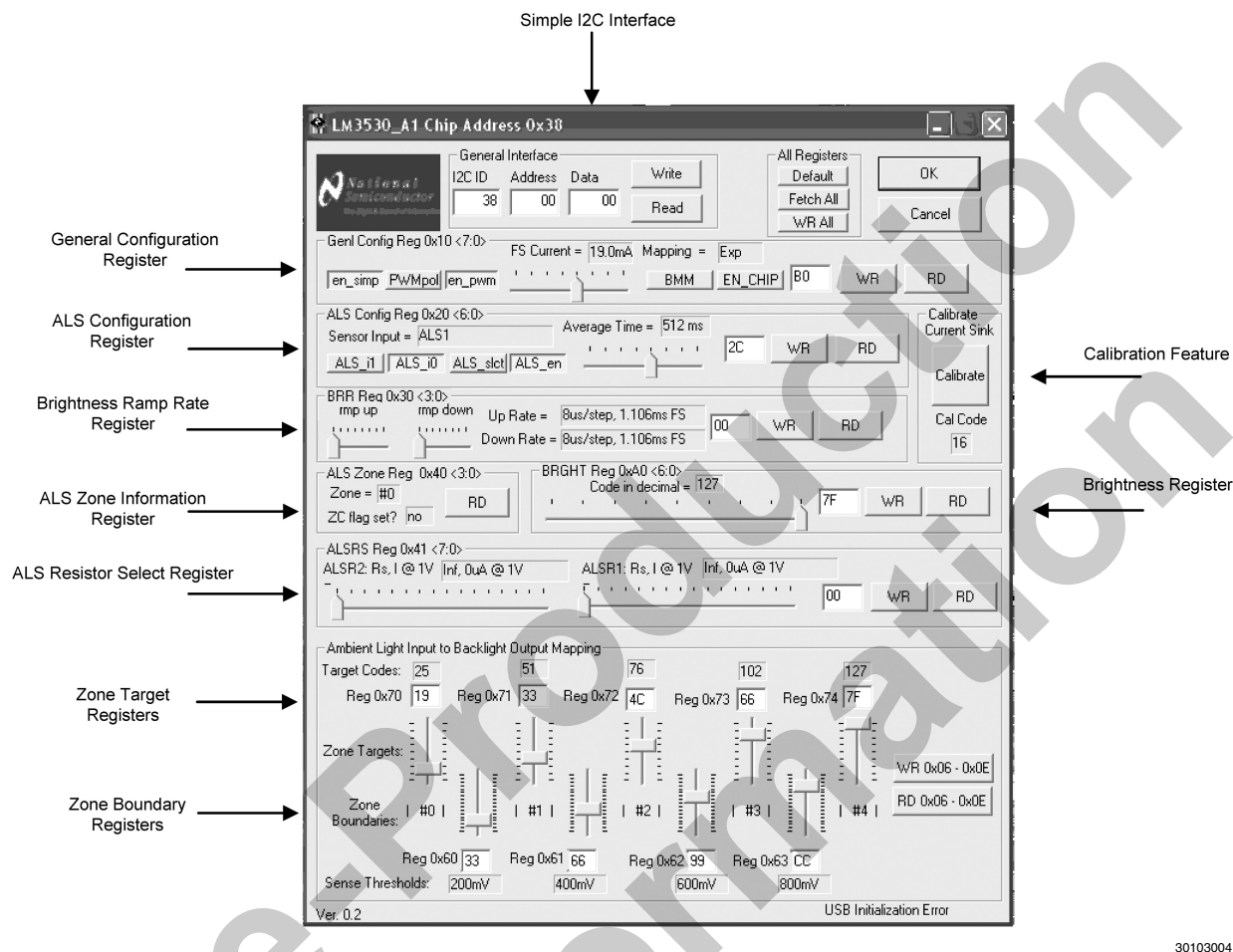
LM3530 G.U.I.

FIGURE 6. LM3530.exe Program

Simple I²C Interface

The top middle portion of the GUI has a simple I²C interface (General Interface). In this section are three text boxes (I²C ID, Address, and Data). The I²C ID box is pre-loaded with the device address (0x38). For evaluation of the 25V devices with an I²C I.D. of 0x36, simply enter 36 in the I²C ID field. The Address field is writable by the user and accepts one of the LM3530's register address's. The Data field is both writable and readable by the user and contains the data to be written or the data to be read back. The Write and Read buttons select either an I²C write or an I²C read.

