DESCRIPTION

The IS32PM3510 is an asynchronous multi-topology COT PWM controller that employs a single inductor to provide excellent voltage regulation. In a Buck-Boost topology regulated output voltage is maintained when the input voltage is either less or greater than the desired output voltage, making it especially suitable for automotive applications, where this wide input voltage variation is expected. With a 150kHz to 650kHz programmable operating frequency that can be either adjusted with an external resistor or synchronized with an external clock, optimum inductor and capacitor(s) size can be achieved while maintaining high efficiency. The controller integrates spread spectrum function that effectively reduces overall EMI profile.

The IS32PM3510 can also be configured for either Buck or Boost operation with a single switch, and features robust protection functions with power good signal output, PGOOD, for MCU fault flag reporting.

The IS32PM3510 is available in an eTSSOP-16 package with an exposed thermal pad for enhanced thermal dissipation.

FEATURES

- Wide input voltage: 4.5V to 55V
- Supports buck, boost and buck-boost topologies
- ±1.5% feedback voltage accuracy over -40°C ~ +150°C
- Adjustable operating frequency: 150kHz-650kHz
  - Spread spectrum for EMI profile optimization
  - External clock synchronization capability
- Internally fixed soft start to avoid inrush current
- Power good signal output
- Integrated bootstrap diode
- 1.5μA shutdown supply current
- Built-in robust protections with fault reporting:
  - Input over current protection
  - Output over voltage protection
  - Output over current protection
  - FS/SYNC resistor open/short protection
  - Thermal shutdown
- AEC-Q100 Qualified
- Operating temperature range from -40°C ~ +150°C junction temperature

EVALUATION BOARD PHOTO

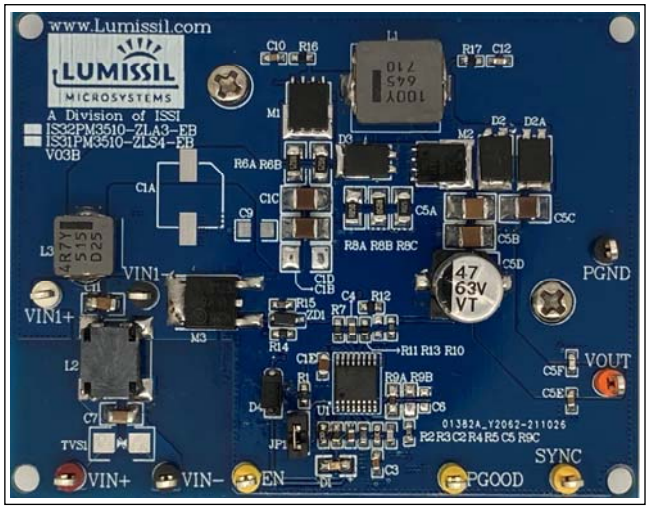


Figure 1: Photo of IS32PM3510 Evaluation Board

RECOMMENDED EQUIPMENT

- 9~16V, 6A DC power supply
- Electronic load or adjustable resistor load
- Multi-meter

Caution: If the load current is 3A, the input current could be close to 5A with 9V power supply input. Please pay attention to the current limit of your power supply.

RECOMMENDED INPUT AND OUTPUT RATINGS

- Input: 9~16VDC
- Output: 12V/0~3A

ABSOLUTE MAXIMUM RATINGS

- Input voltage ≤ 55VDC

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

PROCEDURE

The IS32PM3510 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 VIN+ of the board and the negative terminal of the power supply to the VIN- of the board.
2) Connect the electronic load (or adjustable resistor load) to the VOUT terminal and PGND terminal of board.
3) Close jumper JP1 to enable device and open JP1 to shutdown the device. An external MCU also can control the device by the EN terminal of board
   Note 1: If the EN terminal is connected to an MCU, please open JP1 to avoid MCU damage due to high voltage on the VCC pin.

4) External resistor sets the operating frequency (400kHz default). It also can be used to synchronize the operating frequency with an external clock signal (amplitude greater than 2V and 50% duty cycle) applied on the SYNC terminal of board.
5) PGOOD indicates power good state. High=good. Low=fault (LED D1 will be lighted up). If connect the PGOOD terminal to an MCU, please remove R2 and R3 then pull up by a 10KΩ resistor at the MCU side to avoid MCU damage due to high voltage from the VDD pin.
   R2, R3, D1 are used for power good state indication.
   Note 2: This circuit is not necessary for real application.
6) Turn on the power supply and output voltage is presented.
7) To measure the output voltage, please connect the voltage meter (multi-meter) on the VOUT terminal and PGND terminal of the board. No matter the power supply voltage or output current are changed (in SPEC), the output voltage of the evaluation board will be always constant.
   Note 3: if the output load is fixed which means the output power is constant, the power supply current will change following the power supply voltage. The lower power supply voltage the higher the power supply current. Please pay attention to the current limit of your power supply, especially at lower power supply voltages.
8) This evaluation board includes an EMI suppression filter circuit and is designed to meet the CISPR-25 conducted EMI standard. To meet class 5 level, the power supply must be connected to VIN+ terminal and VIN- terminal. To save the input common mode chock, connecting the power supply to VIN1+ terminal and VIN1- terminal still can meet class 5 level.

ORDERING INFORMATION

Part No.	Temperature Range	Package
IS32PM3510-ZLA3-EB	-40°C to +125°C (Automotive)	eTSSOP-16, Lead-free

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

DETAILED DESCRIPTION

OUTPUT VOLTAGE SETTING

The output voltage is set by selecting the values of the FB resistor divider, R_{FB1}(R9A) and R_{FB2}(R9C), according to the following equation:

$$V_{OUT} = V_{FB_TH} \times \frac{R_{FB1} + R_{FB2}}{R_{FB2}}$$

Where V_{FB_TH}= 1.2V (Typ.).

Table 1 R_{FB} Resistance Versus Output Voltage

V_{OUT}	R_{FB1} (kΩ)	R_{FB2} (kΩ)
5V	32 (1%)	10 (1%)
12V	90 (1%)	10 (1%)
24V	190 (1%)	10 (1%)
48V	390 (1%)	10 (1%)

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

FREQUENCY SETTING

The operating frequency of the device is programmable from 150kHz to 650kHz range using a single resistor R_{FSET} connected between FS/SYNC pin to ground. In automotive applications, an operating frequency of 400kHz is a good compromise between component size and efficiency. It makes it easier to filter switching noise from sensitive frequency bands and pass the EMI test.

