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ISL8130EVAL3Z - Sepic Converter

Introduction

ISL8130EVAL3Z is a sepic converter, which features the universal PWM controller, ISL8130. The evaluation board delivers 10V output at 2A. All the necessary components are within the 1.78" x 1.24" PCB area.

The ISL8130 is designed to drive N-Channel MOSFETs in a synchronous rectified buck topology for up to 25A instant MOSFET current and can be configured for boost, buck/boost and sepic converters as well. The ISL8130 integrates control, output adjustment, monitoring and protection functions into a single package. The ISL8130 provides simple, voltage mode control with fast transient response.

This application note describes how to use the ISL8130 to generate V_{OUT} from power supply of voltage either higher or lower than the V_{OUT}.

Features

- Operates From:
  - 4.5V to 5.5V Input for 5V Input
  - 5.5V to 16V Input
- Resistor-Selectable Switching Frequency from 100kHz to 1.4MHz
- Voltage Margining and External Reference Tracking Modes
- Kelvin Current Sensing
  - Upper MOSFET $r_{DS(ON)}$ for Current Sensing for Buck and Buck/Boost Converter
  - Precision Resistor/Inductor DCR for Boost and Sepic Converter
- Extensive Protection Functions:
  - Overvoltage, Overcurrent, Undervoltage
- Power Good Indicator

Evaluation Board Specifications

TABLE 1. EVALUATION BOARD ELECTRICAL SPECIFICATIONS

SPEC	DESCRIPTION	MIN	TYP	MAX	UNIT
V_{IN}	Board Input Range	5.6	10	16	V
IOC	Input Current	5			A
V_{OUT}	I_{OUT} = 0A	9.5	10	10.5	V
I_{OUT}	V_{IN} = 5.6V	2			A
η	V_{IN} = 5.6V, IOUT = 2A		88.6		%
η	V_{IN} = 8.4V, IOUT = 2A		90.3		%

Recommended Equipment

The following equipment is recommended for evaluation:

- 0V to 20V power supply with 10A source current capability
- Electronic load capable of sinking 2A @ 20V
- Digital Multi meters (DMMs)
- 100MHz Quad-Trace Oscilloscope

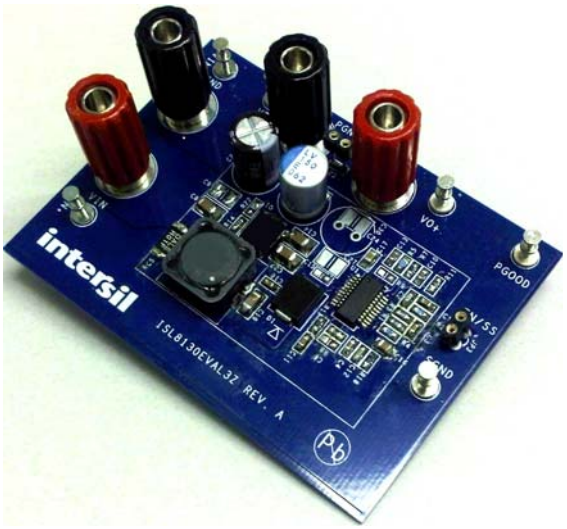


FIGURE 1. ISL8130EVAL3Z TOP VIEW

TABLE 2. RECOMMENDED COMPONENT SELECTION FOR QUICK EVALUATION

V_{OUT} (V)	R4 (kΩ)	V_{IN} (V)	I_{OUT} (A)	F_{SW}(kHz)/R_5(kΩ)	MOSFET	FORWARD DIODE	INDUCTOR (L, ISAT MEASURED IN PARALLEL)
7	9.53	5.6 to 14	2	500kHz/28.7kΩ	BSO051N03 MS	SL43	4.7µH, 6A
10	6.34	5.6 to 16	2	500kHz/28.7kΩ	BSC059N04 LS	SL42	4.7µH, 7A
12	5.23	5.6 to 14	2	500kHz/28.7kΩ	BSC057N03 LS	SL42	4.7µH, 9A

NOTES:

1. Please select the output capacitor with a voltage rating higher than the output.
2. Please contact Intersil Sales for assistance.

