

# LM5158 Flyback Converter Evaluation Module



## ABSTRACT

The LM5158EVM-FLY evaluation module showcases the features and performance of the LM5158 as wide input non-synchronous flyback controller to produce multiple output voltage rails for typical applications of the 3-phase inverter gate driver bias supplies. The standard configuration is designed to provide a regulated output of 10 V at 250 mA from an input of 8 V to 16 V, and three isolated 20-V rails at 75 mA, 75 mA, and 150 mA, respectively. The switching frequency is 250 kHz. This evaluation module was designed for ease of configuration, enabling the user to evaluate different applications on the same module. The PCB has two copper layers.

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## Trademarks

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## 1 Introduction

The LM5158EVM-FLY supports the following features and performance capabilities:

- Tightly regulated main output voltage:  $V_{O1} = 10 \text{ V} \pm 1\%$
- Three cross-regulated, isolated output voltages:
  - $V_{O2} = 20 \text{ V}$
  - $V_{O3} = 20 \text{ V}$
  - $V_{O4} = 20 \text{ V}$
- Total rated load of 8.5 W:
  - 250 mA at  $V_{O1}$
  - 75 mA at  $V_{O2}$
  - 75 mA at  $V_{O3}$
  - 150 mA at  $V_{O4}$
- Peak efficiency > 90%
- Optional hiccup mode overloading protection
- 250-kHz switching frequency
- 2-layer PCB, 3.5 in  $\times$  2.3 in

## 2 Electrical Parameters

Table 2-1 details the electrical performance standard configuration.

**Table 2-1. Electrical Performance Standard Configuration**

| PARAMETER                                        | TEST CONDITIONS                                 | MIN | TYP | MAX   | UNIT |
|--------------------------------------------------|-------------------------------------------------|-----|-----|-------|------|
| Input Characteristics                            |                                                 |     |     |       |      |
| Input voltage range $V_{IN}$                     | Operation                                       | 8   | 12  | 16    | V    |
| Abs max input voltage $V_{INMAX}$                | Operation without damage                        |     |     | 18    | V    |
| Input voltage turn-on $V_{IN(ON)}$               | Adjustable by the UVLO/SYNC resistors           |     | 7.6 |       | V    |
| Input voltage turn-on $V_{IN(OFF)}$              |                                                 |     | 7.1 |       | V    |
| Output Characteristics                           |                                                 |     |     |       |      |
| Main output voltage $V_{O1}$                     |                                                 |     | 10  |       | V    |
| First isolated output voltage $V_{O2}$           |                                                 |     | 20  |       | V    |
| Second isolated output voltage $V_{O3}$          |                                                 |     | 20  |       | V    |
| Third isolated output voltage $V_{O4}$           |                                                 |     | 20  |       | V    |
| Main output load current $I_{O1}$                |                                                 |     |     | 0.250 | A    |
| First isolated output load current $I_{O2}$      |                                                 |     |     | 0.075 | A    |
| Second isolated output load current $I_{O3}$     |                                                 |     |     | 0.075 | A    |
| Third isolated output load current $I_{O4}$      |                                                 |     |     | 0.150 | A    |
| System Characteristics                           |                                                 |     |     |       |      |
| Switching frequency                              |                                                 |     | 250 |       | kHz  |
| Peak efficiency                                  | $V_{IN} = 12$ V, rated load at all output rails |     | 90  |       | %    |
| Junction temperature                             |                                                 | −40 |     | 150   | °C   |
| Transformer Specifications (Coilcraft ZB1324-AL) |                                                 |     |     |       |      |
| Primary inductances                              |                                                 |     | 8   |       | μH   |
| Turns ratio                                      | (2-4) : (1-3)                                   |     | 1   |       |      |
|                                                  | (5-6) : (1-3)                                   |     | 1.2 |       |      |
|                                                  | (8-7) : (1-3)                                   |     | 2.4 |       |      |
|                                                  | (10-9) : (1-3)                                  |     | 2.4 |       |      |
|                                                  | (12-11) : (1-3)                                 |     | 2.4 |       |      |
| Saturation current                               | 20% inductance reduction                        |     | 5.5 |       | A    |
| Leakage inductance                               |                                                 |     |     | 90    | nH   |

### 3 Application Schematic

The LM5158EVM-FLY is capable of multiple configurations. [Figure 3-1](#) shows the standard configuration of the LM5158EVM-FLY where the parameters in [Table 2-1](#) are valid.

