DESCRIPTION

The IS32LT3961 is a DC-to-DC switching converter that integrates an N-channel MOSFET to operate in a buck configuration. The device can operate from a wide input voltage between 5V and 60V and provides a constant current of up to 2A for driving a single LED or multiple series connected LEDs.

The external high-side resistor, R_{IS}, is used to set a constant LED output current, while allowing the output voltage to be automatically adjusted for a variety of LED configurations.

The IS32LT3961 operates in a fixed frequency mode during switching. There is an external resistor connected between the VCC and TON pins used to configure the on-time (switching frequency). The switching frequency is dithered for spread spectrum operation which will spread the electromagnetic energy into a wider frequency band. This function is helpful for optimizing EMI performance.

Either a logic input PWM signal applied to the enable (EN/PWM) pin or an analog signal applied to ADIM pin will adjust the average LED current. The LED brightness is proportional to either the duty cycle of the PWM signal or the voltage level of the analog signal. The analog dimming function can be used to implement either LED binning or LED over temperature thermal roll off protection.

True average output current operation is achieved with fast transient response by using cycle-by-cycle, controlled on-time method.
The IS32LT3961 is available in an eTSSOP-16 package with an exposed pad for enhanced thermal dissipation. It operates from 5V to 60V over the temperature range of -40°C to +150°C.

FEATURES

- Wide input voltage supply from 5V to 60V
- High-side current sensing with LED string cathode connected directly to GND
- True average output current control with ±5% output current accuracy over operating temperature range of -40°C to +150°C
- 2A maximum output over operating temperature range
- Cycle-by-cycle current limit
- Integrated high-side MOSFET switch
- PWM dimming capability
- Analog dimming for LED binning or thermal roll off protection
- Internal control loop compensation
- Under-voltage lockout (UVLO)
- Low power shutdown (2μA typical)
- Spread spectrum to optimize EMI
- Support an output current monitor signal
- Robust fault protection and reporting function:
  - Single LED short detect
  - LED string open/short
  - LED over temperature thermal roll off
  - Pin-to-GND short
  - Component open/short faults
  - Adjacent pin-to-pin short
  - Thermal shutdown
- AEC-Q100 Qualified

QUICK START

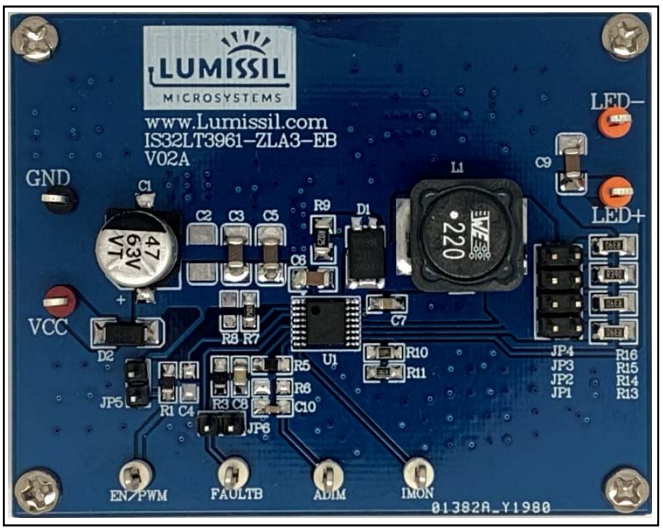

Figure 1 *Photo of IS32LT3961 Evaluation Board*

RECOMMENDED EQUIPMENT

- 60VDC power supply
- LED array
- Multi-meter

RECOMMENDED INPUT AND OUTPUT RATINGS

- Input: 5V~60VDC
- Output: 1~18 LEDs in series

ABSOLUTE MAXIMUM RATINGS

- Input voltage ≤ 60VDC

Caution: Do not exceed the conditions listed above, otherwise the board will be damaged.

PROCEDURE

The IS32LT3961 DEMO Board is fully assembled and tested. Follow the steps listed below to verify board operation.

Caution: Do not turn on the power supply until all connections are completed.

1) Connect the positive terminal of the power supply to the VCC of the board and the negative terminal of the power supply to the GND of the board.