General Configuration Register

The General Configuration Register portion of the GUI contains the programmable features available within the LM3530's General Configuration Register (see). The left-most button (en_simple) corresponds to bit 7 of the register and the right-most button (EN_CHIP) corresponds to bit 0. When a button is pushed a logic '1' is written to the appropriate bit. When a button is un pushed a logic zero is written. The FS current slider programs the full scale currents (bits [5:2]). The slider moved fully to the left corresponds to 5mA of full scale current. When a button is pushed or unpushed or the slider is moved to a new location the WR button must be depressed in order to write the new bit settings to the LM3530's General Configuration Register.

TABLE 1. General Configuration Register Description (0x10)

Bit 7 (PWM Simple Enable	Bit 6 (PWM Polarity)	Bit 5 (EN_PWM) see Figure 8	Bit 4 (Full Scale Current Select)	Bit 3 (Full Scale Current Select)	Bit 2 (Full Scale Current Select)	Bit 1 (Mapping Mode Select)	Bit 0 (I²C Device Enable)
0 = Simple Interface at PWM Input is Diasbled 1 = Simple Interface at PWM Input is Enabled	0 = PWM active high 1 = PWM active low	0 = LED current is not a function of PWM duty cycle 1 = LED current is a function of duty cycle	000 = 5 mA full-scale current 001 = 8.5 A full-scale current 010 = 12 mA full-scale current 011 = 15.5 mA full-scale current 100 = 19 mA full-scale current 101 = 22.5 mA full-scale current 110 = 26 mA full-scale current 111 = 29.5 mA full-scale current			0 = exponential mapping 1 = linear mapping	0 = Device Disabled 1 = Device Enabled

ALS Configuration Register

The ALS Configuration Register portion of the GUI contains the programmable features available within the LM3530's ALS Configuration Register. displays this register and the corresponding bit descriptions. The ALS_i1 and ALS_i2 buttons correspond to bits 6 and 5. When a button is pushed a '1' is written to the bit. When a button is un-pushed a '0' is written. The Average Time slider corresponds to bits [2:0]. With the slider moved all the way to the left the ALS averaging time is set for 32ms. With this slider moved to the right the ALS averaging time is set for 4.096s. Once a button is pushed (or unpushed) or a slider is moved to the desired location the WR button must be pushed in order to write the new configuration to the ALS Configuration Register.

TABLE 2. ALS Configuration Register Description (0x20)

Bit 7	Bit 6 ALS Input Select	Bit 5 ALS Input Select	Bit 4 ALS Enable	Bit 3 ALS Enable	Bit 2 ALS Averaging Time	Bit 1 ALS Averaging Time	Bit 0 ALS Averaging Time
N/A	00 = The Average of ALS1 and ALS2 is used to control the LED brightness 01 = ALS1 is used to control the LED brightness 10 = ALS2 is used to control the LED brightness 11 = The ALS input with the highest voltage is used to control the LED brightness		00 or 10 = ALS is **disabled.** The Brightness Register is used to determine the LED current. 01 = ALS is **enabled**, but not selected. As a result the Brightness Register is used to determine the LED Current. 11 = ALS inputs are **enabled.** Ambient light determines the LED current.		000 = 32 ms 001 = 64 ms 010 = 128 ms 011 = 256 ms 100 = 512 ms 101 = 1024 ms 110 = 2048 ms 111 = 4096 ms		

Brightness Ramp Rate Register (BRR Reg)

The BRR Reg portion of the GUI contains the programmable features available within the Brightness Ramp Rate Register. displays this register and the corresponding bit descriptions. The left slider rmp up programs bits [3:2] and the right most slider programs bits [1:0]. A slider fully to the left programs the bits with 0's (8 µs/step) and a slider fully to the right programs the bits with 1's (65.538 ms/step). Once the slider is moved to the desired location the WR button must be pushed to write the new code to the BRR Register.

