AN-2249 LM3532 Evaluation Kit

1 Introduction

The LM3532 Evaluation Board is designed to fully evaluate the LM3532 Triple Output, White LED Driver with I²C-Compatible Interface. For a detailed description of the LM3532 refer to the LM3532 datasheet. The board comes equipped with 3 series strings of 10 white LEDs. Additionally there are two ambient light sensors (Avago APDS-9005) which feed into the LM3532's ambient light sensor inputs (ALS1 and ALS2). Each Input and/or output from the LM3532 has its own separate header pin to serve as a test-point. Figure 1 shows the schematic of the Evaluation Board.

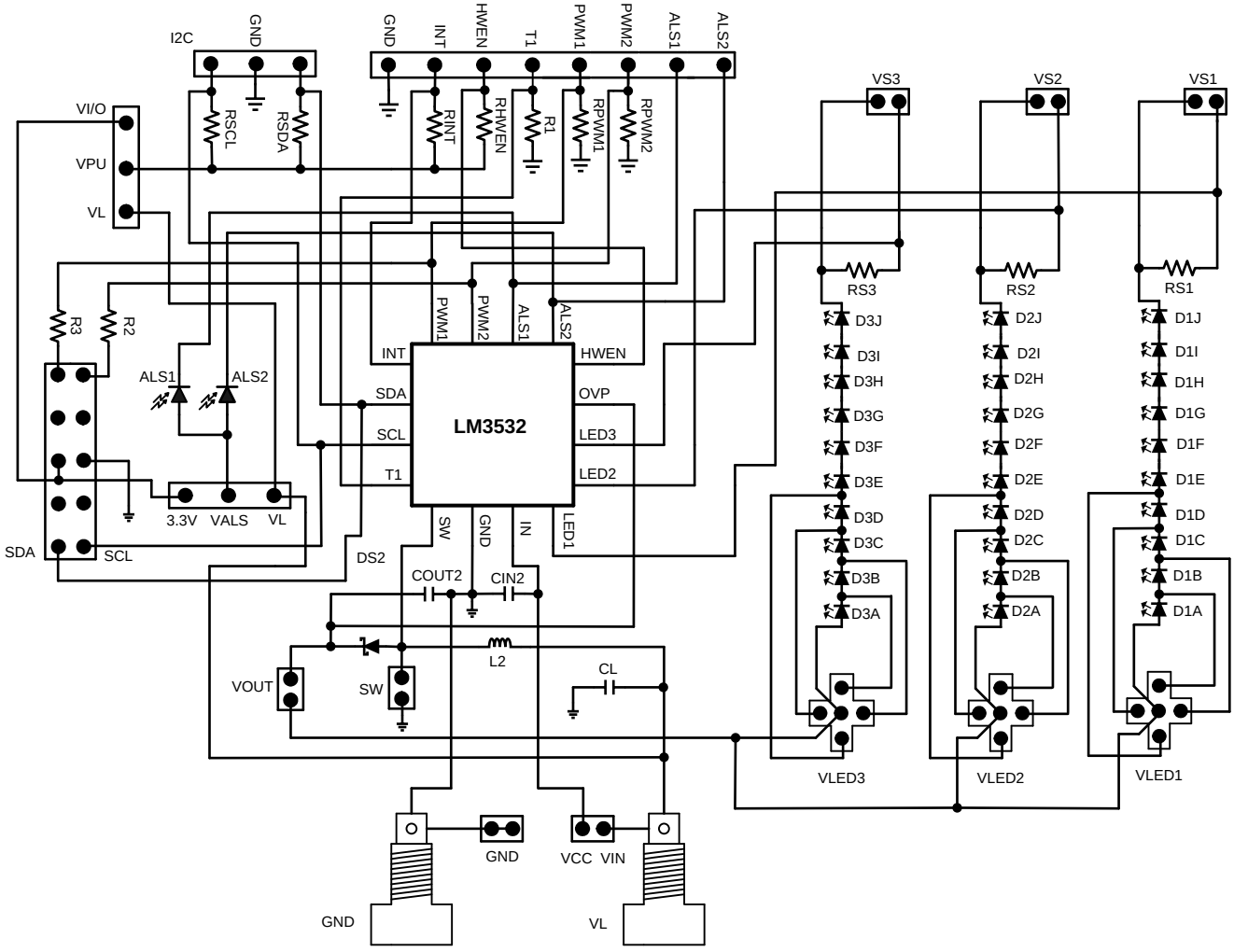

Figure 1. LM3532 Evaluation Board Schematic

The software supplied with the LM3532 Evaluation Kit (LM3532 GUI.exe) provides an easy method to evaluate all the features of the device via a PC. The LM3532 GUI.exe, when loaded on a PC, communicates to the LM3532 Eval Board through the Texas Instruments USB to I^2C controller (USB2ANY).