2) Connect the cathode of the LED panel (LED arrays) to the LED- terminal and connect the anode of the LED panel (LED arrays) to the LED+ terminal.
3) Connect jumpers JP1, JP2, JP3 and JP4 on the board to select the output current.

JP1	JP2	JP3	JP4	R_{IS}(Ω)	I_{LED}(mA)
1	0	0	0	0.39	0.512
1	1	0	0	0.195	1.025
1	1	1	0	0.13	1.538
1	1	1	1	0.0975	2.051

4) To test PWM dimming, apply an external PWM signal to the EN/PWM terminal of the board. If PWM dimming is not used, close the jumper JP5 and the output PWM will be 100%.
Note: if connect PWM signal to the EN/PWM terminal, the JP5 must be open to avoid PWM generator damage due to the high voltage on the VCC pin.
5) To test analog dimming, apply an external 0.4V~2.0V voltage signal to ADIM terminal of the board. If analog dimming is not used, leave ADIM floating and the output will be 100%.
6) Turn on the power supply and the LED panels (LED arrays) will be lighted up.
7) FAULTB is the fault reporting output, which is pulled up to VDD by R3 on board. It will be pulled low whenever a fault condition is detected. Please refer to table 3 for more details on fault conditions. If not tested, leave FAULTB terminal floating.
Note: if FAULTB is connected to an MCU, JP6 must be open and pulled up on the MCU side to avoid MCU damage due to the VDD voltage (6V Typical).
8) The IMON pin voltage level is proportional to the output current. Measuring the IMON voltage provides an LED current output status monitoring, if not implemented, leave the IMON terminal floating. Please refer to the "OUTPUT CURRENT MONITOR" description of the datasheet for more details.

ORDER INFORMATION

Part No.	Temperature Range	Package
IS32LT3961-ZLA3-EB	-40°C to +125°C (Automotive)	eTSSOP-16, Lead-free

Table 1 *Ordering Information*

For pricing, delivery, and ordering information, please contacts Lumissil's analog marketing team at analog@Lumissil.com or (408) 969-6600.

DETAILED DESCRIPTION

OUTPUT CURRENT SETTING

The LED current is configured by an external sense resistor, R_{IS}, with a value determined by the following Equation (1):

$$I_{LED} = \frac{V_{IS}}{R_{IS}} \qquad (1)$$

Where the analog dimming function is disabled (V_{ADIM}>2V) and V_{IS} = 0.2V (Typ.).

Note that R_{IS}= 0.1Ω is the minimum allowed value for the sense resistor in order to maintain the switch current below the specified maximum value.

Table 2 R_{IS} Resistance Versus Output Current

R_{IS} (Ω)	Nominal Average Output Current (mA)
0.3	667
0.2	1000
0.1	2000

The resistor R_{IS} should be a 1% resistor with enough power tolerance and good temperature characteristic to ensure accurate and stable output current.

FREQUENCY SELECTION

During switching the IS32LT3961 operates in a constant on-time mode. The on-time is adjusted by the external resistor, R_{TON}, which is connected between the VCC and TON pins.

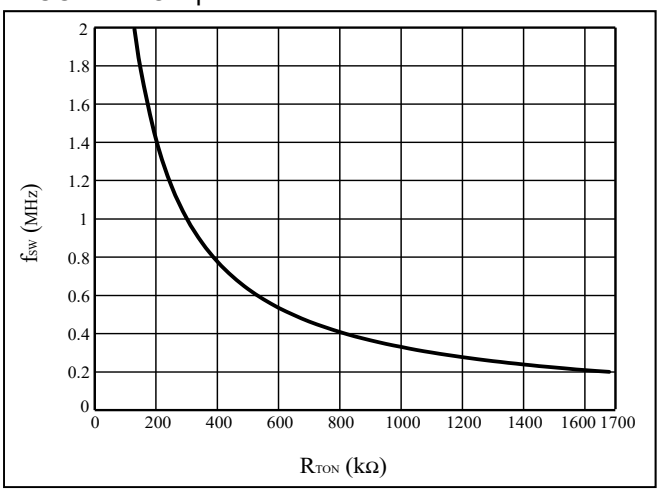

Figure 2 *Operating Frequency vs. R_{TON} Resistance*

The approximate operating frequency can be calculated by below Equation (2):

$$f_{SW} = \frac{1}{k \times (R_{TON} + R_{INT}) + 0.07} \quad (2)$$

Where k= 0.0029, with f_{SW} in MHz, R_{TON} and R_{INT} (internal resistance, 20kΩ) in kΩ.