TABLE 3. Brightness Ramp Rate Register Description (0x30)

Bit 7	Bit 6	Bit 5 (BRRI3)	Bit 4 (BRRI2)	Bit 3 (BRRI1)	Bit 2 (BRRD3)	Bit 1 (BRRD2)	Bit 0 (BRRD1)
N/A	N/A	000 = 8 µs/step 001 = 1.024 ms/step 010 = 2.048 ms/step 011 = 4.096 ms/step 100 = 8.192 ms/step 101 = 16.384 ms/step 110 = 32.768 ms/step 111 = 65.538 ms/step)			000 = 8 µs/step 001 = 1.024 ms/step 010 = 2.048 ms/step 011 = 4.096 ms/step 100 = 8.192 ms/step 101 = 16.384 ms/step 110 = 32.768 ms/step 111 = 65.538 ms/step		

ALS Zone Information Register

The ALS Zone Information Register section of the GUI displays the contents of the ALS Zone Information Register each time the RD button is pushed. details the bit information of this register. The (ZC flag set?) text box corresponds to bit [3] and will return a (yes) if a new ALS zone was entered since the last read of the ALS Zone Information Register. The (Zone =) text box corresponding to bits [2:0], displays the current ALS zone.

TABLE 4. ALS Zone Information Register (0x40)

Bit 7	Bit 6t	Bit 5	Bit 4	Bit 3 ALS Enable	Bit 2 (Z2)	Bit 1 (Z1)	Bit 0 (Z0)
N/A	N/A	N/A	N/A	1 = the active ALS input has changed to a new ambient light zone as programmed in the Zone Boundary Registers (ZB0 — ZB3) 0 = no zone change	000 = Zone 0 001 = Zone 1 010 = Zone 2 011 = Zone 3 100 = Zone 4		

Brightness Register (0xA0)

The BRGHT Reg portion of the GUI provides Read and Write capabilities for the Brightness Register. The single slider will transition the brightness codes from all zeroes (slider fully left) to all 1's (slider fully right). When the slider is moved to the desired location the WR button must be pushed in order to write the new Brightness Register code. Alternatively, the hexadecimal code can be entered into the textbox to the right of the slider and the WR button can be pushed to write this new code. When the RD button is pushed the Brightness Register contents are readback and displayed in this textbox. and detail the brightness register codes and their corresponding percentage of full scale current. corresponds to the exponential response, and corresponds to the linear response (see General Configuration Register bit [1]).

TABLE 5. Brightness Register Data (Exponential Mapping)

BRT Data (Hex)	% Full Scale Current	BRT Data (Hex)	% of Full Scale Current	BRT Data (Hex)	% of Full Scale Current	BRT Data (Hex)	% of Full Scale Current
0x00	0.00%	0x20	0.500%	0x40	2.953%	0x60	17.813%
0x01	0.080%	0x21	0.523%	0x41	3.125%	0x61	18.750%
0x02	0.086%	0x22	0.555%	0x42	3.336%	0x62	19.922%
0x03	0.094%	0x23	0.586%	0x43	3.500%	0x63	20.859%
0x04	0.102%	0x24	0.617%	0x44	3.719%	0x64	22.266%
0x05	0.109%	0x25	0.656%	0x45	3.906%	0x65	23.438%
0x06	0.117%	0x26	0.695%	0x46	4.141%	0x66	24.844%
0x07	0.125%	0x27	0.734%	0x47	4.375%	0x67	26.250%
0x08	0.133%	0x28	0.773%	0x48	4.648%	0x68	27.656%
0x09	0.141%	0x29	0.820%	0x49	4.922%	0x69	29.297%
0x0A	0.148%	0x2A	0.867%	0x4A	5.195%	0x6A	31.172%
0x0B	0.156%	0x2B	0.914%	0x4B	5.469%	0x6B	32.813%
0x0C	0.164%	0x2C	0.969%	0x4C	5.781%	0x6C	34.453%
0x0D	0.172%	0x2D	1.031%	0x4D	6.125%	0x6D	35.547%
0x0E	0.180%	0x2E	1.078%	0x4E	6.484%	0x6E	38.828%
0x0F	0.188%	0x2F	1.148%	0x4F	6.875%	0x6F	41.016%
0x10	0.203%	0x30	1.219%	0x50	7.266%	0x70	43.203%
0x11	0.211%	0x31	1.281%	0x51	7.656%	0x71	45.938%
0x12	0.227%	0x32	1.359%	0x52	8.047%	0x72	48.438%
0x13	0.242%	0x33	1.430%	0x53	8.594%	0x73	51.406%
0x14	0.250%	0x34	1.523%	0x54	9.063%	0x74	54.141%
0x15	0.266%	0x35	1.594%	0x55	9.609%	0x75	57.031%
0x16	0.281%	0x36	1.688%	0x56	10.078%	0x76	60.703%
0x17	0.297%	0x37	1.781%	0x57	10.781%	0x77	63.984%
0x18	0.320%	0x38	1.898%	0x58	11.250%	0x78	67.813%
0x19	0.336%	0x39	2.016%	0x59	11.953%	0x79	71.875%
0x1A	0.352%	0x3A	2.109%	0x5A	12.656%	0x7A	75.781%
0x1B	0.375%	0x3B	2.250%	0x5B	13.359%	0x7B	79.688%
0x1C	0.398%	0x3C	2.367%	0x5C	14.219%	0x7C	84.375%
0x1D	0.422%	0x3D	2.508%	0x5D	15.000%	0x7D	89.844%
0x1E	0.445%	0x3E	2.648%	0x5E	15.859%	0x7E	94.531%
0x1F	0.469%	0x3F	2.789%	0x5F	16.875%	0x7F	100.00%