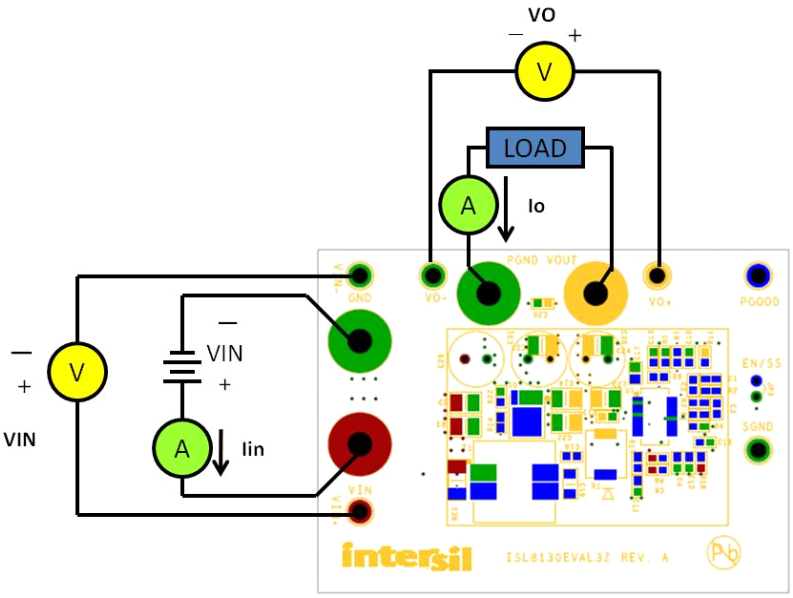


FIGURE 2. ISL8130EVAL3Z TEST SET-UP

Quick Test Setup

1. Ensure that the Evaluation board is correctly connected to the power supply and the electronic load prior to applying any power. Please refer to Figure 2 for proper set-up.
2. Leave JP3 in the open position.
3. Turn on the power supply; V_{IN}< 16V.
4. Adjust input voltage V_{IN} within the specified range and observe output voltage. The output voltage variation should be within 5%.
5. Adjust load current within 2A. The output voltage variation should be within 5%.
6. Use oscilloscope to observe output ripple voltage and phase node ringing. For accurate measurement, please refer to Figure 3 for proper probe set-up.
7. Optimization. Please refer to Table 2 on page 1 for optimization recommendation.
8. For 5V input applications, please tie the VCC5V to VIN and do not allow V_{IN} to go above 5.5V.

NOTE: Test points: VIN+, VIN-, VO+ and VO- are for voltage measurement only. Do not allow high current through these test points.

Probe Set-up

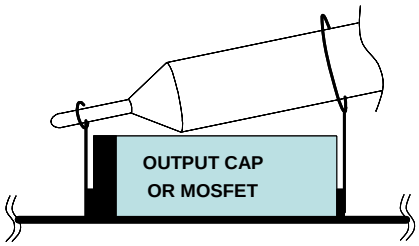


FIGURE 3. OSCILLOSCOPE PROBE SET-UP

VOUT Setting

The output voltage is set by the resistor divider, R_4 and R_1.

$$V_{OUT} = \frac{R_4 + R_1}{R_4} \times 0.6V \quad \text{(EQ. 1)}$$

Resistor R_{11} is a resistor jumper for loop gain measurement. It is recommended to set R_{11} = 50Ω for loop gain measurement.

Component Selection

Component Voltage Stress

The controller, ISL8130, the input capacitors and the flying capacitors, C18 and C19, see the input voltage. MOSFET and forward diode see the voltage stress of $V_{IN} + V_{OUT}$.

Duty Cycle Calculation

The duty cycle of the sepic converter can be estimated using Equation 2.

$$D = \frac{V_{OUT} + V_F}{V_{IN} + V_{OUT} + V_F} \quad \text{(EQ. 2)}$$

Where: V_F is the forward voltage of the diode, D1.

Given:

V_{IN} = 8.4V, V_{OUT} = 10V, V_F = 0.5V

We have nominal duty cycle of 44.4%.

Maximum duty cycle and minimum duty cycle can be estimated by Equation 3 and Equation 4 respectively.

$$D_{max} = \frac{V_{OUT} + V_F}{V_{INmin} + V_{OUT} + V_F} \quad \text{(EQ. 3)}$$

$$D_{min} = \frac{V_{OUT} + V_F}{V_{INmax} + V_{OUT} + V_F} \quad \text{(EQ. 4)}$$

Coupled Inductor Selection

A coupled inductor with 1:1 turns ratio is recommended for sepic converter. Such a coupled inductor is specified in two ratings; the parallel ratings and the series ratings. In this application note, inductor parameters refers to the parallel rating unless otherwise noted.

It is recommended to select inductor so that the ripple current to DC current ratio is between 30% to 50%. For low-core-loss magnetic material, higher ripple ratio would ease the compensation design and help to reduce the size of the inductor.