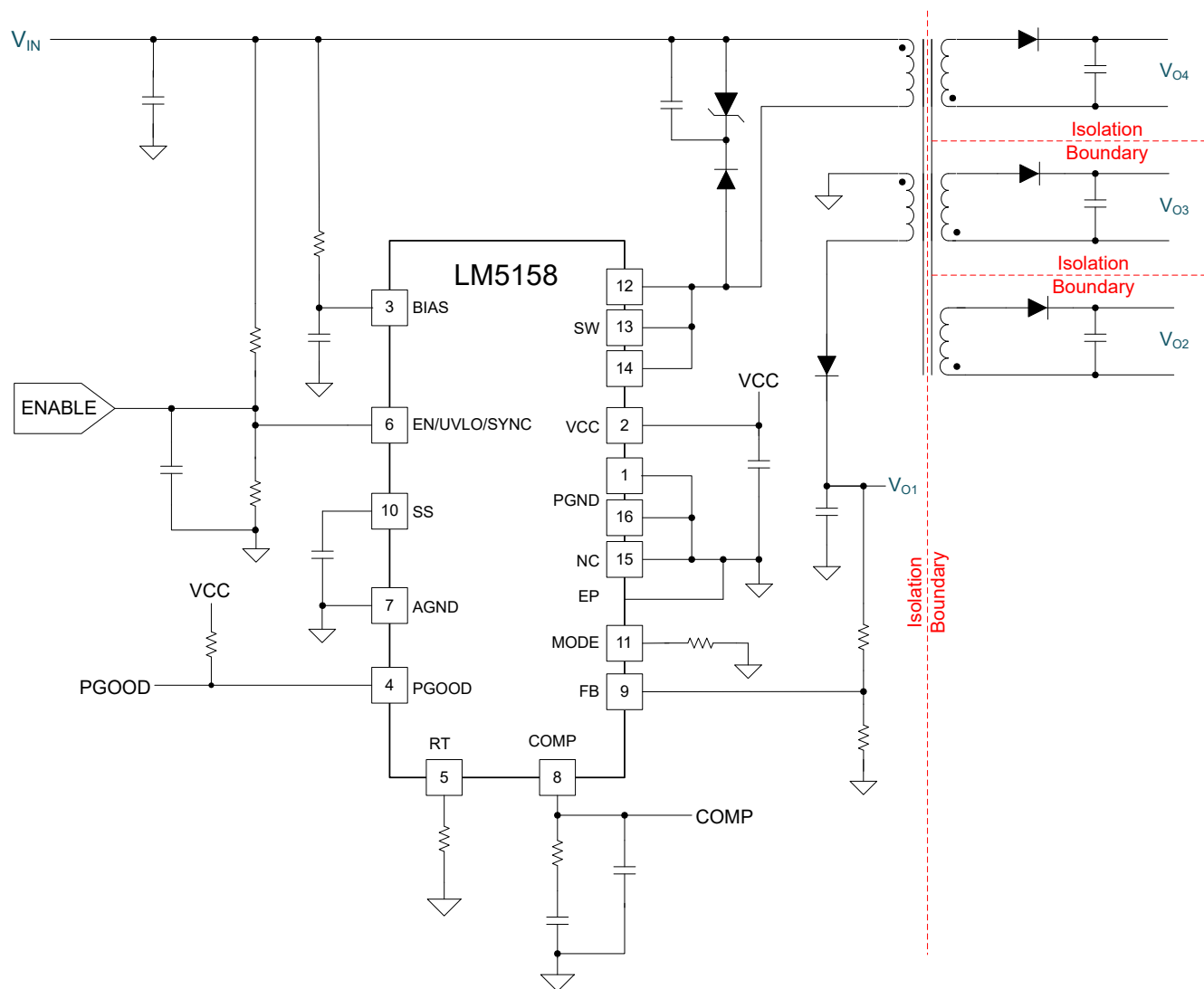


**Figure 3-1. Application Circuit**

## 4 EVM Picture

Figure 4-1 is a 3D printout of the EVM from the CAD tool. The actual color of the board can differ. The EVM also includes circuits for extra configurations. Not all components are populated on the EVM.

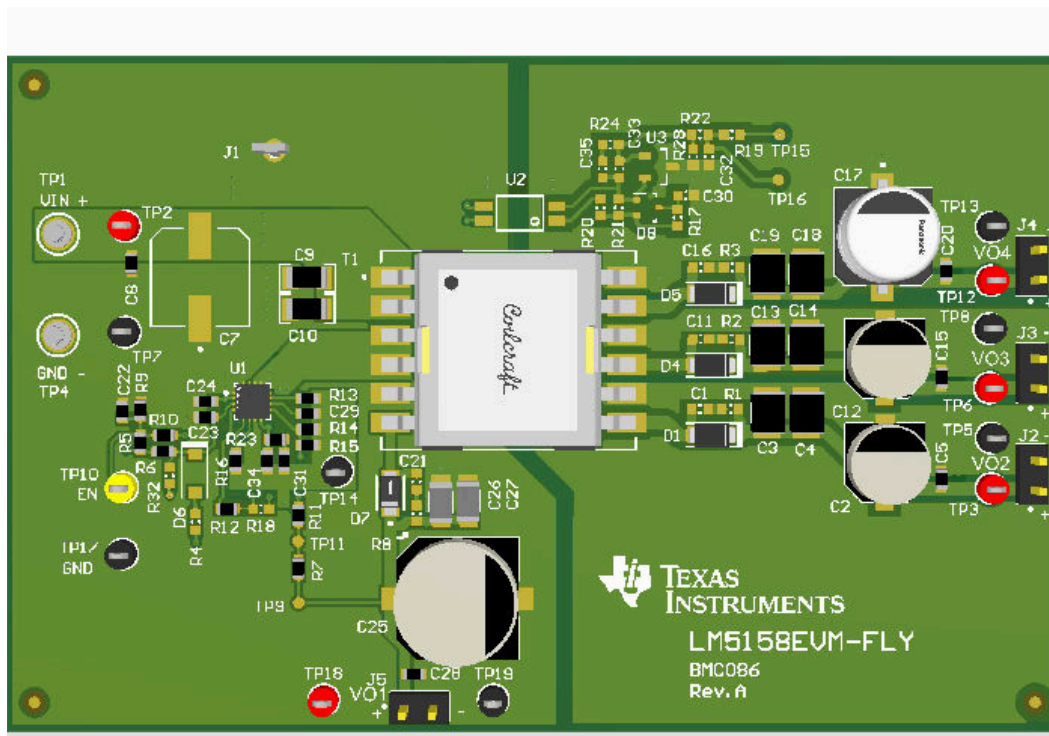


Figure 4-1. EVM Picture

## 5 Test Setup and Procedure

### 5.1 EVM Test Setup Schematic

Figure 5-1 shows the correct equipment connections and measurement points.