Higher frequency operation results in smaller component size but increases the switching losses. It may also increase the high-side MOSFET gate driving current and may not allow sufficient high or low duty cycle. Lower frequency gives better performance but results in larger component size. In automotive applications, an operating frequency of 400kHz is good choice to compromise for both component size and efficiency, and keep the switching noise out of the sensitive frequency bands and easily pass EMI test.

ANALOG DIMMING

The IS32LT3961 also offers an analog dimming function input pin, ADIM, whose dimming voltage range is 0.4V to 2V. The current sense voltage threshold, V_{IS}, can be regulated by the ADIM pin voltage. If the ADIM pin is pulled up above 2V, analog dimming is disabled and the output current is given by Equation (1). When the ADIM voltage is driven below 2V, V_{ADIM} will proportionally control the current sense voltage threshold V_{IS} resulting in a change in the output current as given by Equation (3):

$$I_{LED\_ADIM} = \frac{V_{ADIM} - 0.4V}{1.6V} \times \frac{V_{IS}}{R_{IS}} \quad (3)$$

FAULT HANDLING

The IS32LT3961 is designed to detect the following faults and report via open drain FAULTB pin:

- Pin open
- Pin-to-ground short
- Pin-to-neighboring pin short
- Output LED string open and short
- Single LED short
- External component open or short
- Thermal shutdown

Please check Table 2 for the details of the fault actions.

Note that the FAULTB pin is an open drain structure. If it is monitored by a host, an external pull up resistor R_{PU} from the supply of the host to FAULTB pin is needed. The recommended R_{PU} value is 10kΩ.

Table 3 Fault Actions

Fault Type	LED String	Detect Condition		FAULTB Pin		Fault Recovering
Inductor shorted	Dim	Trigger OCP. Turn off high-side MOSFET immediately. Retry after 10ms.		Pull Low immediately		Inductor shorted removed. No OCP triggered and FAULTB pin recover after 10ms.
R_{IS} shorted	Dim	Trigger OCP. Turn off high-side MOSFET immediately. Retry after 10ms.		Pull Low immediately		R_{IS} shorted removed. No OCP triggered and FAULTB pin recover after 10ms.
R_{IS} open	Off	Detect high differential sense voltage. Turn off high-side MOSFET immediately. Retry after 10ms.		Pull Low after 20us deglitch time.		R_{IS} open removed. FAULTB pin recover after 10ms.
LED string open	Off	No PWM dimming:	Low R_{IS} voltage trigger EAO high-clamp for 10ms.	No PWM dimming:	Pull Low after 10ms.	LED open removed. FAULTB pin recover after 10ms.