Please refer to Equation 5 for recommended inductor value:

$$L_P = \frac{V_{IN}}{\Delta i_R \times I_{Omax} \times F_{SW}} \times D \times (1 - D) \quad \text{(EQ. 5)}$$

Where D is the duty cycle, Δi_R is the inductor ripple ratio, I_{omax} is the maximum load current. With I_{omax} = 2A, F_{SW} = 500kHz, Δi_R= 40%. The recommended inductance is 5.18µH. The DC magnetizing current of the coupled inductor can be estimated by:

$$I_{INDmax} = \frac{I_{Omax}}{1 - D_{max}} \quad \text{(EQ. 6)}$$

The peak magnetizing current is:

$$I_{INDPK} = I_{INDmax} + \frac{1}{2} \bullet \frac{(V_{OUT} + V_F) \bullet (1 - D_{max})}{L_P \bullet F_{SW}} \quad \text{(EQ. 7)}$$

The inductor should be of saturation current higher than that calculated by Equation 7. DRC127-4R7 is selected with actual inductance of 4.7µH.

It is recommended to select inductor with saturation current higher than the maximum overcurrent threshold. Please refer to “Current Sensing” on page 3 for details.

Current Sensing

For accurate overcurrent detection, it is recommended to set the voltage across the current sensing resistor, R_{CS} higher than 50mV. Taking variation into consideration, when precision current sensing resistor is used, R_{SEN} = 665Ω.

The DC current of the output winding can be estimated by:

$$I_{INWIND} = I_{Omax} \bullet \frac{V_{OUT} + V_F}{V_{INmin}} \quad \text{(EQ. 8)}$$

The OC threshold should be higher than the peak input winding current at maximum load current. The maximum peak inductor usually occurs at V_{INmin} and can be calculated by Equation 9.

$$I_{INPK} = I_{Omax} \bullet \frac{V_{OUT} + V_F}{V_{INmin}} + \frac{1}{4} \bullet \frac{(V_{OUT} + V_F) \bullet (1 - D_{max})}{L_P \bullet F_{SW}} \quad \text{(EQ. 9)}$$

Refer to Equation 10 for R_{CS} calculation.

$$R_{CS} < \frac{R_{SEN} \times I_{OCSET(min)}}{I_{INPK}} \quad \text{(EQ. 10)}$$

Where: I_{OCSET} is the OCSET pin sinking current for overcurrent detection. The $I_{OCSET(min)}$ = 80µA.

The maximum overcurrent threshold can be calculated by Equation 11.

$$I_{OCmax} = \frac{R_{SEN} \times I_{OCSET(max)}}{R_{CS}} \quad \text{(EQ. 11)}$$

Where $I_{OCSET(max)}$ = 120µA. When input winding current reaches the OC threshold, the inductor peak magnetizing current can be estimated by Equation 12.

$$I_{OCMAG} = \frac{I_{OCmax}}{D_{min}} - \frac{1}{4} \bullet \frac{(V_{OUT} + V_F) \bullet (1 - D_{min})}{L_P \bullet F_{SW}} \bullet \frac{1 - 2 \bullet Dmin}{Dmin} \quad \text{(EQ. 12)}$$

The R_{CS} should be rated for the power loss at the maximum OC trip point.

For most accurate current sensing setting, please use Kelvin connection for OCSET and ISEN pins. Please refer to Figure 4 for reference.

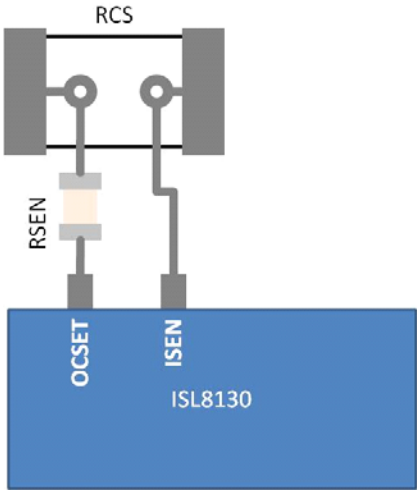


FIGURE 4. ISL8130 CURRENT SENSING LAYOUT EXAMPLE

Output Capacitors

It is recommended to use a combination of aluminum capacitors with high capacitance and low ESR ceramic capacitors at the output for optimum ripple and load transient performance.

The low ESL and ESR ceramic capacitors should be placed close to the MOSFET and diode. The loop formed by the MOSFET, the flying capacitors, C18 and C19, the forward diode and the output ceramic capacitors should be minimized as short as possible.

When selecting the output capacitors, there are two important requirements: the ripple current and the stability.

The output RMS current worst case occurs at V_{INmin} and maximum load. See Equation 13 for output ripple current calculation:

$$I_{ORMS} = I_{OUT} \bullet \sqrt{\frac{1}{1 - D_{max}}} \quad \text{(EQ. 13)}$$

Given:

V_{OUT} = 10V, I_{OUT} = 2A, V_{INmin} = 5.6V

D_{max} = 65.7%

We have:

I_{ORMS} = 3.417A

For applications with F_{SW} < 1MHz, it is still rule of thumb that the aluminum electrolytic capacitors take the ripple current. Please select electrolytic capacitors with ripple current greater than the maximum I_{ORMS}, as calculated by Equation 13.