2 LM3532 Evaluation Board Bill of Materials

Component Symbol	Value	Manufacturer	Part #	Size (L x W x H)
U1	LED Driver	Texas Instruments	LM3532	(1.745mm x 1.845mm x 0.4mm)
L1	22µH, I_{SAT} = 700mA, R_L = 0.36Ω	TDK	LPS4018-223ML	(3.9mm x 3.9mmx 1.7mm)
CIN	2.2 µF, 25V	TDK	C1608X5R1E225K	0603 (1.6mm x 0.8mm x 0.8mm)
COUT	1 µF, 50V	TDK	C2012X7R1H105K	0805 (2mm x 1.25mm x 1.25mm)
D1-D10	White LED	ROHM	SML312WBCW1	0805
RHWEN	4.7 kΩ	Vishay-Dale	CRCW06034K70JNEA	0603
RSDA, RSDA	4.7 kΩ	Vishay-Dale	CRCW06034K70JNEA	0603
RINT	4.7 kΩ	Vishay-Dale	CRCW06034K70JNEA	0603
D1	Schottky, 40V, 250mA	On-Semi	NSR0240V2T1G	SOD-523 (1.2mm x 0.8mm x 0.6mm)
RS1, RS2, RS3	10Ω, 0.1%	Vishay	CRCW080510R0 FKEA	0805
ALS1	0 - 1100 LUX Ambient Light Sensor	Avago	APDS-9005	(1.6mm x 1.5mm x 0.55mm)
ALS2	0 - 1100 LUX Ambient Light Sensor	Avago	APDS-9005	(1.6mm x 1.5mm x 0.55mm)
R2, R3	0Ω	Vishay-Dale	CRCW06030000Z0EA	0603
CL	10µF	TDK	C1608X5R1A106M	0805
RPWM1, RPWM2	4.7kΩ	Vishay-Dale	CRCW06034K70JNEA	0603