		PWM dimming:	Low R_{IS} voltage trigger EAO high-clamp after 20us deglitch time and keeps for 16 PWM cycles.	PWM dimming:	Pull low after 16 PWM cycles.	
LED string partially shorted (including single LED shorted)	Shorted LEDs are off	No PWM dimming:	V_{SCD}<1.15V last for 10ms	No PWM dimming:	Pull Low after 10ms.	Shorted removed. V_{SCD}>1.2V for 10ms and FAULTB pin recover.
		PWM dimming:	V_{SCD}<1.15V after 20us deglitch time and keeps for 16 PWM cycles.	PWM dimming:	Pull low after 16 PWM cycles.	
LED string/ LED cap shorted to GND	Off	No PWM dimming:	V_{SCD}<1.15V last for 10ms	No PWM dimming:	Pull Low after 10ms.	Shorted removed. V_{SCD}>1.2V for 10ms and FAULTB pin recover.
		PWM dimming:	V_{SCD}<1.15V after 20us deglitch time and keeps for 16 PWM cycles.	PWM dimming:	Pull low after 16 PWM cycles.	
BOOT capacitor open	Dim	V_{CC}-V_{LX}>2V at high-side MOSFET ON (High-side can't fully turn on). Turn off high-side MOSFET immediately. Retry after 10ms.		Pull Low immediately		BOOT capacitor open removed, V_{CC}-V_{LX}<2V for 10ms and FAULTB pin recover.
BOOT capacitor shorted	Off	Bootstrap circuit UVLO and turn off high-side MOSFET immediately.		No PWM dimming:	Pull Low after 10ms.	BOOT capacitor shorted removed. Release from UVLO and FAULTB pin recover after 10ms
				PWM dimming:	Pull low after 16 PWM cycles.	
R_{TON} resistor open	Dim	On-time exceeds 20μs or trigger OCP, then turn off high-side MOSFET immediately. Retry after 10ms.		Pull Low immediately		R_{TON} resistor open removed. No over 20us on-time or OCP triggered. FAULTB pin recover after 10ms
R_{TON} resistor shorted	Dim	The device operating at minimum on/off time, maybe trigger the other fault conditions.		No reporting		R_{TON} resistor shorted removed.
Diode short	Off	Trigger OCP. Turn off high-side MOSFET immediately. Retry after 10ms.		Pull Low immediately		Diode shorted removed. No OCP triggered and FAULTB pin recover after 10ms.
Diode open	Dim	V_{LX}<-1.1V. turn off high-side MOSFET immediately. Retry after 10ms.		Pull Low immediately		Diode open removed. FAULTB pin recover after 10ms.
VOUT/ISP short to GND	Off	Trigger OCP. Turn off high-side MOSFET immediately. Retry after 10ms.		Pull Low immediately		Shorted removed. FAULTB pin recover after 10ms.
R_{CS} open	Dim	V_{LX}<-1.1V. turn off high-side MOSFET immediately. Retry after 10ms.		Pull Low immediately		R_{CS} open removed. FAULTB pin recover after 10ms.
Thermal Shutdown	Off	The die temperature exceeds 170°C		Pull Low immediately		The die temperature cools down below 150°C. FAULTB pin recovers immediately.