The other important factor is stability. The right-half-plane zero, f_{RHP} of a sepic converter imposes a big challenge for stability. It is recommended to set cross over frequency below the f_{RHP} and above the boost converter natural resonant frequency, f_N. It is recommended to use sufficient output capacitors so that the f_N is much lower than f_{RHP}. Equation 14 is provided for total output capacitance estimation.

$$C_{out} > \left(\frac{I_{Omax}}{V_{INmin}}\right)^2 \bullet L_P \bullet 400 \quad \text{(EQ. 14)}$$

For right-half-plane zero calculation, f_{RHP}:

$$f_{RHP} = \frac{V_{in} \bullet (1 - D)}{2\pi \bullet I_{OUT} \bullet L_P} \quad \text{(EQ. 15)}$$

For sepic converter natural resonant frequency, f_N:

$$f_N = \frac{1 - D}{2\pi \bullet \sqrt{C_{OUT} \bullet L_P}} \quad \text{(EQ. 16)}$$

Flying Capacitors

High ripple current rated ceramic capacitors are preferred for the flying capacitors. The flying capacitor ripple current is at maximum when $V_{IN} = V_{INmin}$ and can be estimated by Equation 17:

$$I_{FLYRMS} = I_{OUT} \bullet \sqrt{\frac{V_{OUT} + V_F}{V_{INmin}}} \quad \text{(EQ. 17)}$$

Given:

V_{OUT} = 10V, I_{OUT} = 2A, V_{INmin} = 5.6V

We have:

I_{FLYRMS} = 2.74A

Please select flying capacitor with ripple current higher than I_{FLYRMS}. The flying capacitor would also resonate with the leakage inductor of the coupled inductor. It is recommended to use sufficient CFLY so that the resonating frequency be lower than half of the switching frequency.

The leakage inductance can be measured in the setup shown in Figure 5.

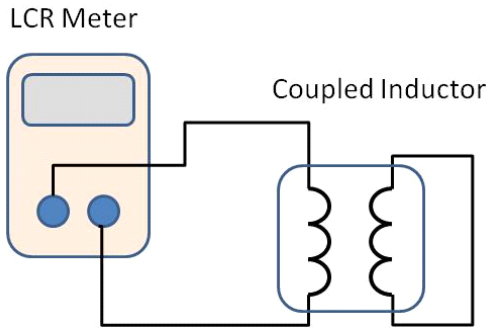


FIGURE 5. LEAKAGE INDUCTANCE MEASUREMENT SETUP

Equation 18 gives the recommended C_{FLY}:

$$C_{FLY} > \left(\frac{1}{\pi \bullet F_{SW}}\right)^2 \bullet \frac{1}{L_S} \quad \text{(EQ. 18)}$$

Given L_S = 0.1µH and F_{SW} = 500kHz, the recommended C_{FLY} should be greater than 4.4µF. When ceramic capacitors are used, attention should be paid to the DC degrading characteristic. Please contact capacitor vendor for more details.