3 LM3532 Evaluation Board Layout

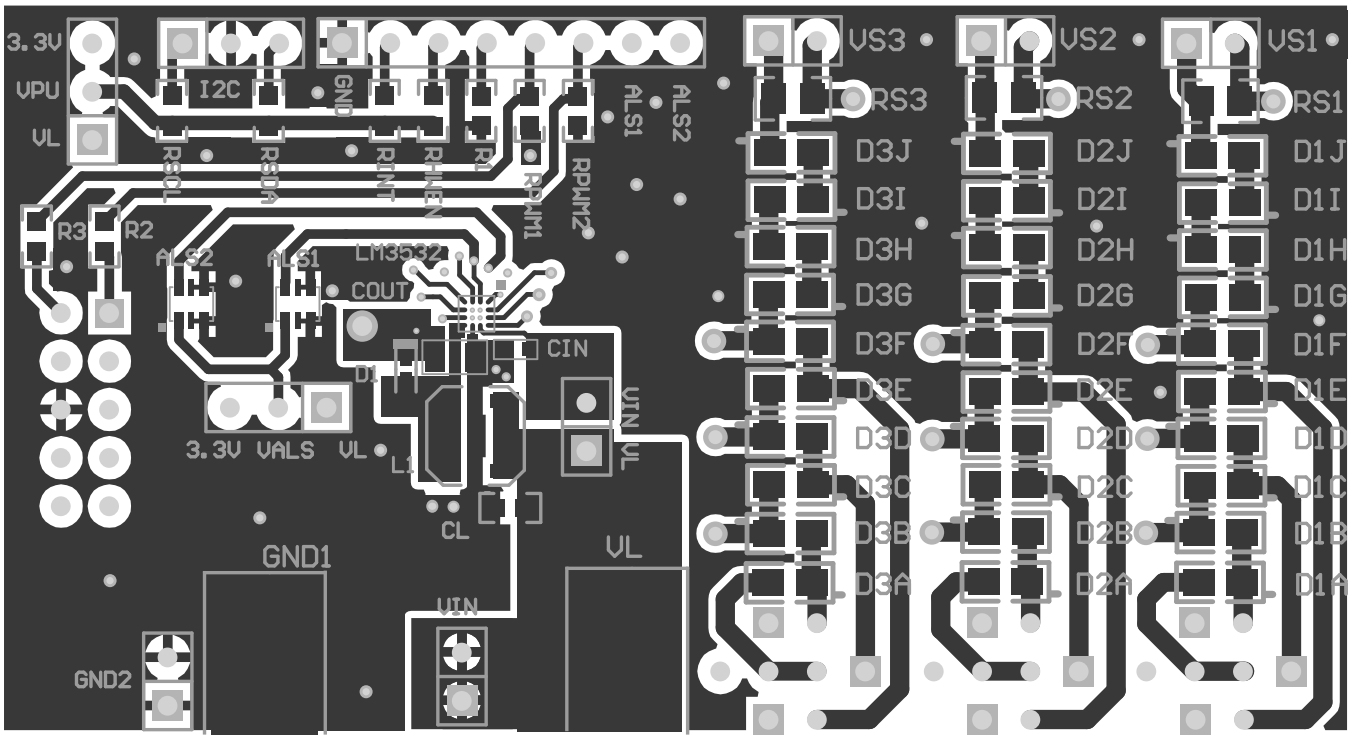

Figure 2. Top Layer

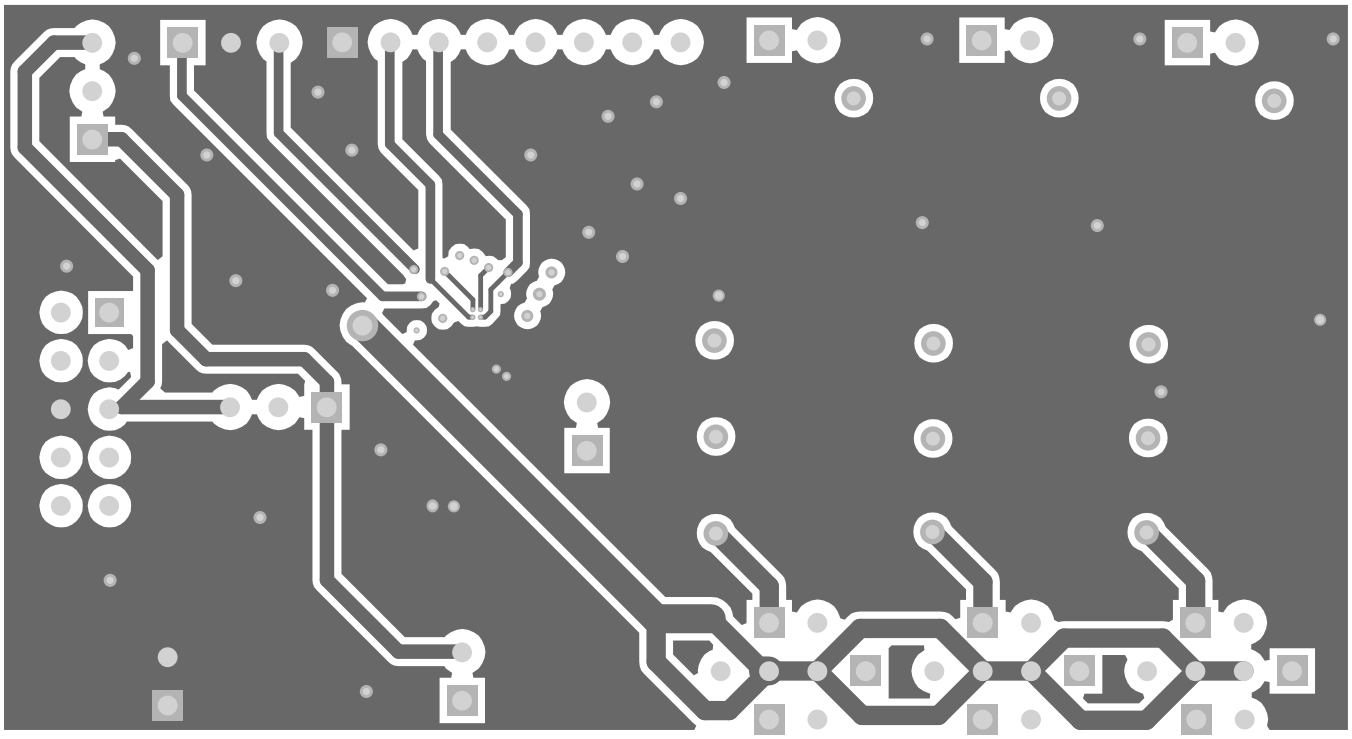

Figure 3. Mid Layer 1

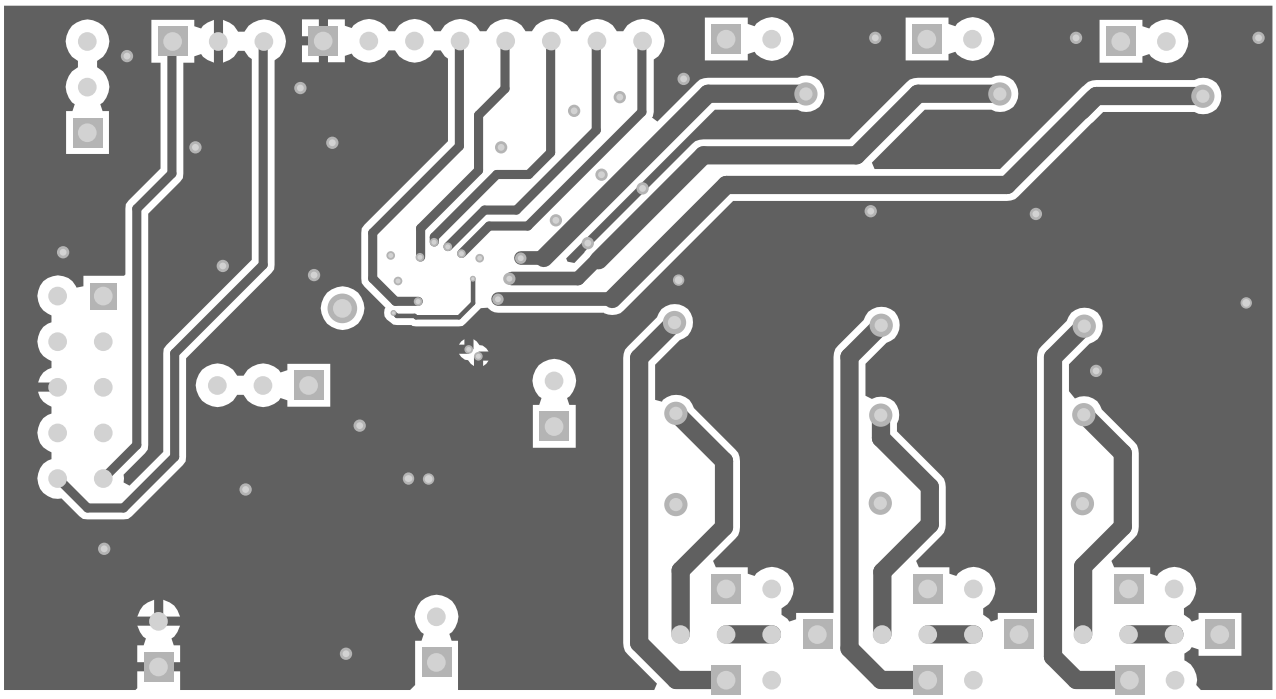

Figure 4. Mid Layer 2

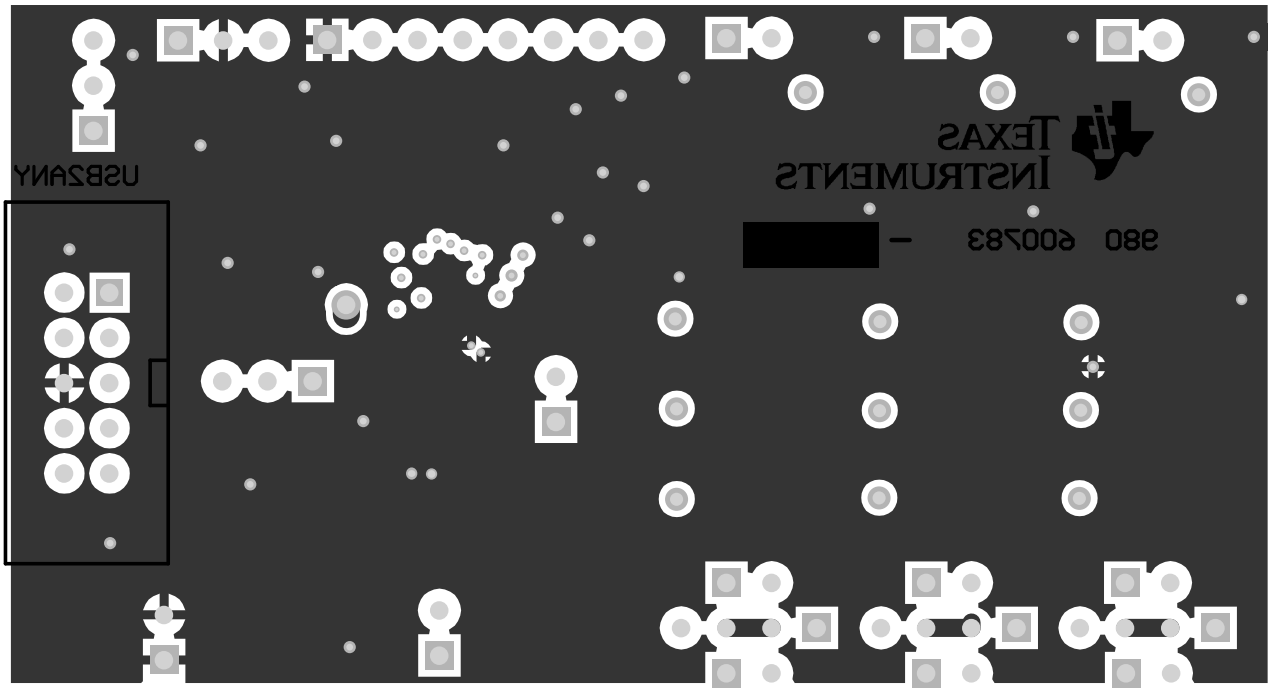

Figure 5. Bottom Layer

4 LM3532 Board Set-up

To operate the LM3532 Evaluation Board connect a jumper across the (VIN VL) header, a jumper at the (3.3V VPU VL) header, and a jumper at the VOUT header. The board should come with these jumpers already installed. The jumper at (VIN VL) connects the supply at VL to the IN pin of the device. The jumper at (3.3V VPU VL) connects the on-board pull-up resistors at SDA, SCL, HWEN, and INT to the center pin (VPU). VPU can be connected to either the supply at VL or the regulated 3.3V supply from the USB2ANY board. The jumper at VOUT will connect the output of the LM3532's boost converter to the LED string anodes. Once all the jumpers are in place, connect a 2.5V to 5.5V supply at the VL and GND banana plugs.

5 USB2ANY Interface board

The LM3532 Evaluation Board can be controlled directly by connecting an I^2C master to the SCL and SDA headers, or through the USB2ANY interface board. The USB2ANY board is designed to interface the LM3532 Eval Board to a PC which runs the LM3532 GUI.exe software. The LM3532 GUI.exe program needs to have the two .dll files (USB2ANY_API.dll and HID_API.dll) copied to the same folder which contains the LM3532 GUI.exe program. Once the LM3532 Evaluation Board has power applied, plug the USB2ANY into the bottom side connector with the included ribbon cable, then open the LM3532 GUI.exe program.

6 LM3532 GUI.exe (Graphical User Interface)

The LM3532 graphical user interface program (LM3532 GUI.exe) provides an easy method to demonstrate all the features within the LM3532. The program is divided into 6 separate tabbed sections: a Configuration Tab, a separate tab for each Control Bank (A, B, C), an Ambient Light Sensor (ALS) Tab, and a Demo Tab which provides controls to drive the PWM inputs via the USB2ANY's PWM output channels. Writing to the device happens automatically when any of the pull-down menu's are selected, or when a button is pushed.

7 LM3532 Configuration Tab

The Configuration Tab (Figure 6) contains the global registers for the LM3532 that control the current sink assignments, the enable registers, the feedback enable/disable, and the ramp rates. There is also a field for direct read and writes to the I^2C registers. Additionally there is a Default button which when pushed, places the LM3532 GUI.exe in the default state and writes all the LM3532 registers to their default (power-on reset) state. Table 1 through Table 5 describe these registers in detail.