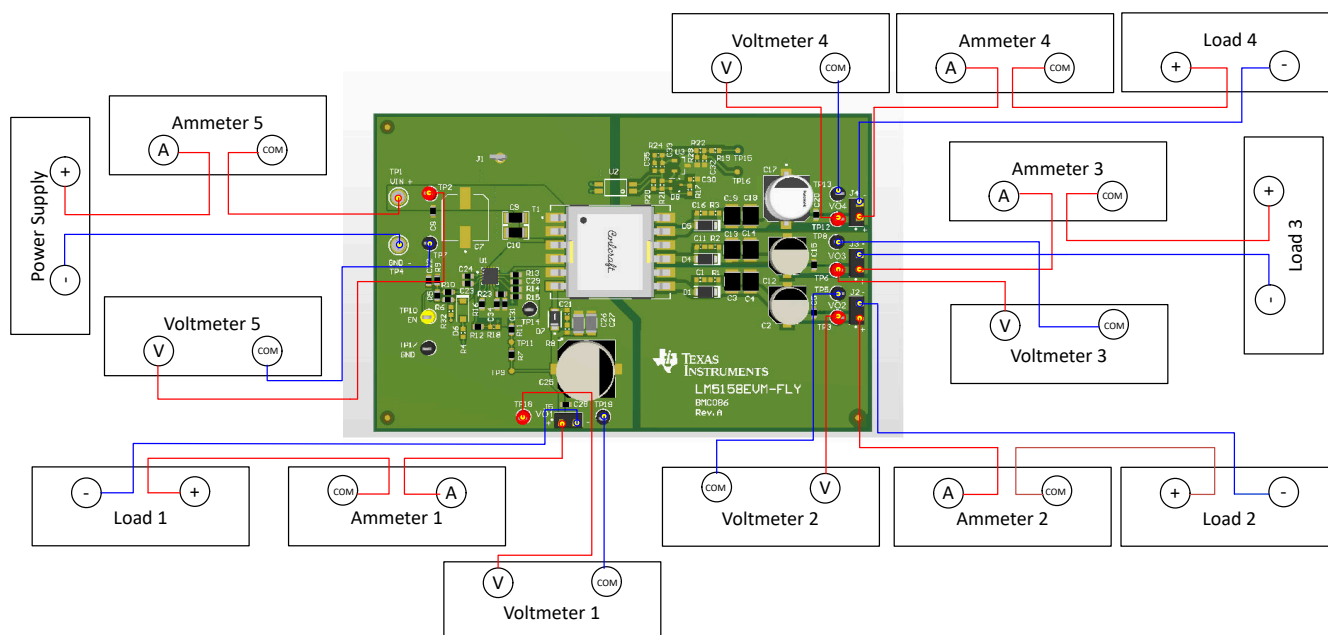


**Figure 5-1. Test Setup**

### 5.2 Test Equipment

**Power Supply:** Use an input voltage source that is a variable supply capable of 0 V to 16 V and sources at least 5 A.

**Multimeters:**

- Voltmeter 1: Non-isolated 10-V main output voltage  $V_{O1}$ , connect from TP18 (+) to TP19 (–).
- Voltmeter 2: Isolated 20-V output voltage  $V_{O2}$ , connect from TP3 (+) to TP5 (–).
- Voltmeter 3: Isolated 20-V output voltage  $V_{O3}$ , connect from TP6 (+) to TP8 (–).
- Voltmeter 4: Isolated 20-V output voltage  $V_{O4}$ , connect from TP12 (+) to TP13 (–).
- Voltmeter 5: Input voltage  $V_I$ , connect from TP2 (+) to TP7 (–).
- Ammeter 1:  $V_{O1}$  main output current, must be able to handle 1 A
- Ammeter 2:  $V_{O2}$  output current, must be able to handle 0.5 A
- Ammeter 3:  $V_{O3}$  output current, must be able to handle 0.5 A
- Ammeter 4:  $V_{O4}$  output current, must be able to handle 0.5 A
- Ammeter 5: Input current, must be able to handle 3 A

**Loads:** Electronic loads, pure resistive loads, or a combination of both, can be used at the four outputs.

- An electronic load can be used for each output rail. The electronic load should be constant resistance (CR) or constant current (CC) capable. It should safely handle 0.5 A at 20 V.
- Resistive load can also be used. Limit the minimum resistance for each output, which corresponds to the maximum power, with the following:
  - Load 1: 40  $\Omega$  or 250 mA
  - Load 2: 266.7  $\Omega$  or 75 mA
  - Load 3: 266.7  $\Omega$  or 75 mA
  - Load 4: 133.3  $\Omega$  or 150 mA

## 6 Test Data and Performance Curves

Figure 6-1 through Figure 6-24 present the typical performance of the LM5158EVM-FLY. Based on measurement techniques and environmental variables, measurements can differ slightly to the data presented.

### 6.1 Efficiency

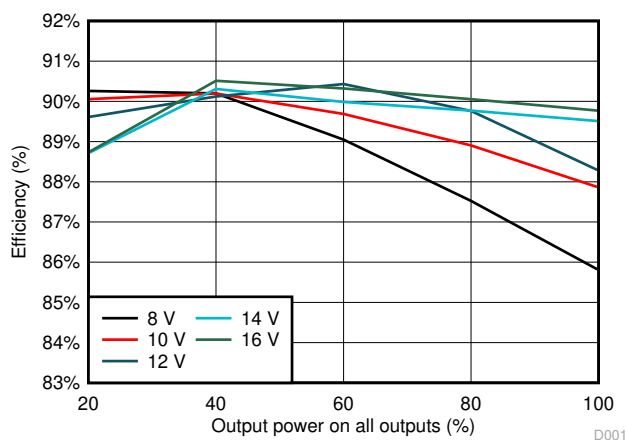


Figure 6-1. Efficiency Under Different Input Voltages and Load Levels

### 6.2 Output Regulation

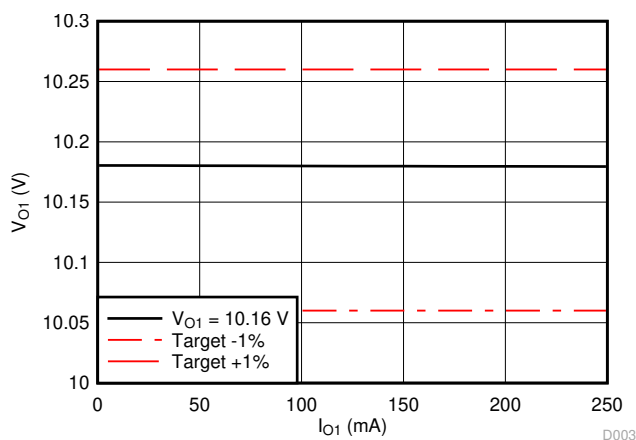


Figure 6-2. Main Output Voltage Regulation Versus Main Output Load ( $I_{O2}$ ,  $I_{O3}$ ,  $I_{O4}$  = 10%)

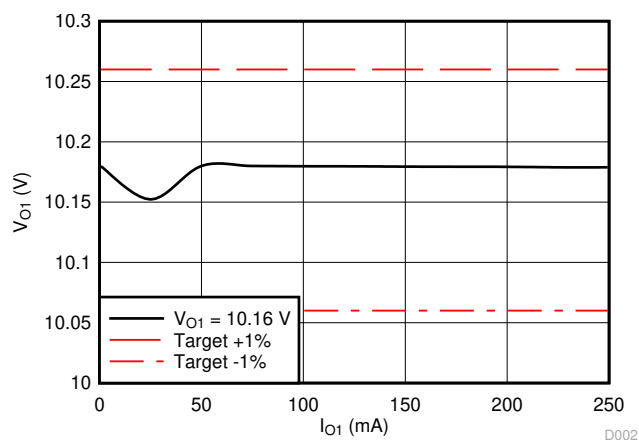


Figure 6-3. Main Output Voltage Regulation Versus Main Output Load ( $I_{O2}$ ,  $I_{O3}$ ,  $I_{O4}$  = 100%)