Typical Performance Curves

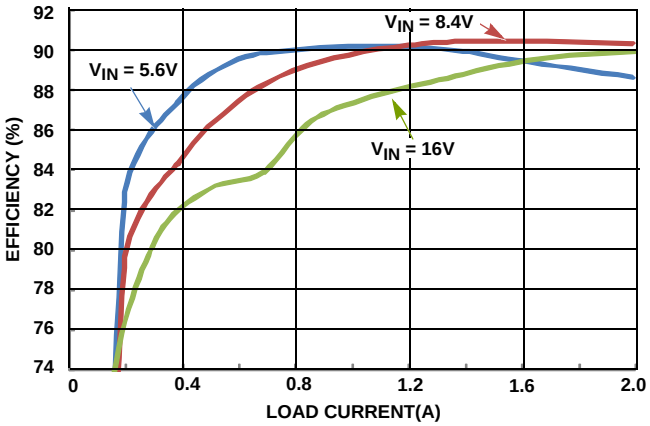


FIGURE 6. EFFICIENCY vs LOAD CURRENT

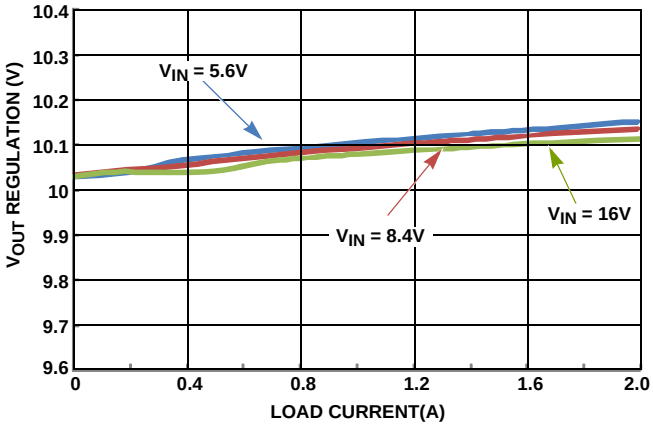


FIGURE 7. V_{OUT} LOAD REGULATION

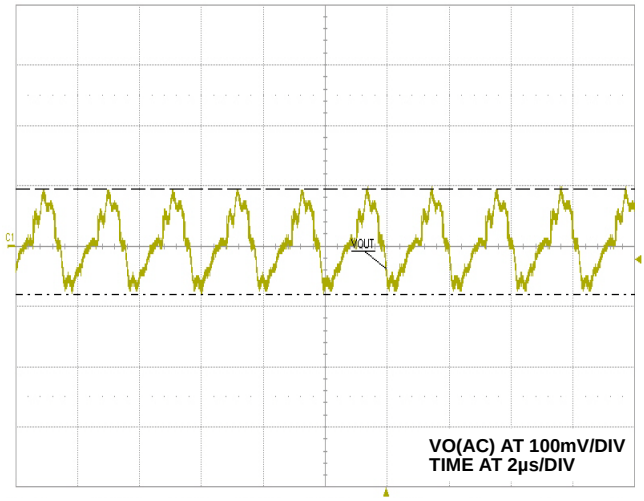


FIGURE 8. OUTPUT RIPPLE (V_{IN} = 5.6V, LOAD = 2A, 20MHz BW)

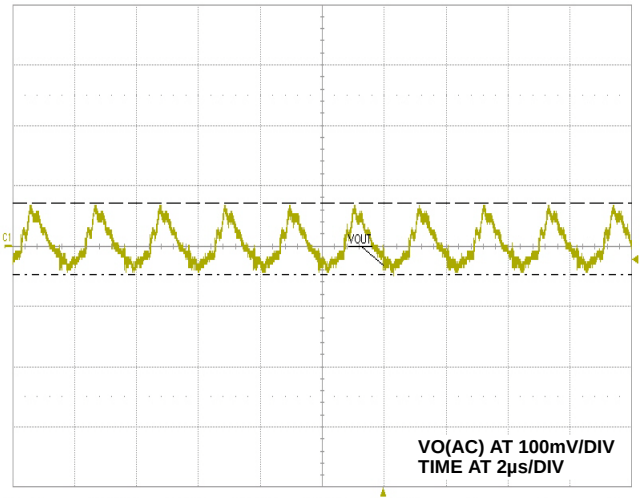


FIGURE 9. OUTPUT RIPPLE (V_{IN} = 8.4V, LOAD = 2.A, 20MHz BW)

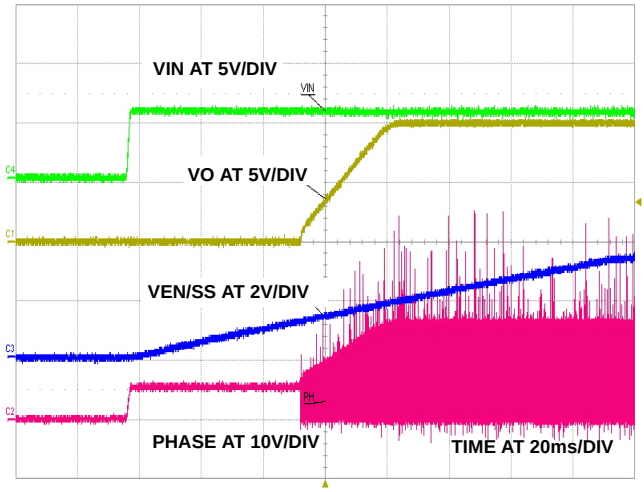


FIGURE 10. SOFT-START (V_{IN} = 5.6V, C_{SS} - 0.47µF)

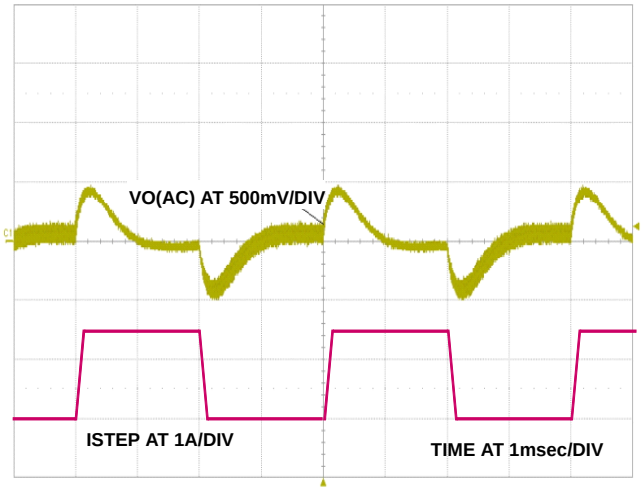


FIGURE 11. LOAD TRANSIENT (V_{IN} = 5.6V, LOADSTEP FROM 0.5A to 1.5A)