To set a desired frequency, the resistor value can be calculated by following equation:

$$R_{FSET} = \frac{5 \times 10^4}{f_{SW} - 12} - 3.5$$

(74.9kΩ ≤ R_{FSET} ≤ 358.8kΩ)

Where R_{FSET} is in kΩ. f_{SW} is the operating frequency in kHz.

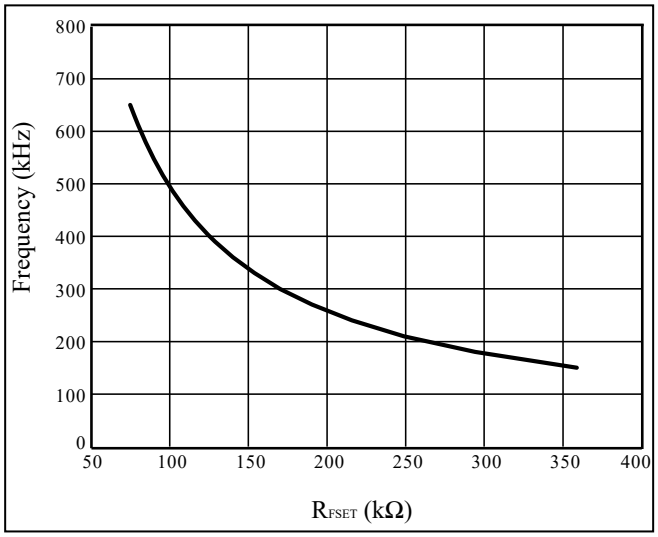


Figure 2: Operating Frequency vs. R_{FSET} Resistance

If the FS/SYNC pin is connected to an extremely low or high value resistor, equivalent to an open or shorted to ground condition, the operating frequency will be clamped by internal 400kHz oscillator.

INDUCTOR SELECTION

The operating frequency and inductor selection are interrelated in that higher operating frequencies allow the use of smaller inductor value. If the operating frequency is decided, inductor value involves trade-offs in performance. Larger inductance reduces inductor current ripple resulting in smaller output current ripple, however it also brings in unwanted parasitic resistance that degrades performance. The inductor value is determined based upon the operating frequency, output current, allowable current ripple, and input voltage and output voltage. Use the following equations to estimate the approximate inductor value:

For Boost:

$$L_{BOOST} \geq \frac{V_{CC_MIN} \times \left(V_{OUT} - V_{CC_MIN}\right)}{f_{SW} \times \Delta I_L \times V_{OUT}}$$

For Buck:

$$L_{BUCK} \geq \frac{V_{OUT} \times \left(V_{CC_MAX} - V_{OUT}\right)}{f_{SW} \times \Delta I_L \times V_{CC_MAX}}$$

Where V_{CC_MIN} is the minimum input voltage in volts, V_{CC_MAX} is the maximum input voltage in volts, V_{OUT} is the output voltage in volts, f_{SW} is the operating frequency in hertz. ΔI_L is allowable inductor peak to peak ripple current in Amp. The inductor value has a direct effect on ripple current. The highest current ripple happens in the Buck region at maximum input voltage. To keep the circuit in Continuous Conductive Mode (CCM), the maximum inductor current ripple should be less than twice the minimum load current. If the application requires all operation regions, choose the inductor value based on the Buck's Equation.

For high efficiency, choose an inductor with low core loss. The inductor should have low DC resistance to reduce the I^2R losses, and its rating current must be greater than the maximum input average current and saturation current greater than maximum inductor peak current with some safety margin. To minimize radiated EMI noise, a shielded inductor is always a good choice.

MAXIMUM OUTPUT CURRENT AND CURRENT SENSE RESISTOR R_{CS} SELECTION

When the input voltage is much lower than the output voltage, the IS32PM3510 operates in constant OFF-Time and inductor peak current control Boost mode. In Boost operation, the switch M_1 is always on. In the switch M_2 on phase, the inductor current ramps up through the switch M_2 and the current sense resistor R_{CS} to ground. The inductor peak current control is detected by the current sense resistor R_{CS} connected in series with the switch M_2.

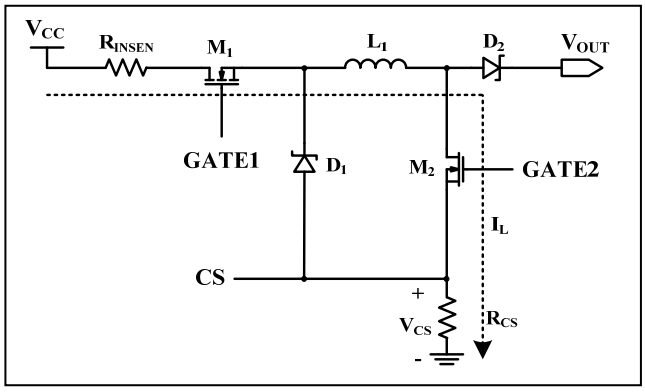


Figure 3 Boost Peak Current Detection in M_2 On Phase

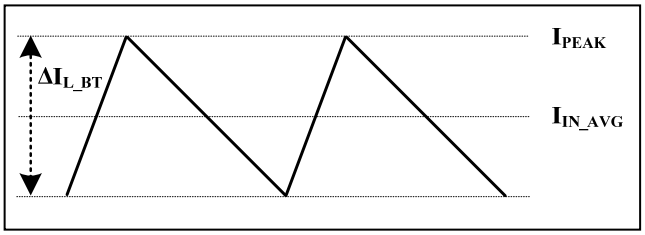


Figure 4 Boost Inductor Current

The inductor peak current limit protection threshold is set by the R_{CS} resistor, which determines the maximum output current of the Boost operation. So the maximum average load current at the minimum input voltage is:

$$I_{OUTBT_MAX} = \frac{I_{IN_AVG} \times V_{CC_MIN}}{V_{OUT}}$$

$$= \left(I_{PEAK} - \frac{\Delta I_{L_BT}}{2}\right) \times \frac{V_{CC_MIN}}{V_{OUT}}$$

$$= \left(\frac{V_{CS_TH1}}{R_{CS}} - \frac{\Delta I_{L_BT}}{2}\right) \times \frac{V_{CC_MIN}}{V_{OUT}}$$

Where, I_{IN_AVG} is the input average current at the

minimum input voltage V_{CC_MIN}. V_{CS_TH1} is peak current limit threshold, typical 77mV for Boost operation. ΔI_{L_BT} is the inductor current ripple at minimum input voltage in Boost operation.