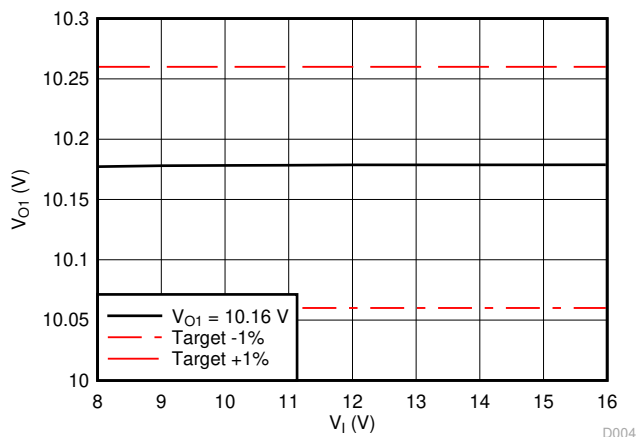


Figure 6-4. Main Output Voltage Regulation Versus Input Voltage ( $I_{O2}$ ,  $I_{O3}$ ,  $I_{O4}$  = 100%)

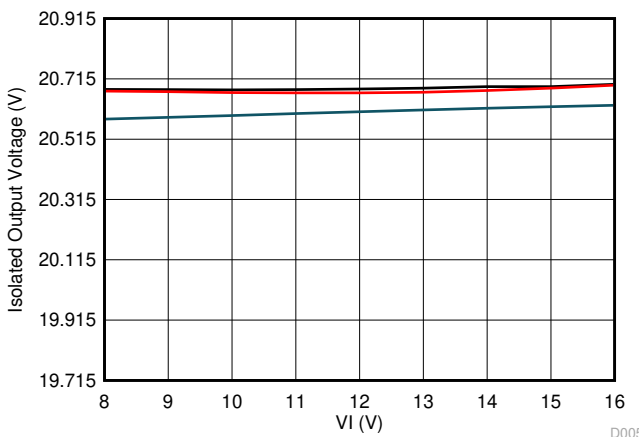


Figure 6-5. Voltage Regulation of Isolated Outputs Versus Input Voltage at 10% load

## 6.3 Steady-State Waveforms

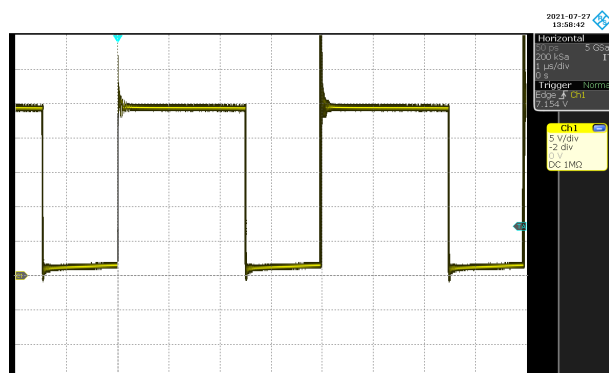


Figure 6-6. SW Waveform at 100% Load, Under 16-V Maximum  $V_{IN}$

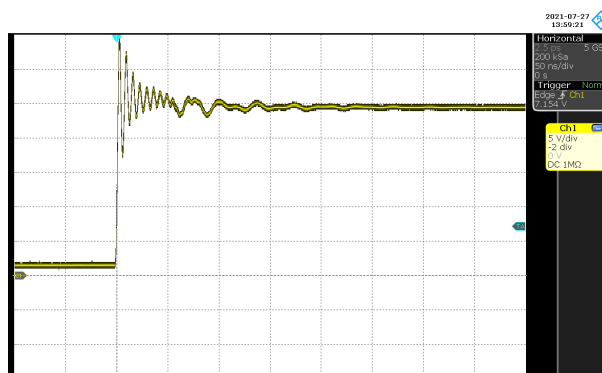


Figure 6-7. Zoomed SW Waveform at 100% Load, Under 16-V Maximum  $V_{IN}$

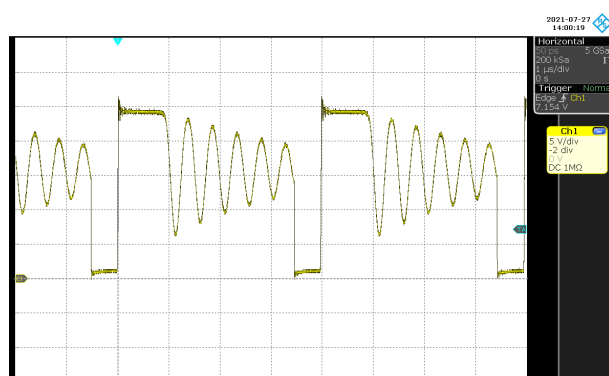


Figure 6-8. SW Waveform at 10% Load, Under 16-V Maximum  $V_{IN}$

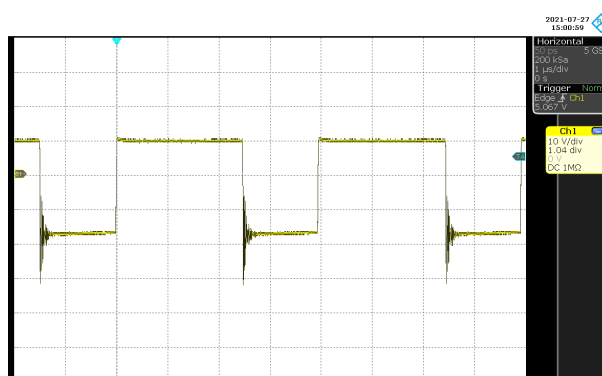


Figure 6-9. PIV of D7 (main Output Rectifier) Under 100% Load and 16-V Maximum  $V_{IN}$

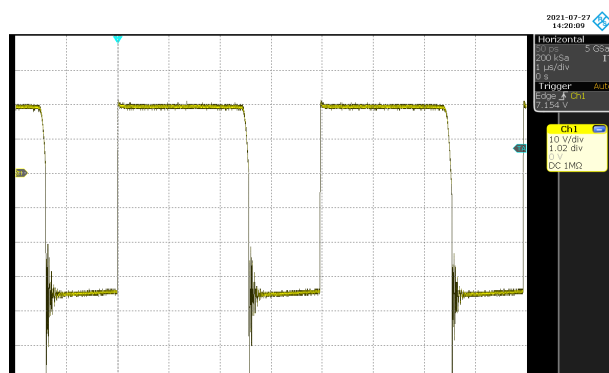


Figure 6-10. PIV of D1 ( $V_{O2}$  Rectifier) Under 100% Load and 16-V Maximum  $V_{IN}$