TABLE 6. Brightness Register Data (Linear Mapping)

BRT Data (Hex)	% Full Scale Current (Linear)	BRT Data (Hex)	% of Full Scale Current (Linear)	BRT Data (Hex)	% of Full Scale Current (Linear)	BRT Data (Hex)	% of Full Scale Current (Linear)
0x00	0.00%	0x20	25.20%	0x40	50.39%	0x60	75.59%
0x01	0.79%	0x21	25.98%	0x41	51.18%	0x61	76.38%
0x02	1.57%	0x22	26.77%	0x42	51.97%	0x62	77.17%
0x03	2.36%	0x23	27.56%	0x43	52.76%	0x63	77.95%
0x04	3.15%	0x24	28.35%	0x44	53.54%	0x64	78.74%
0x05	3.94%	0x25	29.13%	0x45	54.33%	0x65	79.53%
0x06	4.72%	0x26	29.92%	0x46	55.12%	0x66	80.31%
0x07	5.51%	0x27	30.71%	0x47	55.91%	0x67	81.10%
0x08	6.30%	0x28	31.50%	0x48	56.69%	0x68	81.89%
0x09	7.09%	0x29	32.28%	0x49	57.48%	0x69	82.68%
0x0A	7.87%	0x2A	33.07%	0x4A	58.27%	0x6A	83.46%
0x0B	8.66%	0x2B	33.86%	0x4B	59.06%	0x6B	84.25%
0x0C	9.45%	0x2C	34.65%	0x4C	59.84%	0x6C	85.04%
0x0D	10.24%	0x2D	35.43%	0x4D	60.63%	0x6D	85.83%
0x0E	11.02%	0x2E	36.22%	0x4E	61.42%	0x6E	86.61%
0x0F	11.81%	0x2F	37.01%	0x4F	62.20%	0x6F	87.40%
0x10	12.60%	0x30	37.80%	0x50	62.99%	0x70	88.19%
0x11	13.39%	0x31	38.58%	0x51	63.78%	0x71	88.98%
0x12	14.17%	0x32	39.37%	0x52	64.57%	0x72	89.76%
0x13	14.96%	0x33	40.16%	0x53	65.35%	0x73	90.55%
0x14	15.75%	0x34	40.94%	0x54	66.14%	0x74	91.34%
0x15	16.54%	0x35	41.73%	0x55	66.93%	0x75	92.13%
0x16	17.32%	0x36	42.52%	0x56	67.72%	0x76	92.91%
0x17	18.11%	0x37	43.31%	0x57	68.50%	0x77	93.70%
0x18	18.90%	0x38	44.09%	0x58	69.29%	0x78	94.49%
0x19	19.69%	0x39	44.88%	0x59	70.08%	0x79	95.28%
0x1A	20.47%	0x3A	45.67%	0x5A	70.87%	0x7A	96.06%
0x1B	21.26%	0x3B	46.46%	0x5B	71.65%	0x7B	96.85%
0x1C	22.05%	0x3C	47.24%	0x5C	72.44%	0x7C	97.64%
0x1D	22.83%	0x3D	48.03%	0x5D	73.23%	0x7D	98.43%
0x1E	23.62%	0x3E	48.82%	0x5E	74.02%	0x7E	99.21%
0x1F	24.41%	0x3F	49.61%	0x5F	74.80%	0x7F	100.00%

ALS Resistor Selector Register

The ALS Resistor Select Register section of the GUI controls the internal ALS resistors. details the bit information of this register. The two sliders select one of the 16 available internal resistances from either ALS1 to GND or ALS2 to GND. Once the appropriate slider is set to its correct position, the WR button must be pressed in order to load the ALS Resistor Select Register with the new data. A read of the ALSRS register will automatically update the field to the right of the sliders and also update the slider.