The inductor peak current limit is cycle-by-cycle protection. Once the inductor peak current exceeds the current limit threshold, the GATE2 immediately pulls low to turn off the low-side power NMOS until the next switching cycle. If the output is over load, the inductor peak current keeps hitting the peak current limit and persists in longer than 2.5ms (Typ.) time frame, the IS32PM3510 will trigger hiccup protection, stop switching for t_{SKIP} and restart with the soft-start sequence. The hiccup will repeat until the peak current limit condition is removed. Besides the inductor peak current limit, the CS pin has a secondary peak current limit threshold, typical 110mV for Boost operation. Once the inductor peak current hits the secondary current limit, the hiccup protection is triggered directly.

When the input voltage is much higher than the output voltage, the IS32PM3510 operates in constant ON-Time and inductor valley current control Buck mode. In Buck operation, the switch M_2 is always off. In the switch M_1 off phase, the inductor current ramps down through the current sense resistor R_{CS} and the Schottky diode D_1, the inductor L_1 and the Schottky diode D_2 into the output loading. The inductor valley current control is detected by the current sense resistor R_{CS} connected in series with the Schottky diode D_1.

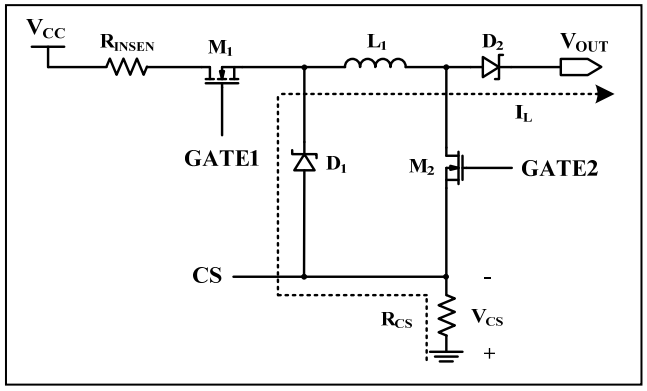


Figure 5 Buck Valley Current Detection in M_1 Off Phase

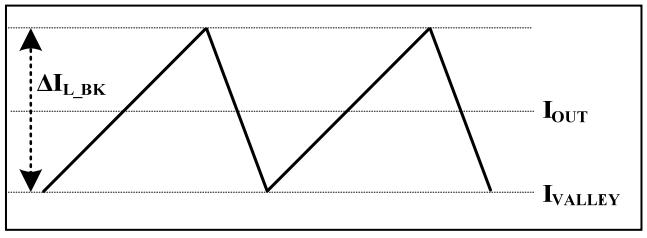


Figure 6 Buck Inductor Current

The inductor valley current limit protection threshold is set by the R_{CS} resistor, which determines the maximum output current of the Buck operation. So the maximum average load current is:

$$I_{OUTBK_MAX} = I_{VALLEY} + \frac{\Delta I_L}{2} = \frac{|V_{CS_TH1}|}{R_{CS}} + \frac{\Delta I_{L_BK}}{2}$$

Where, V_{CS_TH1} is valley current limit threshold, typical -67mV for Buck. ΔI_{L_BK} is the inductor current ripple in Buck operation.

The inductor valley current limit is cycle-by-cycle protection. If the output is over load, the inductor valley current exceeds the valley current limit and persists in longer than 2.5ms (Typ.) time frame, the IS32PM3510 will trigger hiccup protection, stop switching for t_{SKIP} and restart with the soft-start sequence. The hiccup will repeat until the valley current limit condition is removed. Similar to the Boost operation, the CS pin has a secondary peak current limit threshold, typical -110mV for Buck operation. Once the inductor peak current hits the secondary current limit, the hiccup protection is triggered directly.

Therefore, the R_{CS} resistor value is chosen based on the required maximum output current.

If the maximum load current is given, I_{OUT_MAX}, the maximum current sense resistor R_{CS} value for the Boost operation is:

$$R_{CSBT_MAX} = \frac{2 \times V_{CS_TH1} \times V_{CC_MIN}}{2 \times I_{OUT_MAX} \times V_{OUT} + \Delta I_{L_BT} \times V_{CC_MIN}}$$

Where, V_{CS_TH1} is peak current limit threshold, typical 77mV for Boost.

With the same maximum load current, the maximum current sense resistor R_{CS} value for the Buck operation is:

$$R_{CSBK_MAX} = \frac{2 \times |V_{CS_TH1}|}{2 \times I_{OUT_MAX} - \Delta I_{L_BK}}$$

Where, V_{CS_TH1} is valley current limit threshold, typical -67mV for Buck.

The final R_{CS} value should be lower than both of R_{CSBT_MAX} and R_{CSBK_MAX} and a 30% margin is recommended.