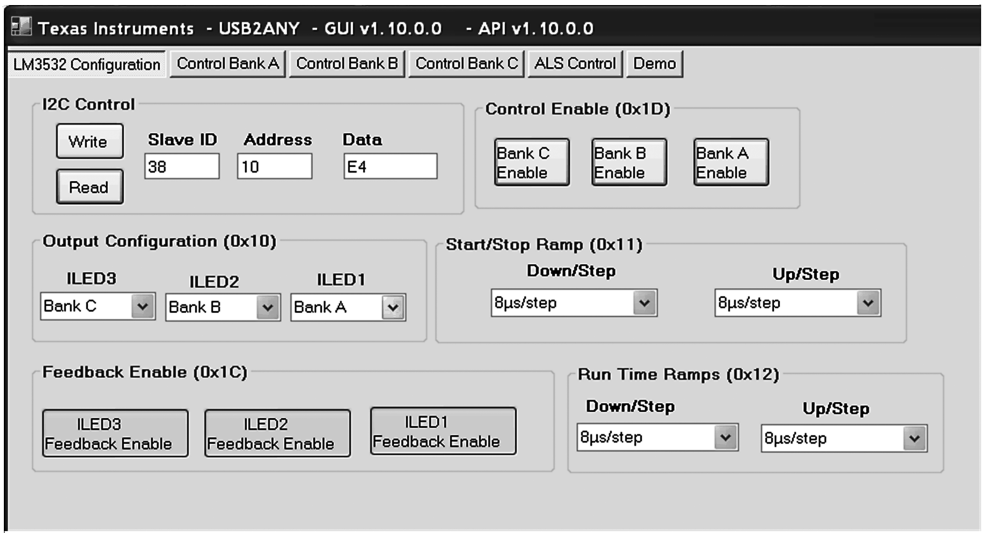

Figure 6. LM3532 Configuration Tab

Table 1. Output Configuration (0x10)

Bits [5:4] ILED3 Control	Bits [3:2] ILED2 Control	Bits [1:0] ILED1 Control
00 = ILED3 is controlled by Control A PWM and Control A Brightness Registers **(default)** 01 = ILED3 is controlled by Control B PWM and Control B Brightness Registers 1X = ILED3 is controlled by Control C PWM and Control C Brightness Registers	00 = ILED2 is controlled by Control A PWM and Control A Brightness Registers **(default)** 01 = ILED2 is controlled by Control B PWM and Control B Brightness Registers 1X = ILED2 is controlled by Control C PWM and Control C Brightness Registers	00 = ILED1 is controlled by Control A PWM and Control A Brightness Registers **(default)** 01 = ILED1 is controlled by Control B PWM and Control B Brightness Registers 1X = ILED1 is controlled by Control C PWM and Control C Brightness Registers

Table 2. Start/Stop Ramp (0x11)

Bits [5:3] Shutdown Ramp	Bits [2:0] Startup Ramp
000 = 8µs/step (2.048ms from Full-Scale to 0) **(default)** 001 = 1.024 ms/step (261 ms) 010 = 2.048 ms/step (522 ms) 011 = 4.096 ms/step (1.044s) 100 = 8.192 ms/step (2.088s) 101 = 16.384 ms/step (4.178s) 110 = 32.768 ms/step (8.356s) 111 = 65.536 ms/step (16.711s)	000 = 8µs/step (2.048ms from 0 to Full-Scale) **(default)** 001 = 1.024 ms/step (261 ms) 010 = 2.048 ms/step (522 ms) 011 = 4.096 ms/step (1.044s) 100 = 8.192 ms/step (2.088s) 101 = 16.384 ms/step (4.178s) 110 = 32.768 ms/step (8.356s) 111 = 65.536 ms/step (16.711s)

Table 3. Run Time Ramps (0x12)

Bits [5:3] Ramp Down	Bits [2:0] Ramp Up
000 = 8µs/step **(default)** 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 = 65.536 ms/step	000 = 8µs/step **(default)** 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 = 65.536 ms/step

Table 4. Feedback Enable (0x1C)

Bit 2 ILED3 Feedback Enable	Bit 1 ILED2 Feedback Enable	Bit 0 ILED1 Feedback Enable
0 = ILED3 is not part of the boost control loop 1 = ILED3 is part of the boost control loop **(default)**	0 = ILED2 is not part of the boost control loop 1 = ILED2 is part of the boost control loop **(default)**	0 = ILED1 is not part of the boost control loop 1 = ILED1 is part of the boost control loop **(default)**

Table 5. Control Enable (0x1D)

Bit 2 Bank C Enable	Bit 1 Bank B Enable	Bit 0 Bank A Enable
0 = Control C is disabled **(default)** 1 = Control C is enabled	0 = Control B is disabled **(default)** 1 = Control B is enabled	0 = Control A is disabled **(default)** 1 = Control A is enabled

8 Control Bank A, B, and C Tabs

There is a separate tab for each of the LM3532's Control Banks (Control Bank A, Control Bank B, and Control Bank C). Each tab has the registers that are specific to each control bank. Table 6 through Table 8 detail the bank specific registers.