TABLE 7. ALS Resistor Select Register Description (0x41)

Bit 7 (ALSR2A)	Bit 6 (ALSR2B)	Bit 5 (ALSR2C)	Bit 4 (ALSR2D)	Bit 3 (ALSR1A)	Bit 2 (ALSR1B)	Bit 1 (ALSR1C)	Bit 0 (ALSR1D)
0000 = ALS2 is high impedance				0000 = ALS2 is high impedance			
0001 = 13.531 kΩ (73.9 µA at 1V)				0001 = 13.531 kΩ (73.9 µA at 1V)			
0010 =9.011 kΩ (111 µA at 1V)				0010 =9.011 kΩ (111 µA at 1V)			
0011 = 5.4116 kΩ (185 µA at 1V)				0011 = 5.4116 kΩ (185 µA at 1V)			
0100 = 2.271 kΩ (440 µA at 1V)				0100 = 2.271 kΩ (440 µA at 1V)			
0101 = 1.946 kΩ (514 µA at 1V)				0101 = 1.946 kΩ (514 µA at 1V)			
0110 = 1.815 kΩ (551 µA at 1V)				0110 = 1.815 kΩ (551 µA at 1V)			
0111 = 1.6 kΩ (625 µA at 1V)				0111 = 1.6 kΩ (625 µA at 1V)			
1000 = 1.138 kΩ (879 µA at 1V)				1000 = 1.138 kΩ (879 µA at 1V)			
1001 = 1.05 kΩ (952 µA at 1V)				1001 = 1.05 kΩ (952 µA at 1V)			
1010 = 1.011 kΩ (989 µA at 1V)				1010 = 1.011 kΩ (989 µA at 1V)			
1011 = 941Ω (1.063 mA at 1V)				1011 = 941Ω (1.063 mA at 1V)			
1100 = 759Ω (1.318 mA at 1V)				1100 = 759Ω (1.318 mA at 1V)			
1101 = 719Ω (1.391 mA at 1V)				1101 = 719Ω (1.391 mA at 1V)			
1110 = 700Ω (1.429 mA at 1V)				1110 = 700Ω (1.429 mA at 1V)			
1111 = 667Ω (1.499 mA at 1V)				1111 = 667Ω (1.499 mA at 1V)			

Zone Boundary Registers and Zone Target Registers

The bottom section of the GUI contains the controls for writing data to the Zone Boundary and Zone Target Registers. The top 5 sliders allow for the 7-bit brightness data to be written to the Zone Target Registers (0 – 4). With the sliders at the bottom corresponding to code 0x00 and the sliders all the way to the top corresponding to code 0x7F. The 4 bottom sliders allow for the 8-bit zone boundary data to be programmed to the Zone Boundary Registers (0 -3). Alternatively, there are text boxes corresponding to each of the Zone Target and Zone Boundary Registers that will accept the raw hex data for each of the registers. Once the data is selected either by moving the slider or by typing the hex number in the appropriate textbox, the (WR 0x06 - 0x0E) button must be pressed in order to write the data to the device. A read from the Zone Boundary and Zone Target Registers is done by pressing the (RD 0x06 – 0x0E) button.

Calibrate Current Sink Field

The exponential code to LED current characteristic of the LM3530 is designed to produce both a high dimming ratio and an "eye perceived linear" brightness ramp vs. code (exponential response). The LM3530 production devices will undergo a permanent exponential characteristic calibration that insures a high dimming ratio and smooth code to code output current characteristic. Early evaluation boards that utilize engineering samples that have not been production calibrated can be calibrated via the LM3530 GUI. The software calibration is volatile, meaning that it must be repeated any time power is removed from the device and reapplied. To calibrate the output characteristic first apply power to the device. Next, click the calibrate button. The process occurs in a second or so, and the LED exponential characteristic is calibrated until power is removed from the device.

Notes

Notes

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LVDS	www.national.com/lvds	Packaging	www.national.com/packaging
Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage References	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Applications & Markets	www.national.com/solutions
Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero
Temperature Sensors	www.national.com/tempsensors	SolarMagic™	www.national.com/solarmagic
PLL/VCO	www.national.com/wireless	PowerWise® Design University	www.national.com/training

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