Typical Performance Curves (Continued)

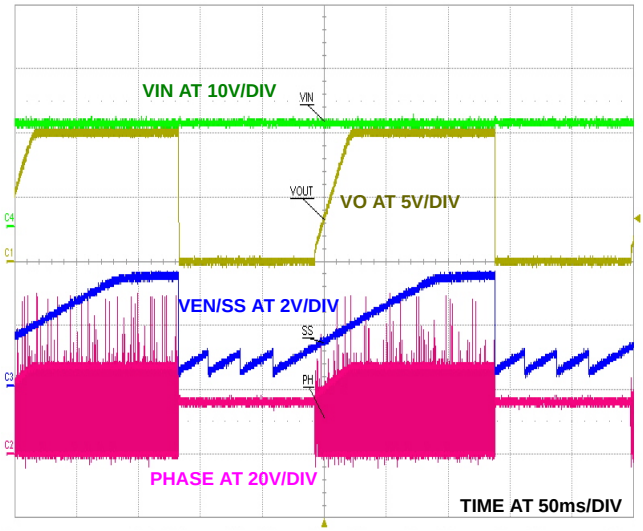


FIGURE 12. OVERCURRENT PROTECTION (V_{IN} = 16V, I_{LOAD} = 6.6A)

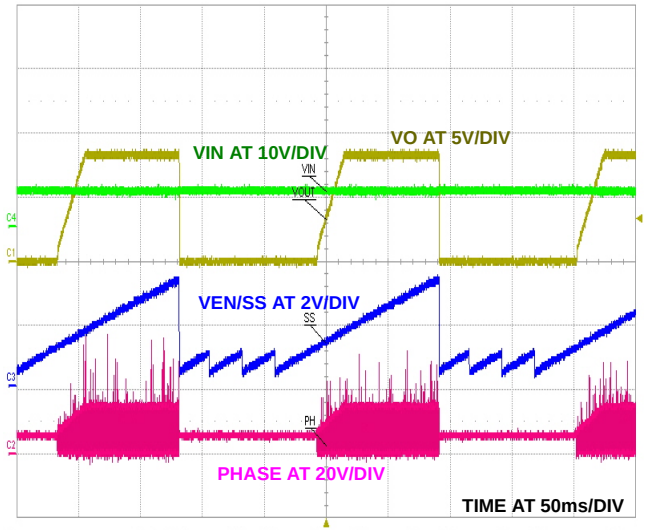
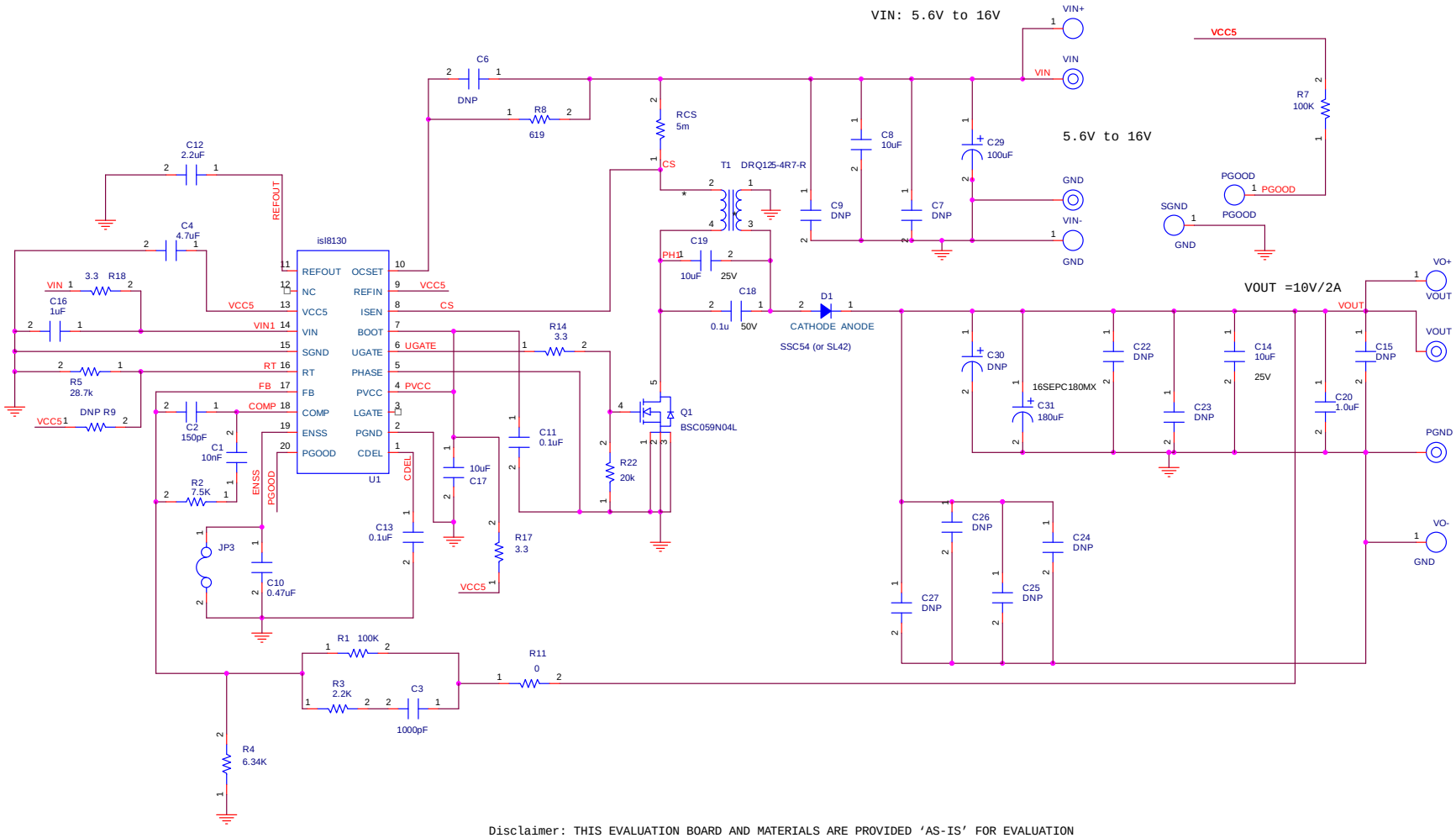