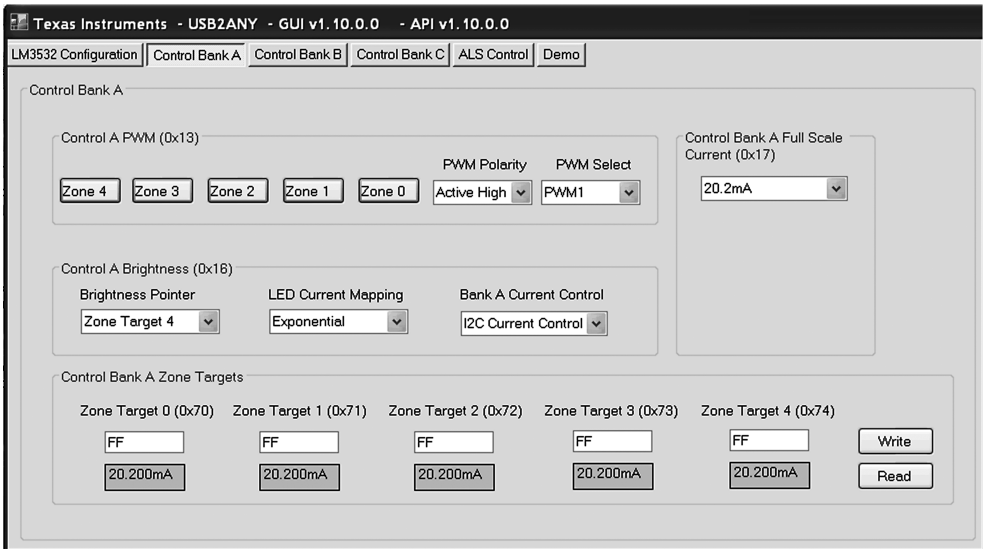

Figure 7. Control Bank Tab (Control Bank A Shown)

Table 6. Control (A/B/C) PWM (0x13/0x14/0x15)

Bit 6 Zone 4 PWM Enable	Bit 5 Zone 3 PWM Enable	Bit 2 Zone 2 PWM Enable	Bit 2 Zone 1 PWM Enable	Bit 2 Zone 0 PWM Enable	Bit 1 PWM Input Polarity	Bit 0 PWM Select
0 = Active PWM input is disabled in Zone 4 **(default)**	0 = Active PWM input is disabled in Zone 3 **(default)**	0 = Active PWM input is disabled in Zone 2 **(default)**	0 = Active PWM input is disabled in Zone 1 **(default)**	0 = Active PWM input is disabled in Zone 0 **(default)**	0 = active low polarity	0 = PWM1 input is mapped to Control Bank A **(default)**
1 = Active PWM input is enabled in Zone 4	1 = Active PWM input is enabled in Zone 3	1 = Active PWM input is enabled in Zone 2	1 = Active PWM input is enabled in Zone 1	1 = Active PWM input is enabled in Zone 0	1 = active high polarity **(default)**	1 = PWM2 is mapped to Control Bank A

Table 7. Control (A/B/C) Brightness (0x16/0x17/0x18)

Bits [4:2] Control A Brightness Pointer (I^2C Current Control Only)	Bit 1 LED Current Mapping Mode	Bit 0 Bank A Current Control
000 = Control X Zone Target 0 001 = Control X Zone Target 1 010 = Control X Zone Target 2 011 = Control X Zone Target 3 1XX = Control X Zone Target 4 **(default)**	0 = Exponential Mapping **(default)** 1 = Linear Mapping	0 = ALS Current Control 1 = I^2C Current Control **(default)**

Table 8. Control (A/B/C) Full-Scale Current (0x17/0x19/0x1B)

Bits [4:0] Control A/B/C Full-Scale Current Select Bits
00000 = 5 mA
00001 = 5.8 mA
00010 = 6.6 mA
00011 = 7.4 mA
00100 = 8.2 mA
00101 = 9 mA
00110 = 9.8 mA
00111 = 10.6 mA
01000 = 11.4 mA
01001 = 12.2 mA
01010 = 13 mA
01011 = 13.8 mA
01100 = 14.6 mA
01101 = 15.4 mA
01110 = 16.2 mA
01111 = 17 mA
10000 = 17.8 mA
10001 = 18.6mA
10010 = 19.4 mA
10011 = 20.2 mA **(default)**
10100 = 21 mA
10101 = 21.8 mA
10110 = 22.6 mA
10111 = 23.4 ma
11000 = 24.2 mA
11001 = 25 mA
11010 = 25.8 mA
11011 = 26.6 mA
11100 = 27.4 mA
11101 = 28.2 mA
11110 = 29 mA
11111 = 29.8 mA

In I^2C Current Control, any of the 5 Zone Target Registers for the particular Control Bank can be the LED brightness register. This is set according to Control A, B, or C Brightness Configuration Registers (Bits [4:2]). In the LM3532 GUI.exe, once a Zone Target value is written, the Write button must be pressed to write the contents of all zone targets to the LM3532.