SCHEMATIC

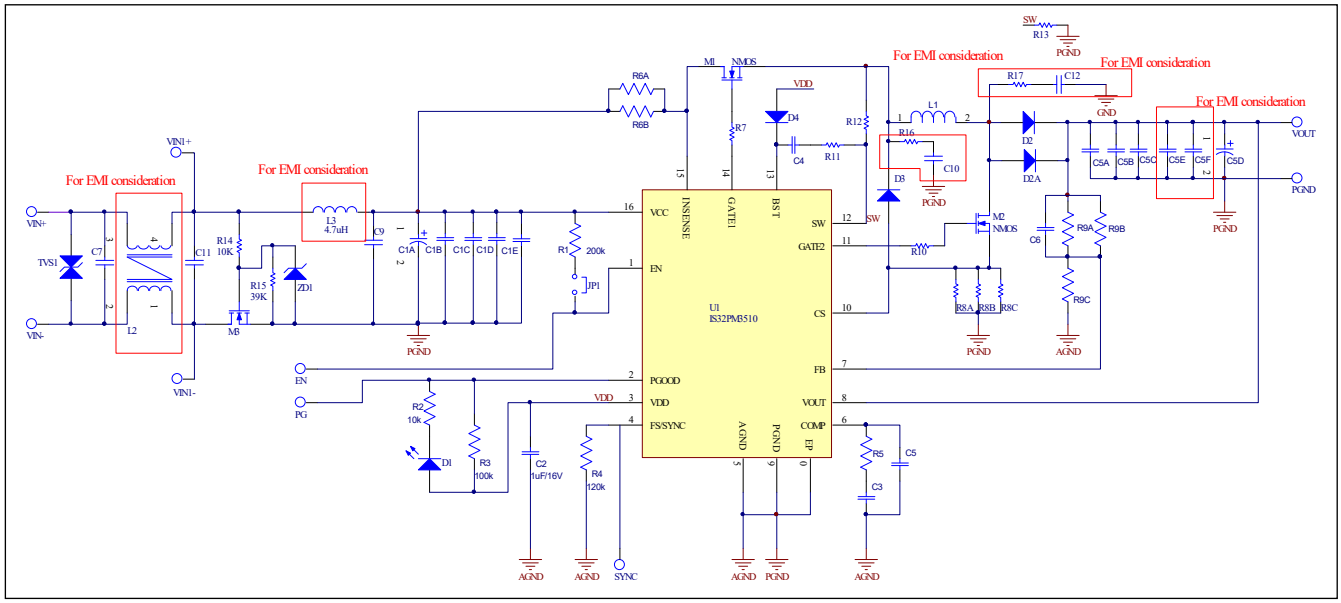


Figure 7: IS32PM3510 Demo Board Schematic

Note 4: R14, R15, ZD1 and M3 form an ideal diode as low loss input reverse polarity protection. They can be replaced by a lower cost Schottky diode, however the much higher forward voltage on Schottky diode will degrade the efficiency and increase thermal on board.

Note 5: The EMI filtering circuits are optional. Using different external components, PCB layout, parameter setting may result in a significantly different EMI performance. Please fine tune EMI filtering circuit based on your actual EMI scan result.

BILL OF MATERIALS

Name	Symbol	Description	Qty	Supplier	Part No.
IC	U1	ASYNCHRONOUS BOOST AND BUCK-BOOST VOLTAGE REGULATOR	1	Lumissil	IS32PM3510
Capacitor	C1C,C1D,C5A,C5B,C5C	CAP,10μF,50V,±10%,SMD	5	Murata	GRM32ER71H106KA12L
Capacitor	C1E,C4	CAP,0.1μF,50V,±10%,SMD	2	Yageo	AC0603KRX7R9BB104
Capacitor	C5E,C5F	CAP,0.22μF,50V,±10%,SMD	2	Yageo	AC0603KRX7R9BB224
Capacitor	C2	CAP,1μF,50V,±10%,SMD	1	SAMSUNG	AC0603KKX7R9BB105
Capacitor	C3	CAP,22nF,50V,±10%,SMD	1	SAMSUNG	AC0603KKX7R9BB223
Capacitor	C5	CAP,100pF,50V,±10%,SMD	1	SAMSUNG	AC0603KRX7R9BB101
Capacitor	C7,C11	CAP,1μF,50V,±10%,SMD	2	SAMSUNG	AC1206KKX7R9BB105
Capacitor	C5D	E-CAP,47μF,63V,±10%,SMD	1	Panasonic	EEEFK1J470P
Capacitor	C1A,C9,C6,R9B,R13,TVS1,C1B,	No connect	7		
Capacitor	C10,C12	CAP,1nF,50V,±10%,SMD	2	SAMSUNG	AC0603KRX7R9BB102
Resistor	R6A,R6B	RES,0.02R,1206,±5%,SMD	2	UNI-ROYAL	1206W4F200MT5E
Resistor	R8A	RES,0.025R,1206,±5%,SMD	1	UNI-ROYAL	CS06W4F250MT5E
Resistor	R8B,R8C	RES,0.05R,1206,±5%,SMD	2	UNI-ROYAL	CS06W4F500MT5E

Resistor	R7,R10, R11,R12	RES,0R,0603,±5%,SMD	4	Panasonic	ERJ-3GEY0R00V
Resistor	R1	RES,200k,0603,±5%,SMD	1	Yageo	AC0603FR-07200KL
Resistor	R2,R14	RES,10k,0603,±5%,SMD	2	Yageo	AC0603FR-0710KL
Resistor	R15	RES,39k,0603,±5%,SMD	1	Yageo	AC0603FR-0739KL
Resistor	R3	RES,100k,0603,±5%,SMD	1	Yageo	AC0603FR-07100KL
Resistor	R4	RES,120k,0603,±5%,SMD	1	Yageo	AC0603FR-07120KL
Resistor	R5,R9C	RES,10k,0603,±1%,SMD	2	Yageo	AC0603FR-0710KL
Resistor	R9A	RES,91k,0603,±1%,SMD	1	Yageo	AC0603FR-0791KL
Resistor	R16,R17	RES,2R,0603,±5%,SMD	2	UNI-ROYAL	0603WAF200KT5E
MOSFET	M1,M2	48A,60V,NMOS	2	DIODES	DMNH6021SPSQ
MOSFET	M3	22A,60V,NMOS	1	ON	NVD5867NLT4G
Inductor	L1	10μH±20%,Isat≥7.1A	1	Panasonic	ETQP5M100YFC
Inductor	L3	4.7μH±20%, I_R=6.3A	1	Panasonic	ETQP5M4R7YFM
Inductor	L2	700Ω@100MHZ, I_R=5A	1	TDK	ACM90V-701-2PL-TL00
Diode	D3,D2,D2A	5A,100V	3	Littelfuse	DST5100S-A
Diode	D1	RED LED,0603,V_F=3V	1	OSRAM	LS Q976-NR-1
Diode	D4	SS16,1A,60V	1	MDD	SS16
Diode	ZD1	DIODE ZENER, 7.5V, SOD123	1	DIODES	BZT52HC7V5WF-7
PCB	/	77mm × 60mm, FR-4, 4 layers, 1oz copper	1		

Note 6: Bill of materials refers to Figure 7 above.