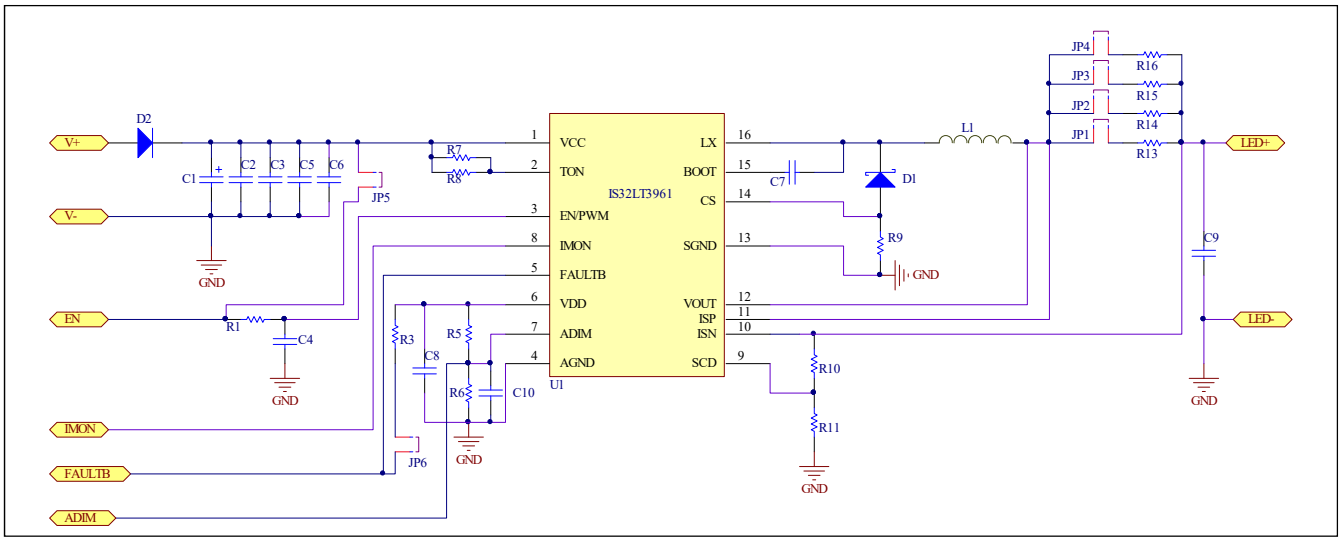

Figure 3 *IS32LT3961 Demo Board Schematic*

BILL OF MATERIALS

Name	Symbol	Description	Qty	Supplier	Part No.
IC	U1	Constant current LED driver	1	Lumissil	IS32LT3961-ZLA3-TR/ IS32LT3961-ZLA3
E-Cap	C1	CAP,47μF,63V,±20%	1	Panasonic	EEV-TG1J470P
Capacitor	C2,C4	NC	2		
Capacitor	C3,C5	CAP,4.7μF,100V,±10%,SMD	2	Yageo	AC1210X475K101T
Capacitor	C6	CAP,1μF,100V,±10%,SMD	1	Yageo	AC1206X105K101T
Capacitor	C7	CAP,100nF,50V,±10%,SMD	1	Yageo	AC0805KKX7R9BB104
Capacitor	C8	CAP,1μF,50V,±10%,SMD	1	Yageo	AC0805KKX7R9BB105
Capacitor	C9	CAP,1μF,50V,±10%,SMD	1	Yageo	AC1206KKX7R9BB105
Capacitor	C10	CAP,1nF,50V,±10%,SMD	1	Yageo	AC0805KKX7R9BB102
Resistor	R1,R3,R5	RES,10k,1/8W,±5%,SMD	3	Yageo	AC0805JR-0710KL
Resistor	R7	RES,750k,1/8W,±5%,SMD	1	Yageo	AC0805FR-07750KL
Resistor	R9	RES,0.025R,1/4W,±1%,SMD	1	UNI-ROYAL	CS06W4F250MT5E
Resistor	R10	RES,36R,1/8W,±5%,SMD	1	Yageo	AC0805JR-07036RL
Resistor	R11	RES,36k,1/8W,±5%,SMD	1	Yageo	AC0805JR-07036KL
Resistor	R13, R14, R15, R16	RES,0.39R,1/4W,±1%,SMD	4	Yageo	RL1206FR-070R39L
Resistor	R6,R8	NC	2		
Diode	D1	5A,100V, Power DI5	1	Diodes	PDS5100
Diode	D2	3A,100V, SMA	1	Diodes	SS310
Inductor	L1	22μH±20%,Isat≥3.77A,SMD	1	Würth Elektronik	744771122

Note: Bill of materials refers to Figure 3 above.