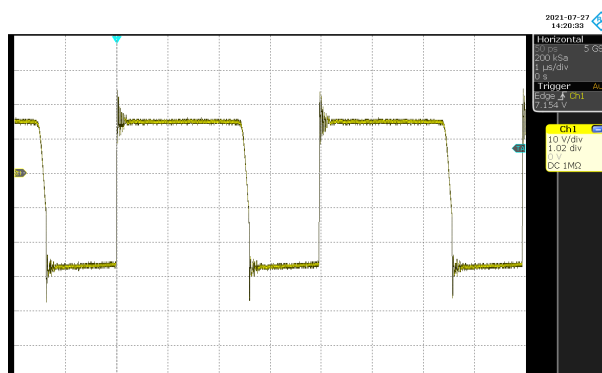


Figure 6-11. PIV of D4 ( $V_{O3}$  Rectifier) Under 100% Load and 16-V Maximum  $V_{IN}$

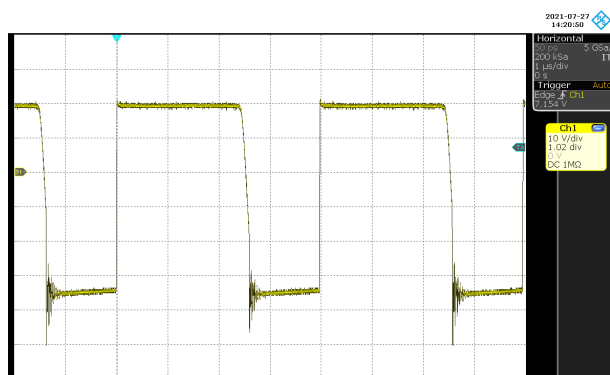


Figure 6-12. PIV of D5 ( $V_{O4}$  Rectifier) Under 100% Load and 16-V Maximum  $V_{IN}$