PCB LAYOUT

Note 7: Since the PCB layout is very critical for the EMI performance, please follow this PCB layout's components placement and trace routing for better EMI performance. If need, please contact Lumissil to acquire the PCB layout files/application note for your PCB layout reference

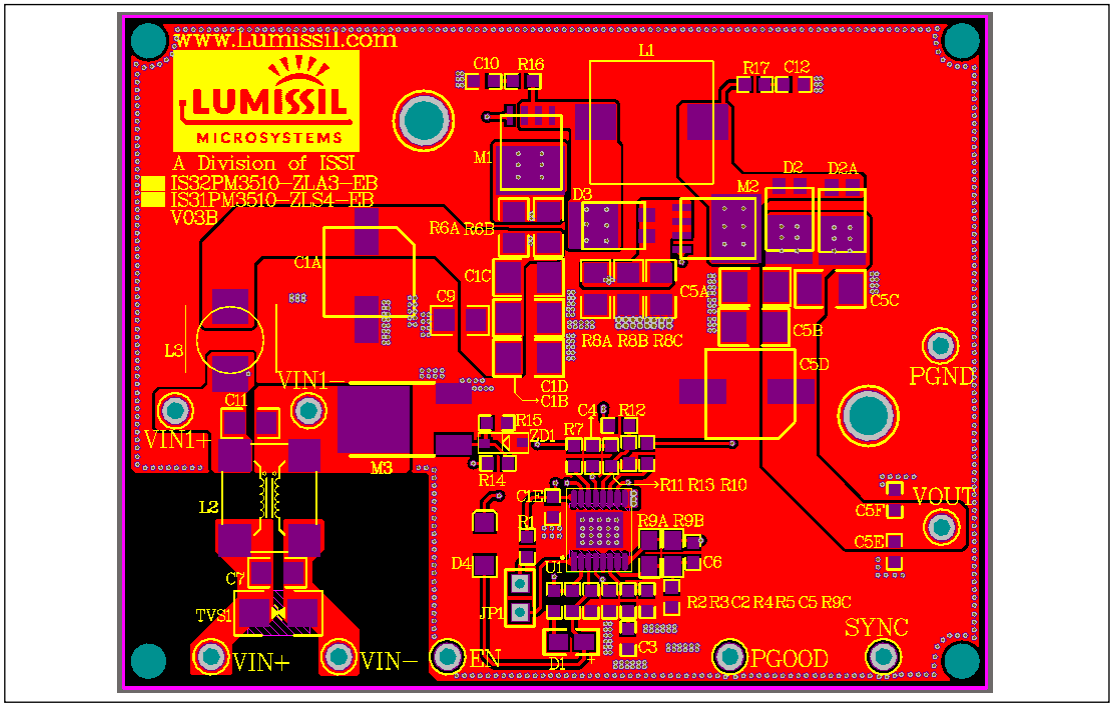


Figure 8: Top layer

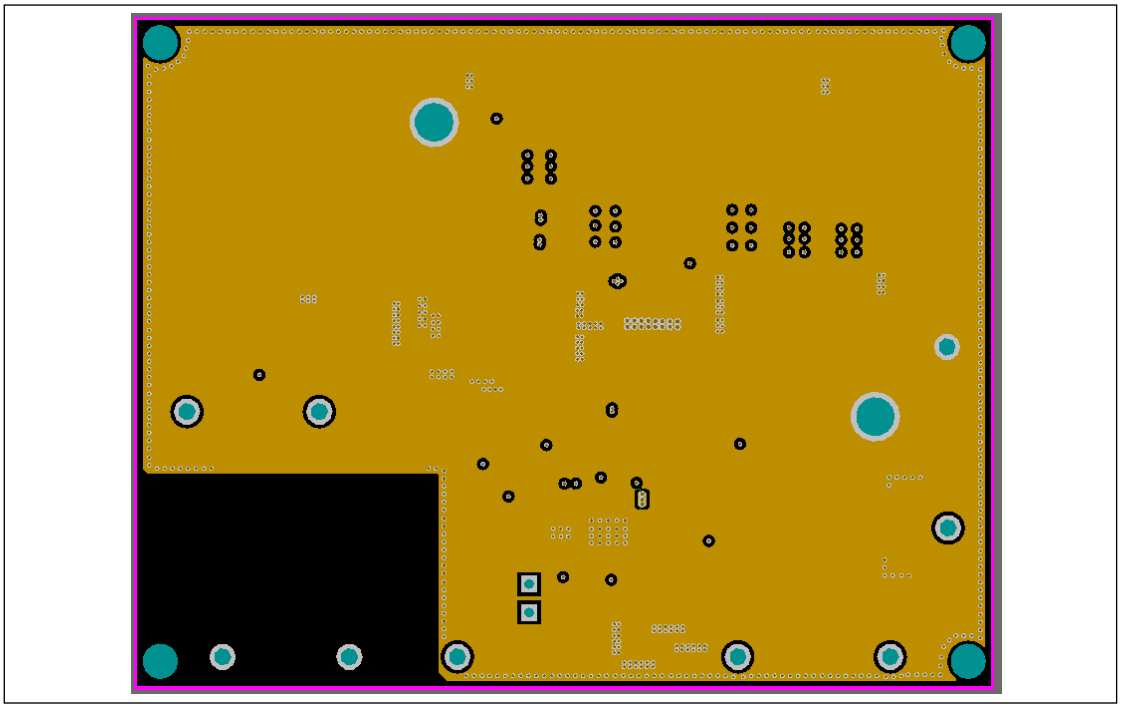


Figure 9: Mid-Layer 1

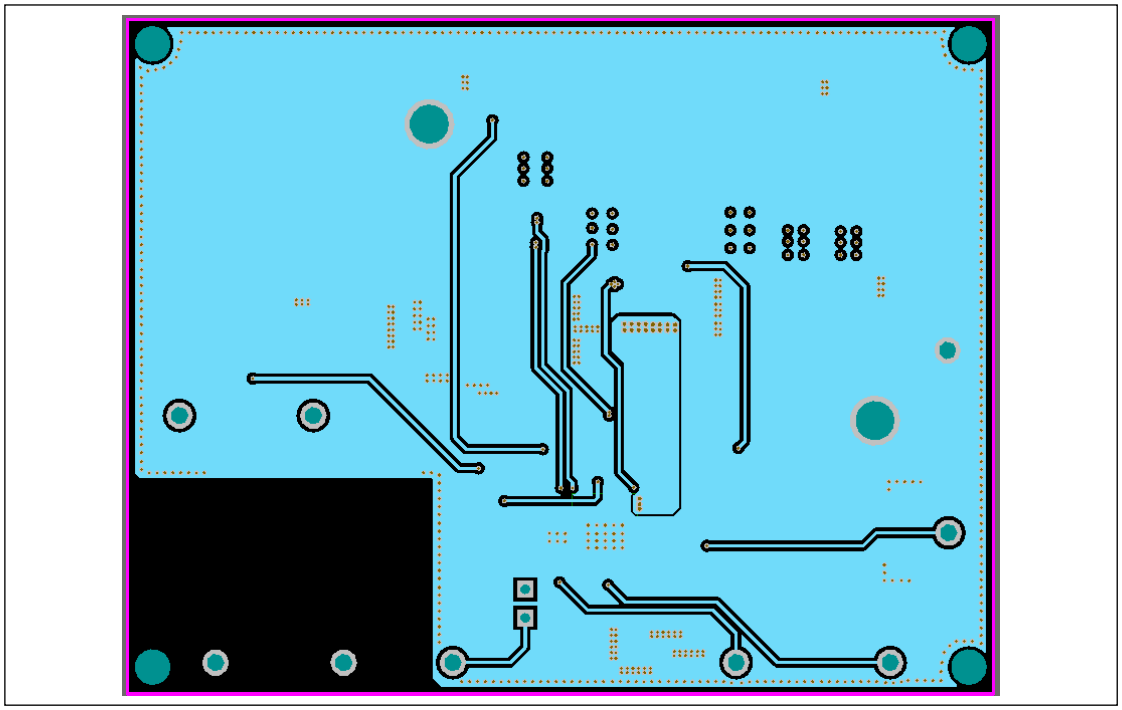