FIGURE 13. OVERCURRENT PROTECTION (V_{IN} = 5.6V, I_{LOAD} = 3.1A)

ISL8130EVAL3Z Schematic



Bill of Materials

ITEM	QTY	REFERENCE	VALUE	DESCRIPTION	PART #	VENDOR
1	1	C1	10nF	Ceramic CAP, NP0 or C0G, 50V, sm0603	Generic	Generic
2	1	C2	150pF	Ceramic CAP, NP0 or C0G, 50V, sm0603	Generic	Generic
3	1	C3	1000pF	Ceramic CAP, NP0 or C0G, 50V, sm0603	Generic	Generic
4	1	C4	4.7µF	Ceramic CAP, X5R, 10V, sm0603	Generic	Generic
5	4	C14, C19, C22, C8	10µF	Ceramic CAP, X5R, 25V, sm1206	Generic	Generic
6	1	C10	0.47µF	Ceramic CAP, X5R, 16V, sm0603	Generic	Generic
7	2	C11, C13	0.1µF	Ceramic CAP, X5R, 16V, sm0603	Generic	Generic
8	1	C12	2.2µF	Ceramic CAP, X5R, 16V, sm0603	Generic	Generic
9	2	C16, C20	1µF	Ceramic CAP, X5R, 16V, sm0603	Generic	Generic
10	1	C17	10µF	Ceramic CAP, X5R, 10V, sm0805	Generic	Generic
11	1	C18	0.1µF	Ceramic CAP, X5R, 50V, sm0805	Generic	Generic
12	1	C29	100µF	Alum Cap, 35V, Ripple Current > 300mA	EEU-FC1V101	Panasonics
13	1	C31	150µF	ALUM CAP, 25V	PLV1E151MDL1TD	Nichicon
14	1	D1		Schottky Diode, 40V, DO-214AB	SSC54	Vishay
15	1	Q1		Single Channel NFET, 40V	BSC059N04L	Infineon
16	1	RCS	10m	Precision RES, SM2010	PMR50HZPFU10L0	ROHM
17	1	R1	100k	Resistor, sm0603, 1%	Generic	Generic
18	1	R2	7.5k	Resistor, sm0603, 1%	Generic	Generic
19	1	R3	2.2k	Resistor, sm0603, 10%	Generic	Generic
20	1	R4	6.34k	Resistor, sm0603, 1%	Generic	Generic
21	1	R5	28.7k	Resistor, sm0603, 1%	Generic	Generic
22	1	R7	100k	Resistor, sm0603, 10%	Generic	Generic
23	1	R8	665	Resistor, sm0603, 1%	Generic	Generic
24	1	R11	0	Resistor, sm0603, 10%	Generic	Generic
25	3	R14, R17, R18	3.3	Resistor, sm0603, 10%	Generic	Generic
26	1	R22	20k	Resistor, sm0603, 1%	Generic	Generic
27	1	T1	4.7µH	1:1 Coupled Inductor	DRQ125-4R7-R	Cooper
28	1	U1		PWM Controller, 20L QSOP	ISL8130IAZ	Intersil
EVALUTION BOARD HARDWARE						
29	1	JP3		jumper_2pin	Generic	Generic
30	2	VOUT, VIN		Banana Jack (Red)	111-0703-002	Emerson
31	2	PGND, GND		Banana Jack (Black)	111-0703-001	Emerson
32	6	VIN+, VO+, VO-, VIN-, SGND, PGOOD		Test Point	1514-2	Keystone
OPTIONAL COMPONENTS						
33	8	C6, C7, C9, C15, C23, C24, C25, C26, C27, C30		DNP		