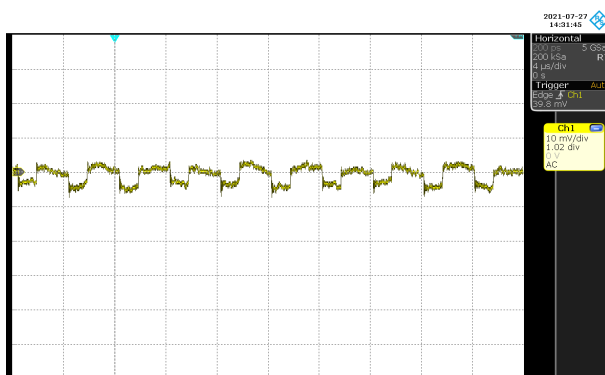


Figure 6-13. Main Output  $V_{O1}$  Ripple Voltage Under 250-mA Load



Figure 6-14. Isolated Output  $V_{O4}$  Ripple Voltage Under 150-mA Load

## 6.4 Start-Up Waveforms

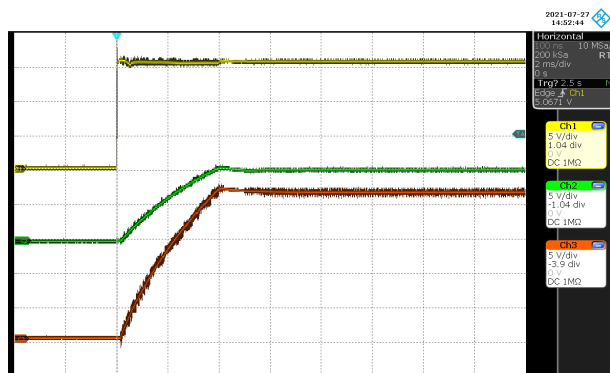


Figure 6-15. Start-Up at 10% Load on Each Output Rail

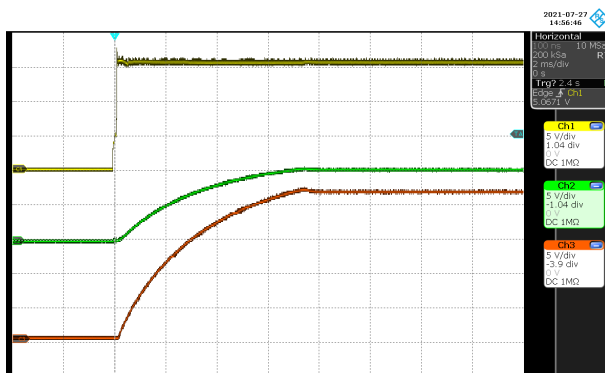


Figure 6-16. Start-Up at 100% Load on Each Output Rail

## 6.5 Dynamic Responses

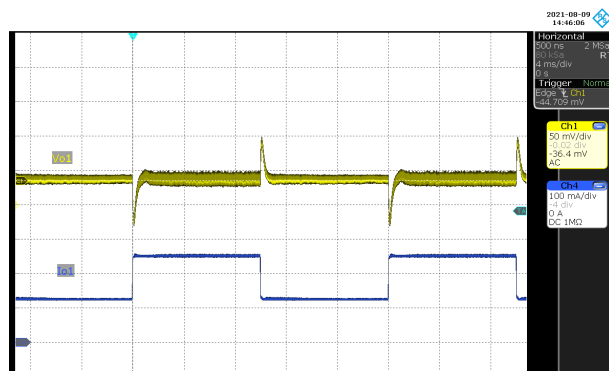


**Figure 6-17.  $V_{O1}$  Response Under Step Load Between 125 mA and 250 mA,  $V_{IN} = 12$  V,  $I_{O2-4} = 10\%$**

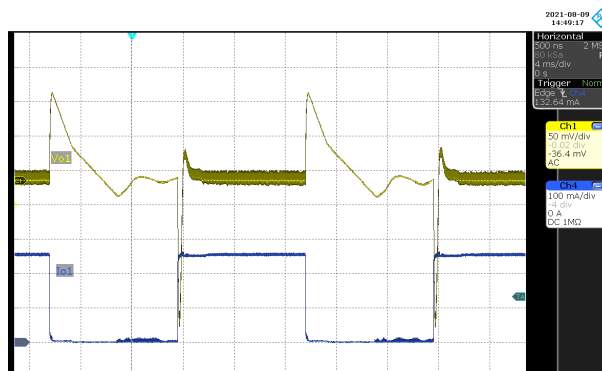


**Figure 6-18.  $V_{O1}$  Response Under Step Load Between 1 mA to 250 mA,  $V_{IN} = 12$  V,  $I_{O2-4} = 10\%$**

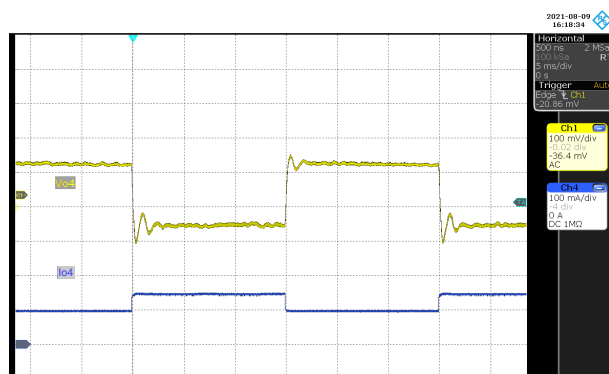


**Figure 6-19.  $V_{O4}$  Response Under Step Load Between 100 mA and 150 mA,  $V_{IN} = 12$  V,  $I_{O1-3} = 10\%$**

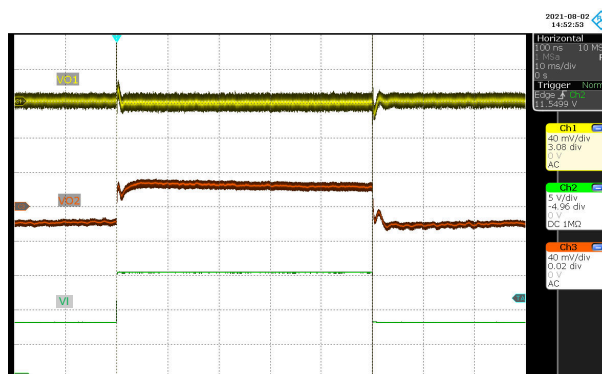


**Figure 6-20.  $V_{O1}$  Response Under Input Change From 8 V to 16 V, 10% Load**

## 6.6 Short-Circuit Protection

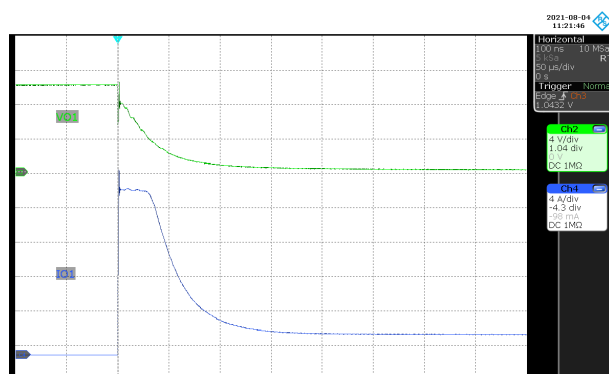


**Figure 6-21. Short-Circuit Protection With Hiccup Mode Disabled,  $V_{IN} = 12$  V ( $R_{13} = 0 \Omega$ )**

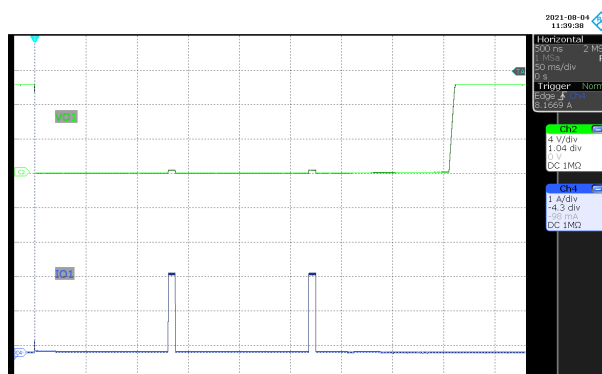


**Figure 6-22. Short-Circuit Protection With Hiccup Mode Enabled,  $V_{IN} = 12$  V ( $R_{13} = 62$  k $\Omega$ ,  $C_{29} = 47$  nF)**

## 6.7 Bode Plots

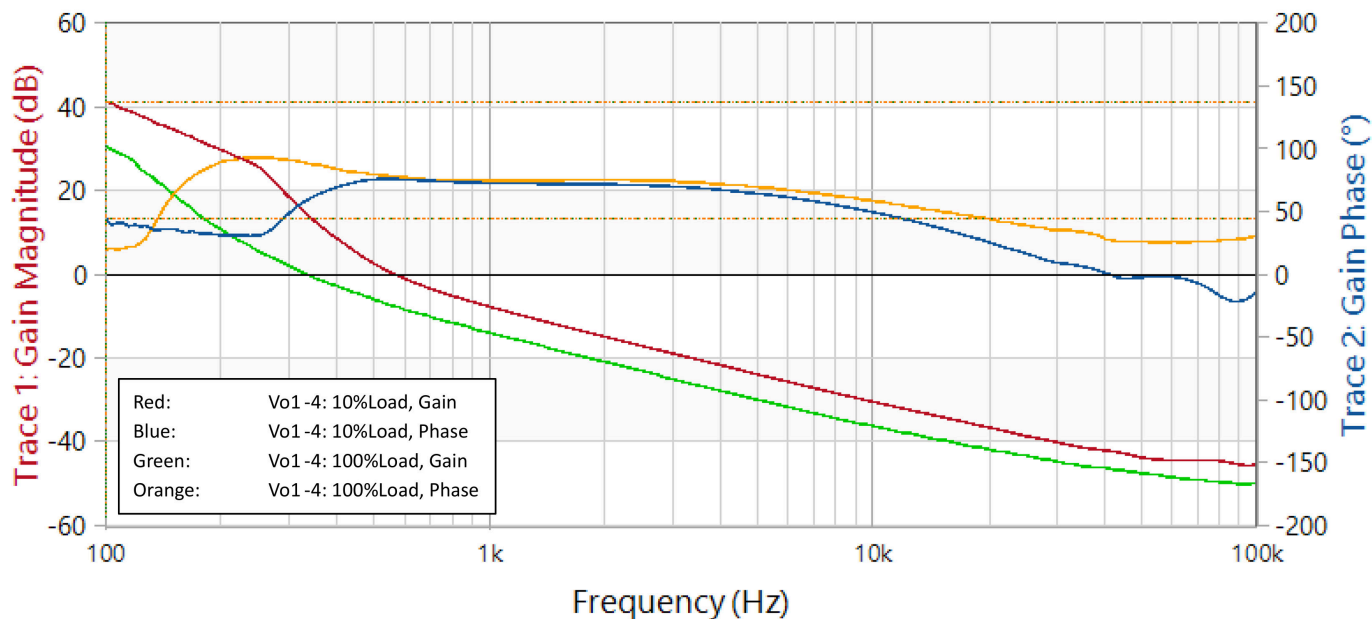


Figure 6-23. Bode Plot ( $V_{IN} = 12\text{ V}$ )