Figure 10: Mid-Layer 2

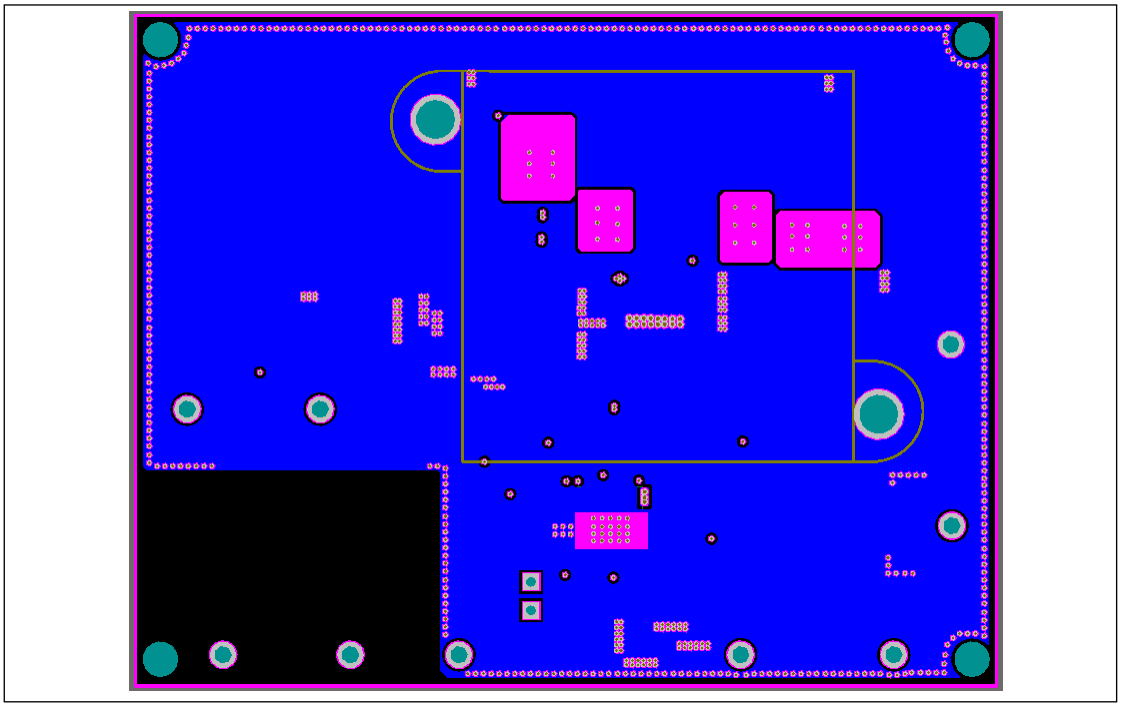


Figure 11: Bottom layer

CONDUCTED EMI PERFORMANCE

Test condition: V_{IN}=12V, V_{OUT}=12V, I_{OUT}=3A, naked board without any shielding

Test standard: CISPR-25 Class 5 conducted EMI (Blue: Peak scanning, Red: Average scanning)

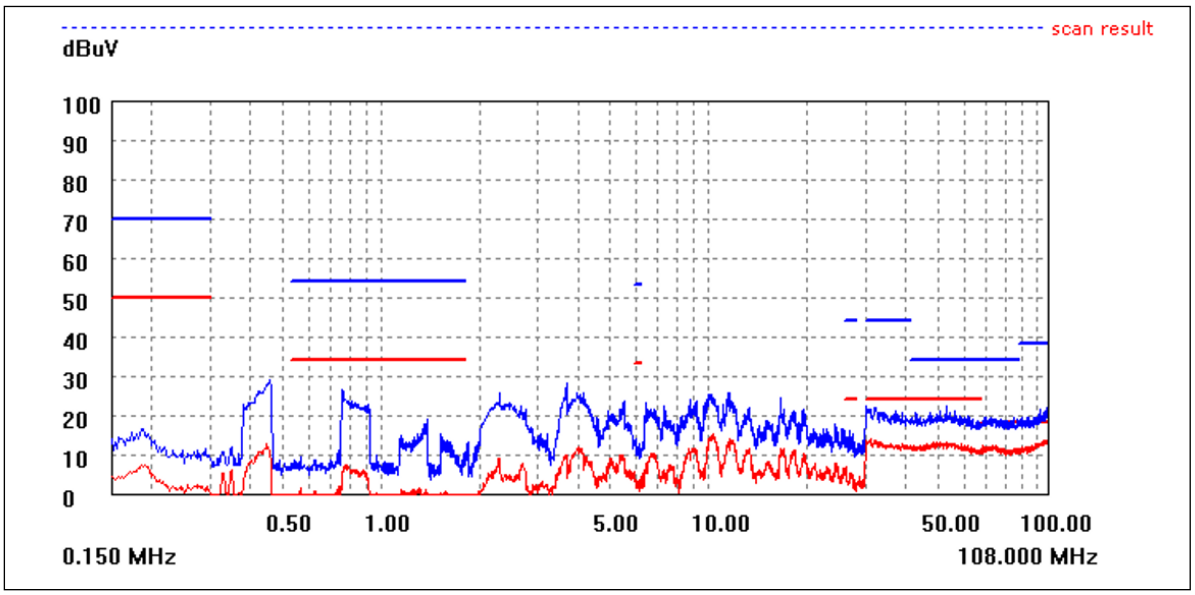


Figure 12: CISPR-25 Class 5 Conducted EMI Scan Vin+ line (With Input Common Mode Chock)