9 Control Bank (A/B/C) Zone Targets

Control A Zone Target Register 0 maps directly to Zone 0 (Address 0x70)
Control A Zone Target Register 1 maps directly to Zone 1 (Address 0x71)
Control A Zone Target Register 2 maps directly to Zone 2 (Address 0x72)
Control A Zone Target Register 3 maps directly to Zone 3 (Address 0x73)
Control A Zone Target Register 4 maps directly to Zone 4 (Address 0x74)

Control B Zone Target Register 0 maps directly to Zone 0 (Address 0x75)
Control B Zone Target Register 1 maps directly to Zone 1 (Address 0x76)
Control B Zone Target Register 2 maps directly to Zone 2 (Address 0x77)
Control B Zone Target Register 3 maps directly to Zone 3 (Address 0x78)
Control B Zone Target Register 4 maps directly to Zone 4 (Address 0x79)

Control C Zone Target Register 0 maps directly to Zone 0 (Address 0x7A)
Control C Zone Target Register 1 maps directly to Zone 1 (Address 0x7B)
Control C Zone Target Register 2 maps directly to Zone 2 (Address 0x7C)
Control C Zone Target Register 3 maps directly to Zone 3 (Address 0x7D)
Control C Zone Target Register 4 maps directly to Zone 4 (Address 0x7E)

10 ALS Control Tab

The ALS Control Tab (Figure 8) contains all the registers that are programmable for the LM3532's Ambient Light Sensor Interface. Table 9 through Table 12 describe these registers. The evaluation board has two on board light sensors (ADPS-9005 from Avago). These connect directly to the LM3532's ALS1 and ALS2 inputs. The APDS-9005 requires a minimum of 1V saturation voltage for proper operation and has a typical response of 400nA/lux. For example, for detecting 0 to 2k Lux across the LM3532's 2V ALS input voltage range would require the APDS9005 be biased from a 3V minimum supply (supplied at the VALS header on the board), with an ALS load resistor of 2V/(2k Lux x 400nA/Lux) = 2.5kOhms. This corresponds to an ALS resistor Select Register code of 0x0F for register 0x20 (ALS1) or 0x0F for register 0x21 (ALS2).

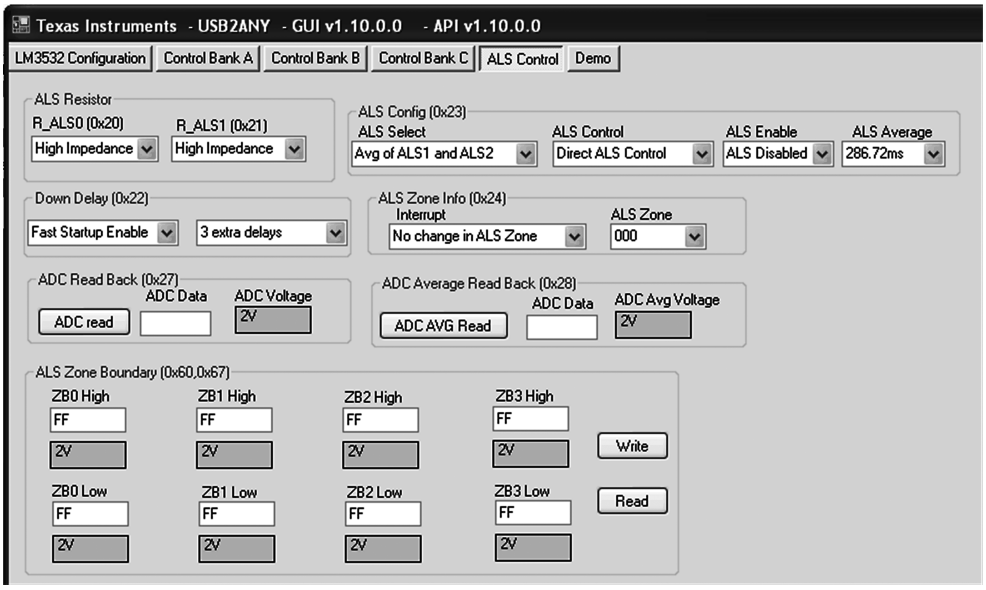

Figure 8. ALS Control Tab

Table 9. ALS Resistor (R_ALS0, 0x20/R_ALS1, 0x21)

Bit [4:0] ALS1/ALS2 Resistor Select Bits
00000 = High Impedance **(default)**
00001 = 37 kΩ
00010 = 18.5 kΩ
00011 = 12.33 kΩ
00100 = 9.25 kΩ
00101 = 7.4 kΩ
00110 = 6.17 kΩ
00111 = 5.29 kΩ
01000 = 4.63 kΩ
01001 = 4.11 kΩ
01010 = 3.7 kΩ
01011 = 3.36 kΩ
01100 = 3.08 kΩ
01101 = 2.85 kΩ
01110 = 2.64 kΩ
01111 = 2.44 kΩ
10000 = 2.31 kΩ
10001 = 2.18 kΩ
10010 = 2.06 kΩ
10011 = 1.95 kΩ
10100 = 1.85 kΩ
10101 = 1.76 kΩ
10110 = 1.68 kΩ
10111 = 1.61 kΩ
11000 = 1.54 kΩ
11001 = 1.48 kΩ
11010 = 1.42 kΩ
11011 = 1.37 kΩ
11100 = 1.32 kΩ
11101 = 1.28 kΩ
11110 = 1.23 kΩ
11111 = 1.19 kΩ

Table 10. Down Delay (0x22)

Bit [5] ALS Fast startup Enable	Bits [4:0] Down Delay
0 = ALS Fast startup is Disabled 1 = ALS Fast startup is Enabled **(default)**	00000 = 6 total Average Period delay for Down Delay Control **(default)** : : : 11111 = 34 total Average Periods of Delay for Down Delay Control

Table 11. ALS Configuration (0x23)