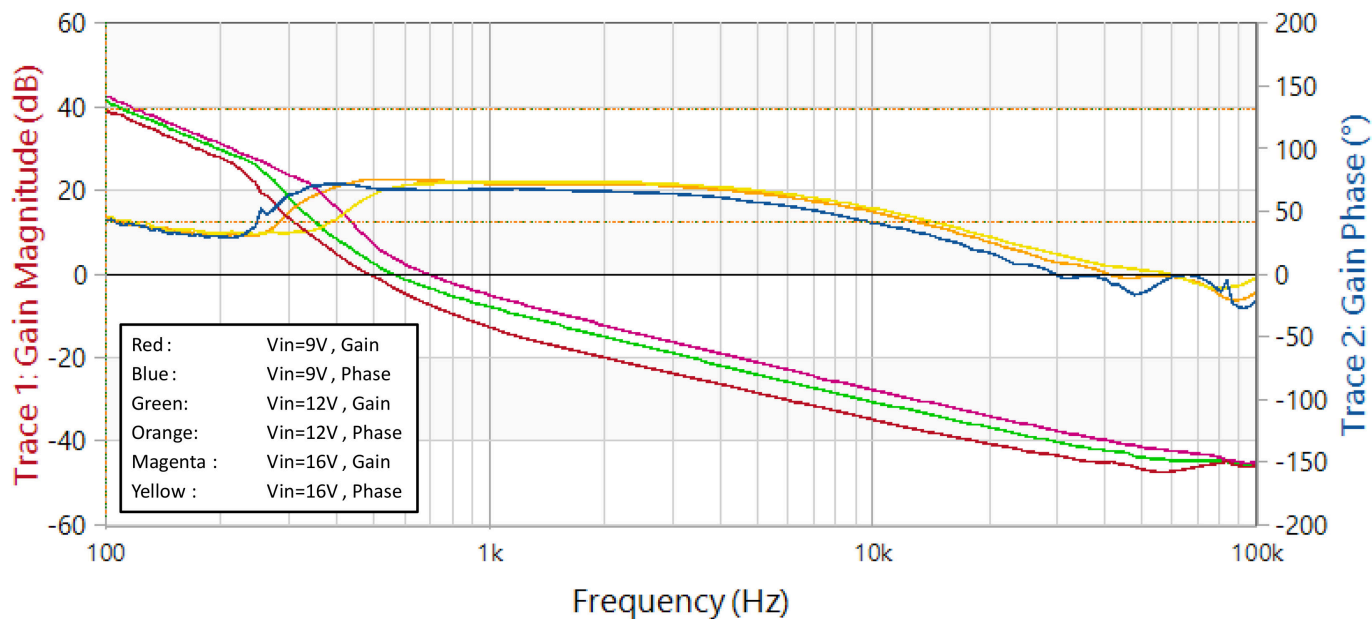


Figure 6-24. Bode Plot (Vo1-4: 100% Load)

## 6.8 Thermal Image

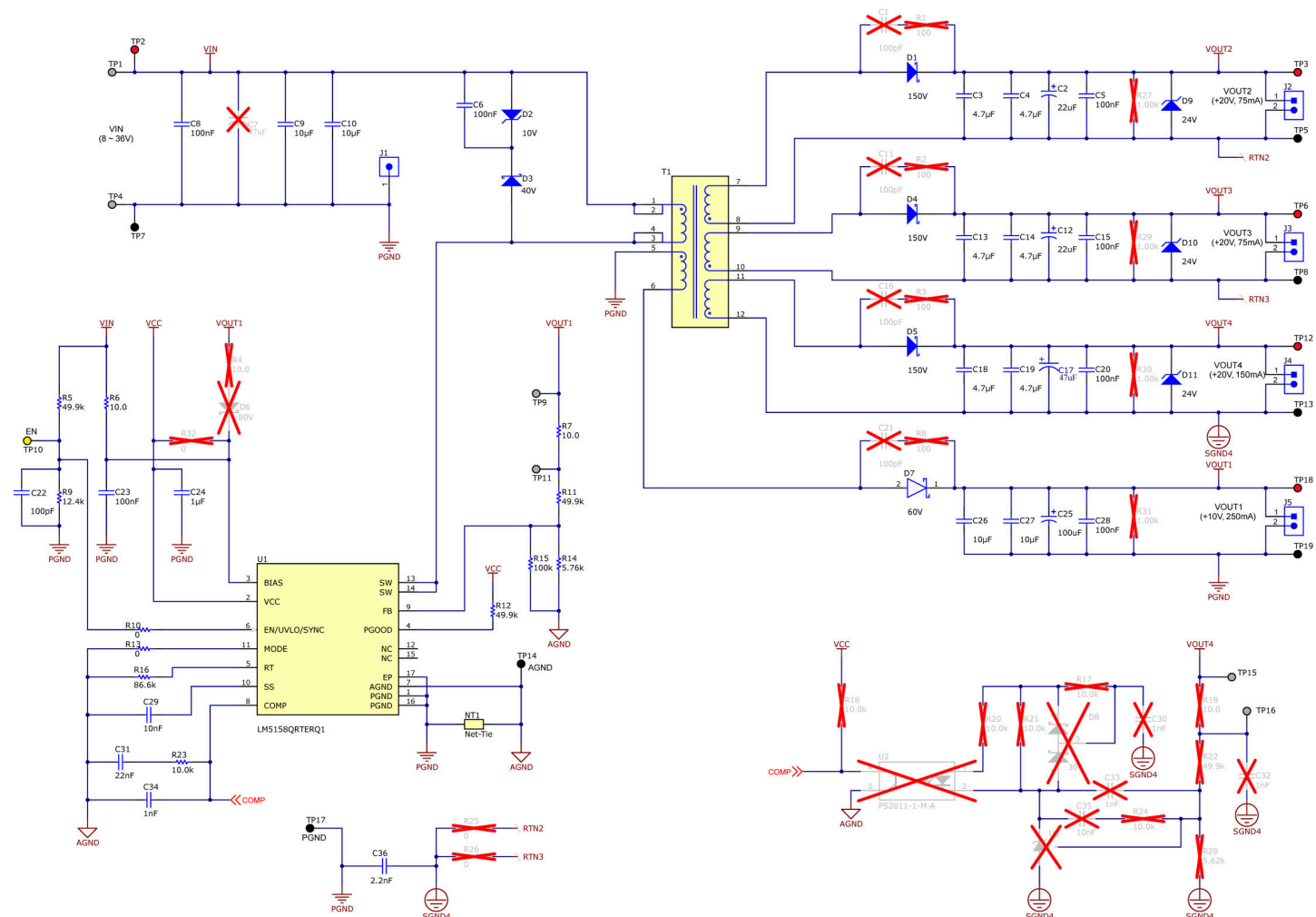
Figure 6-25 shows the thermal image of the EVM at 12 V<sub>IN</sub> and 100% load.