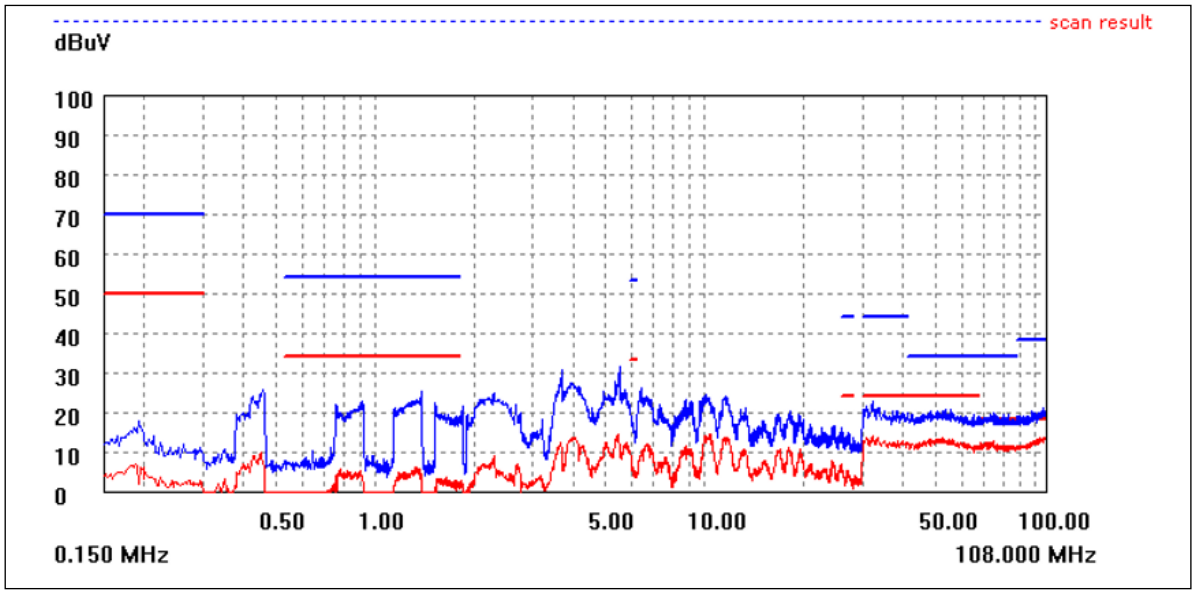


Figure 13: CISPR-25 Class 5 Conducted EMI Scan Vin- line (With Input Common Mode Chock)

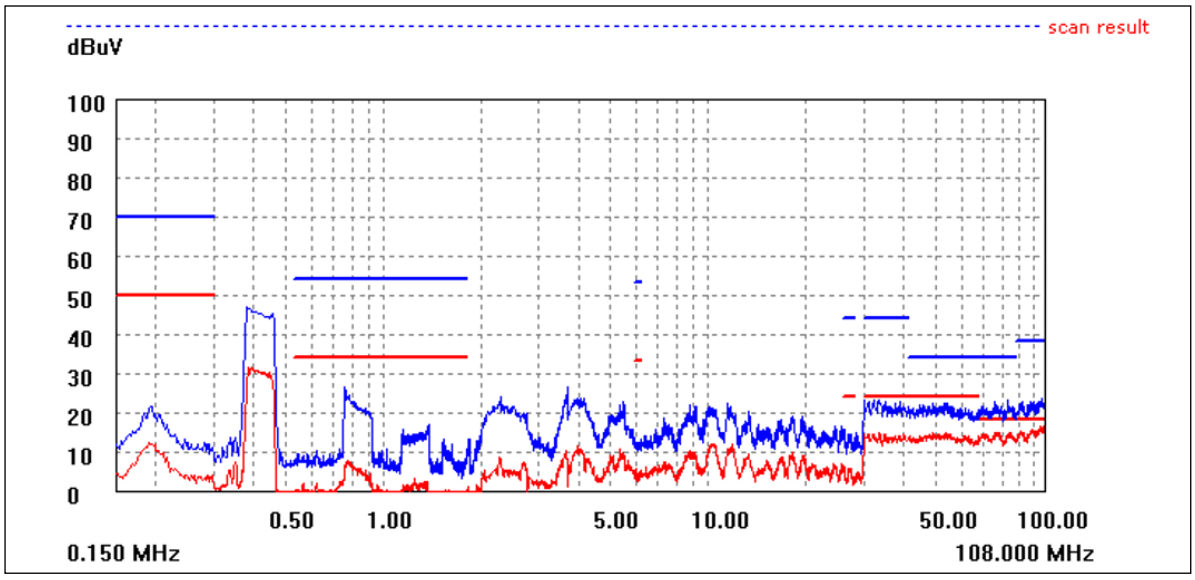


Figure 14: CISPR-25 Class 5 Conducted EMI Scan Vin1+ line (Without Input Common Mode Chock)