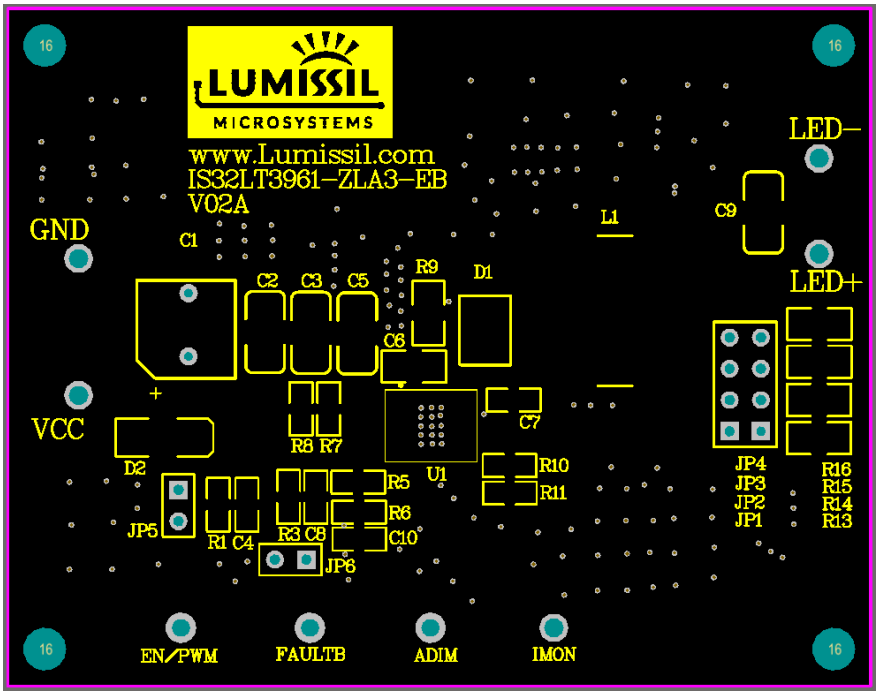

Figure 4 *Board Component Placement Guide - Top Layer*

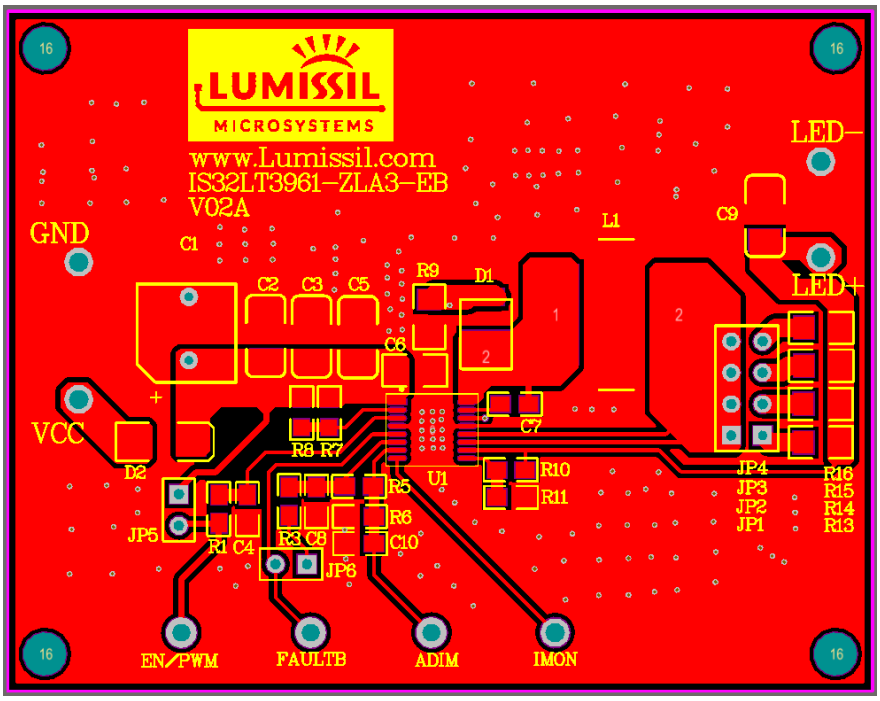

Figure 5 *Board PCB Layout - Top Layer*

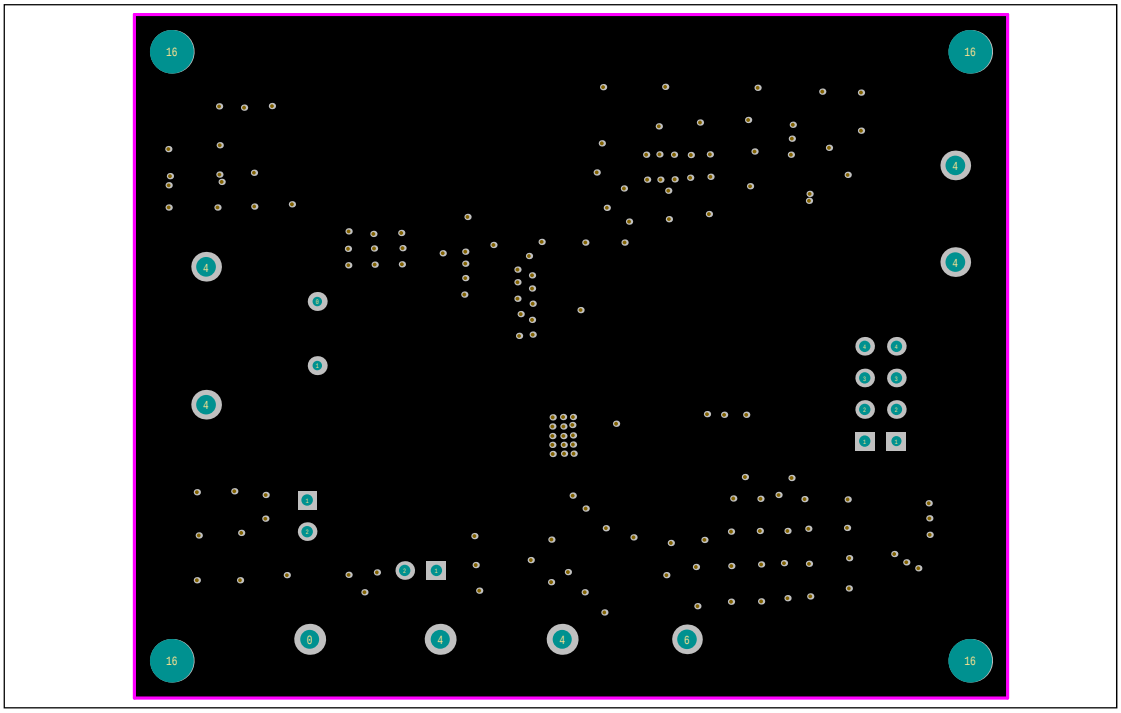