Bits [7:6] ALS Input Select	Bit [5:4] ALS Control	Bit 3 ALS Enable	Bits [2:0] ALS Average Time
00 = Average of ALS1 and ALS2 is used to determine backlight current 01 = Only the ALS1 input is used to determine backlight current **(default)** 10 = Only the ALS2 input is used to determine the backlight current 11 = The maximum of ALS1 and ALS2 is used to determine the backlight current	00 = Direct ALS Control. ALS inputs respond to up and down transitions **(default)** 01 = This setting is for a future mode. 1X = Down Delay Control. Extra delays of 3 x t_{AVE} to 34 x t_{AVE} are added for down transitions, before the new backlight target is programmed.	0 = ALS is disabled **(default)** 1 = ALS is enabled	000 = 17.92 ms 001 = 35.84 ms 010 = 71.68 ms 011 = 143.36 ms 100 = 286.72 ms **(default)** 101 = 573.44 ms 110 = 1146.88 ms 111 = 2293.76 ms

Table 12. ALS Zone Information (0x24)

Bit 3 Zone Change Bit	Bits [2:0] Brightness Zone
0 = No change in ALS Zone **(default)** 1 = There was a change in the ALS Zone since the last read of this register. This bit is cleared on read back.	000 = Zone 0 **(default)** 001 = Zone 1 010 = Zone 2 011 = Zone 3 1XX = Zone 4

11 ALS ZONE BOUNDARIES

There are 4 ALS Zone Boundary registers that form the boundaries for the 5 Ambient Light Zones. Each Zone Boundary register is 8 bits with a maximum voltage of 2V. This gives a step size for each Zone Boundary Register bit of:

$$\text{ZoneBoundaryLSB} = \frac{2V}{255} = 7.8\ \text{mV} \quad (1)$$

ALS Zone Boundary 0 High (Address 0x60), **default = 0x35 (415.7 mV)**
ALS Zone Boundary 0 Low (Address 0x61), **default = 0x33 (400 mV)**

ALS Zone Boundary 1 High (Address 0x62), **default = 0x6A (831.4 mV)**
ALS Zone Boundary 1 Low (Address 0x63), **default = 0x66 (800 mV)**

ALS Zone Boundary 2 High (Address 0x64), **default = 0xA1 (1262.7 mV)**
ALS Zone Boundary 2 Low (Address 0x65), **default = 0x99 (1200 mV)**

ALS Zone Boundary 3 High (Address 0x66), **default = 0xDC (1725.5 mV)**
ALS Zone Boundary 3 Low (Address 0x67), **default = 0xCC (1600 mV)**

12 ADC and ADC Average Readback (0x27, 0x28)

Both the ADC readback and ADC average readback are read-only registers that read the contents at the output of the LM3532's ADC. The ADC readback is the 8-bit data which is sampled at 7.142 ksps and updated every 154 µs. The ADC average readback is the 8-bit value from the ADC Readback Register which is averaged over the programmed ALS Average Time. Once either the ADC Read or ADC Average Read button is pushed, the appropriate field gets updated with the data.

13 Demo Tab

The Demo tab (Figure 9) provides the controls for activating the USB2ANY's PWM outputs which are then applied to the LM3532's PWM inputs. PWM1 and PWM2 correspond to the LM3532's PWM1 and PWM2 inputs. The field (PWM Duty Cycle (%)) is the duty cycle input from the user in steps of 0.1%. Once a new duty cycle is entered and the Update button is pressed, the duty cycle output from the USB2ANY board is changed.

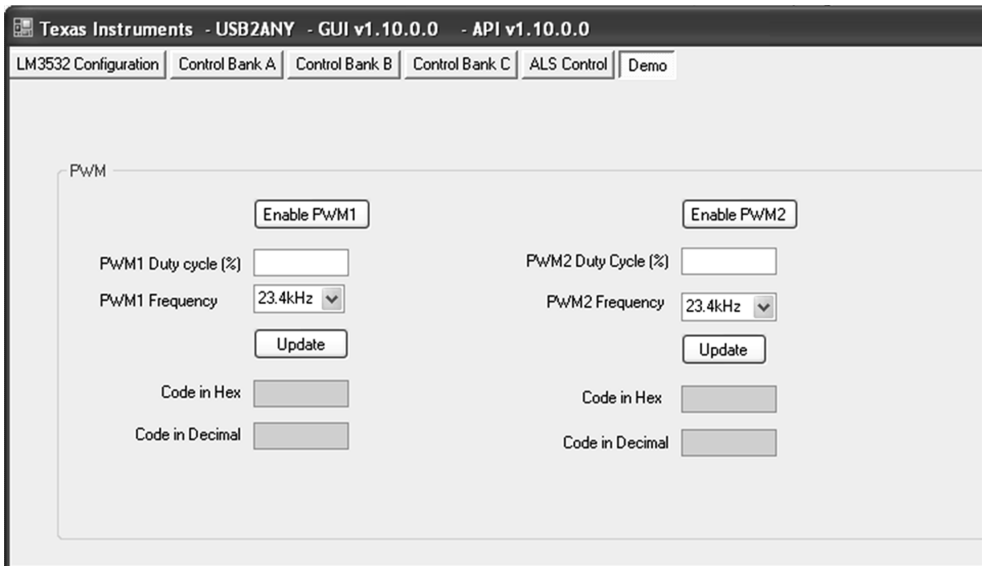

Figure 9. Demo Tab

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