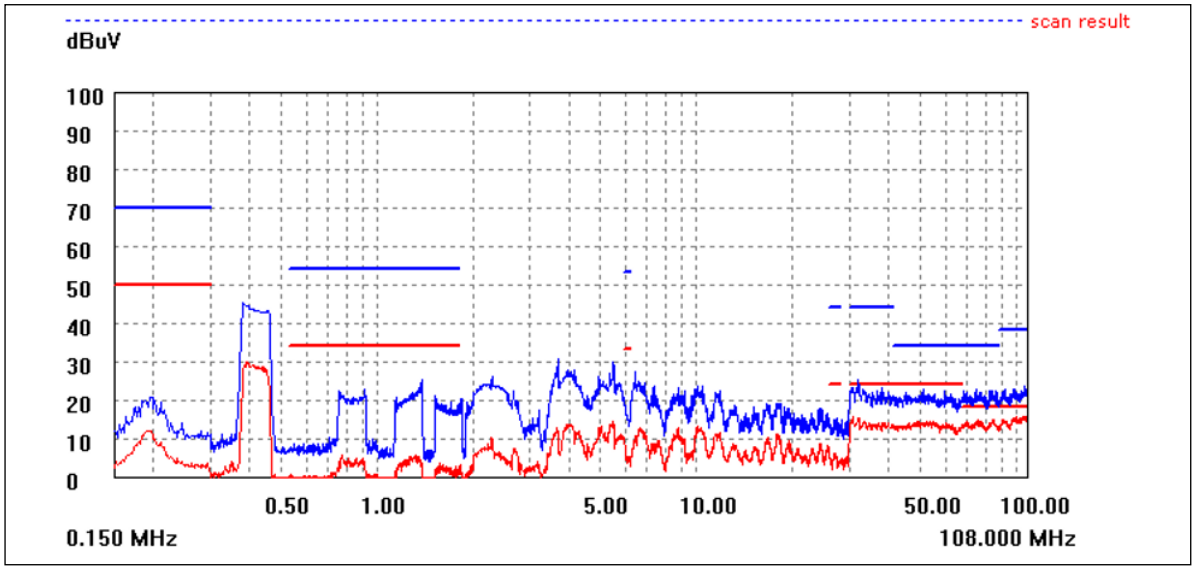


Figure 15: CISPR-25 Class 5 Conducted EMI Scan Vin1- line (Without Input Common Mode Chock)

LOAD REGULATION AND LINE REGULATION

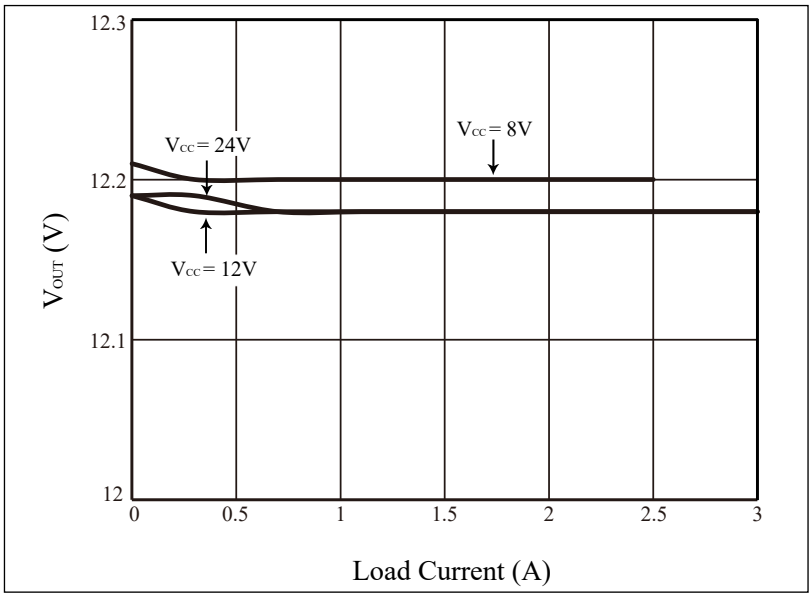


Figure 16: Load Regulation

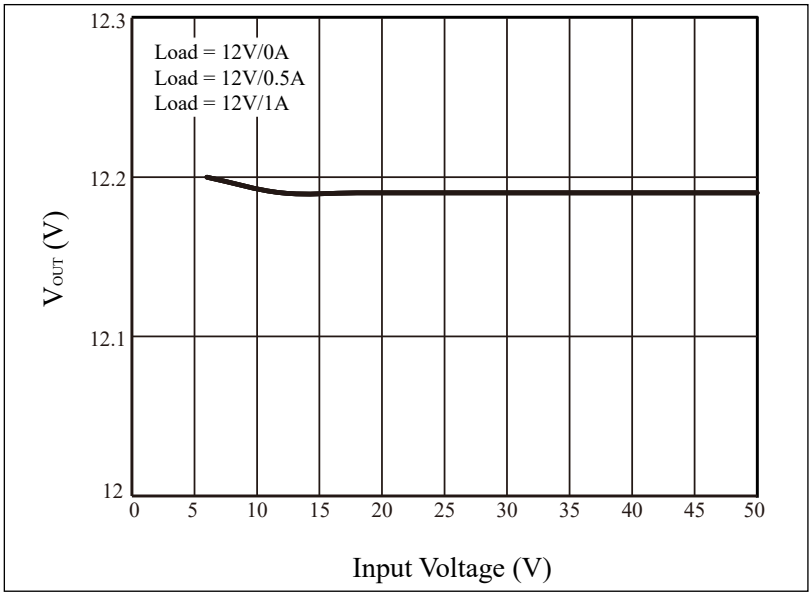


Figure 17: Line Regulation

EFFICIENCY

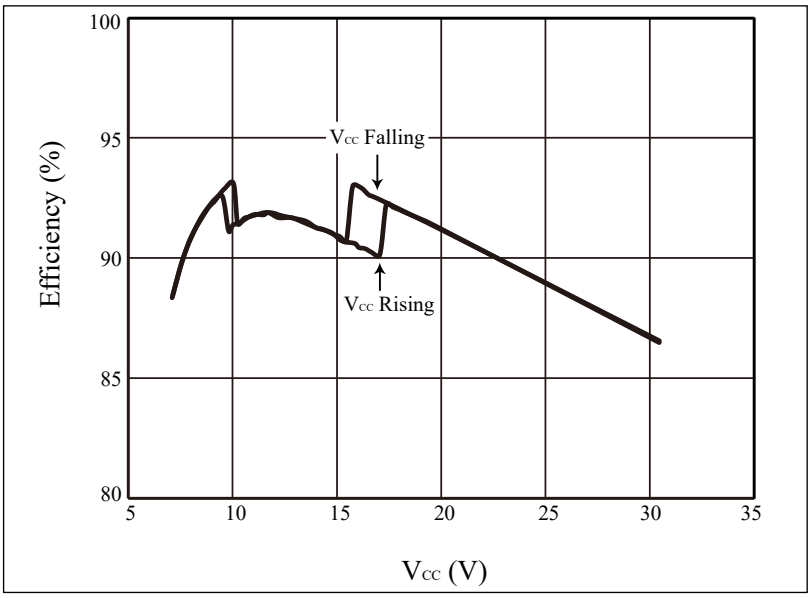


Figure 18: Efficiency vs. V_{CC} (Loading=12V/1A)

REVISION HISTORY

Revision	Detail Information	Date
A	Initial release	2021.11.04

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