ISL8130EVAL3Z PCB Layout

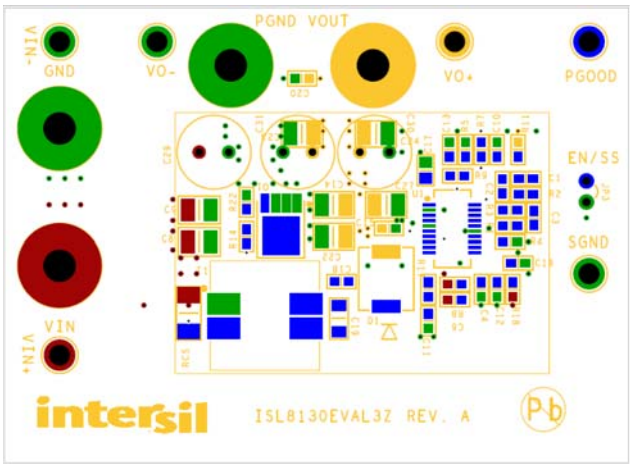


FIGURE 14. TOP SILKSCREEN

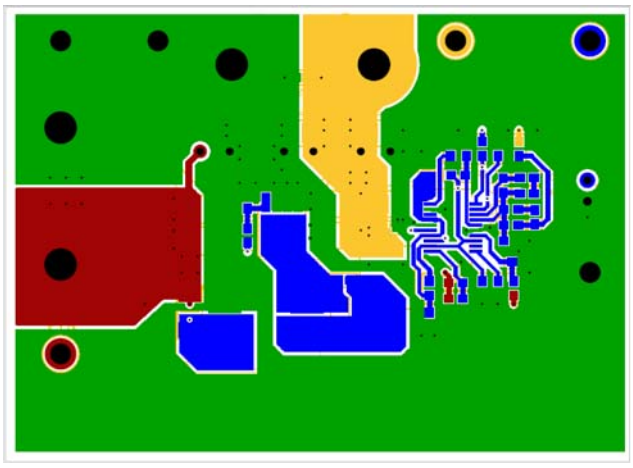


FIGURE 15. TOP LAYER

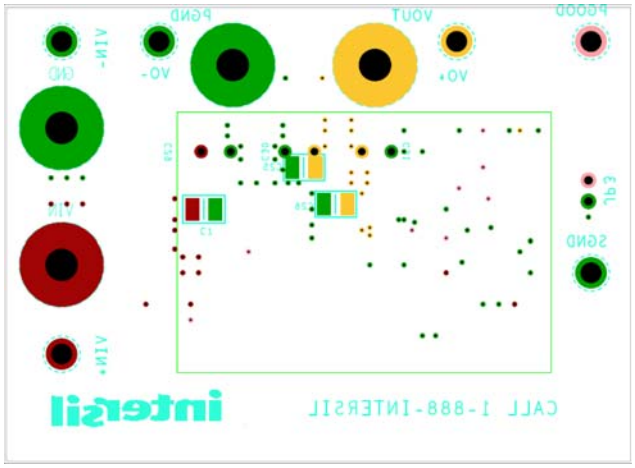


FIGURE 16. BOTTOM SILKSCREEN

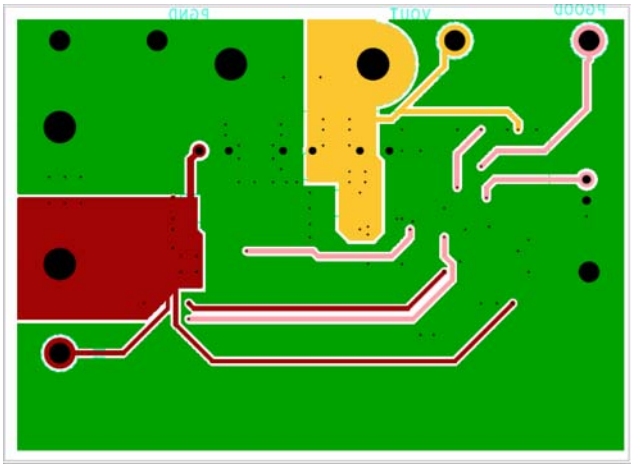


FIGURE 17. BOTTOM LAYER