Figure 6 *Board Component Placement Guide - Bottom Layer*

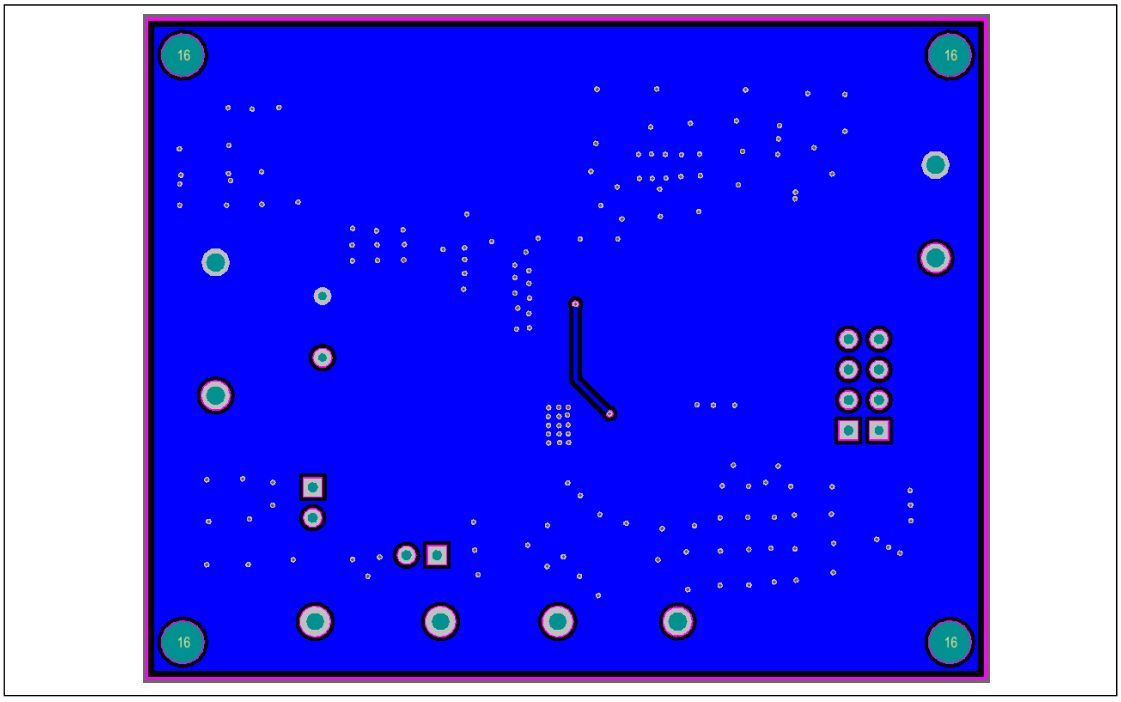

Figure 7 *Board PCB Layout - Bottom Layer*

REVISION HISTORY

Revision	Detail Information	Date
A	Initial release	2021.06.07
B	Update to mess-production	2022.02.23