Figure 6-25. EVM Thermal Image at 12 V<sub>IN</sub> and 100% Load

## 7 Schematic

Figure 7-1 shows the EVM schematic.



Non-populated components are crossed out.

**Figure 7-1. EVM Complete Schematic**

## 8 Bill of Materials

Table 8-1 details the EVM BOM.

**Table 8-1. LM5158EVM-FLY Bill of Materials**

| DESIGNATOR                     | QUANTITY | VALUE         | DESCRIPTION                                                                                                                                  | PACKAGE REFERENCE | PART NUMBER                                          | MANUFACTURER            |
|--------------------------------|----------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------|-------------------------|
| C2, C12                        | 2        | 22 $\mu$ F    | CAP, Polymer Hybrid, 22 $\mu$ F, 50 V, $\pm$ 20%, 0.08 $\Omega$ , AEC-Q200 Grade 1, D6.3xL5.8mm SMD                                          | D6.3xL5.8mm       | EEH-ZC1H220P                                         | Panasonic               |
| C3, C4, C13, C14, C18, C19     | 6        | 4.7 $\mu$ F   | CAP, CERM, 4.7 $\mu$ F, 50 V, $\pm$ 10%, X7R, AEC-Q200 Grade 1, 1210                                                                         | 1210              | C1210C475K5RACAUTO                                   | Kemet                   |
| C5, C6, C8, C15, C20, C23, C28 | 7        | 0.1 $\mu$ F   | CAP, CERM, 0.1 $\mu$ F, 50 V, $\pm$ 10%, X7R, AEC-Q200 Grade 1, 0603                                                                         | 603               | C0603C104K5RACAUTO                                   | Kemet                   |
| C9, C10                        | 2        | 10 $\mu$ F    | CAP, CERM, 10 $\mu$ F, 50 V, $\pm$ 10%, X7R, AEC-Q200 Grade 1, 1206 (alternate: CAP, CERM, 10 $\mu$ F, 50 V, $\pm$ 10%, X5R, AEC-Q200, 1206) | 1206              | CGA5L1X7R1H106K160AE (alternate: GRT31CR61H106KE01L) | TDK (alternate: muRata) |
| C17                            | 1        | 47 $\mu$ F    | 47- $\mu$ F 50-V Aluminum - Polymer Capacitors Radial, Can - SMD 30 m $\Omega$ 4000 Hrs at 125°C                                             | SMD2              | EEH-ZC1H470P                                         | Panasonic               |
| C22                            | 1        | 100 pF        | CAP, CERM, 100 pF, 50 V, $\pm$ 5%, C0G/NP0, AEC-Q200 Grade 0, 0603                                                                           | 603               | CGA3E2NP01H101J080AA                                 | TDK                     |
| C24                            | 1        | 1 $\mu$ F     | CAP, CERM, 1 $\mu$ F, 25 V, $\pm$ 10%, X7R, 0603                                                                                             | 603               | 06033C105KAT2A                                       | AVX                     |
| C25                            | 1        | 100 $\mu$ F   | CAP, Aluminum Polymer, 100 $\mu$ F, 16 V, $\pm$ 20%, 0.035 $\Omega$ , 10 $\times$ 10.3 SMD                                                   | 10 $\times$ 10.3  | 16SVP100M                                            | Panasonic               |
| C26, C27                       | 2        | 10 $\mu$ F    | CAP, CERM, 10 $\mu$ F, 16 V, $\pm$ 10%, X7R, AEC-Q200 Grade 1, 1206                                                                          | 1206              | C1206C106K4RACAUTO                                   | Kemet                   |
| C29                            | 1        | 0.01 $\mu$ F  | CAP, CERM, 0.01 $\mu$ F, 16 V, $\pm$ 10%, X7R, 0603                                                                                          | 603               | C0603C103K4RACTU                                     | Kemet                   |
| C31                            | 1        | 0.022 $\mu$ F | CAP, CERM, 0.022 $\mu$ F, 25 V, $\pm$ 10%, X7R, 0603                                                                                         | 603               | C0603C223K3RACTU                                     | Kemet                   |
| C34                            | 1        | 1000 pF       | CAP, CERM, 1000 pF, 50 V, $\pm$ 5%, X7R, 0603                                                                                                | 603               | C0603C102J5RACTU                                     | Kemet                   |
| C36                            | 1        | 2.2 nF        | 2200-pF $\pm$ 10% 2000-V (2-kV) Ceramic Capacitor X7R (2R1) 1206 (3216 Metric)                                                               | 1206              | 1206Y2K00222KET                                      | Knowles Syfer           |
| D1, D4, D5                     | 3        | 150 V         | Diode, Schottky, 150 V, 1 A, PowerDI123                                                                                                      | PowerDI123        | DFLS1150-7                                           | Diodes Inc.             |
| D2                             | 1        | 10 V          | Diode, Zener, 10 V, 1.5 W, SMA                                                                                                               | SMA               | 1SMA5925BT3G                                         | ON Semiconductor        |
| D3                             | 1        | 40 V          | Diode, Schottky, 40 V, 1 A, AEC-Q101, SMA                                                                                                    | SMA               | B140Q-13-F                                           | Diodes Inc.             |
| D7                             | 1        |               | DIODE SCHOTTKY 60-V 1-A POWERDI123                                                                                                           | PowerDI123        | DFLS160-7                                            | Diodes                  |
| D9, D10, D11                   | 3        | 24 V          | Diode, Zener, 24 V, 500 mW, SOD-123                                                                                                          | SOD-123           | DDZ24C-7                                             | Diodes Inc.             |
| R5, R11, R12                   | 3        | 49.9 k        | RES, 49.9 k, 1%, 0.1 W, 0603                                                                                                                 | 603               | RC0603FR-0749K9L                                     | Yageo                   |
| R6, R7                         | 2        | 10            | RES, 10.0, 1%, 0.1 W, 0603                                                                                                                   | 603               | RC0603FR-0710RL                                      | Yageo                   |
| R9                             | 1        | 12.4 k        | RES, 12.4 k, 1%, 0.1 W, 0603                                                                                                                 | 603               | RC0603FR-0712K4L                                     | Yageo                   |
| R10, R13                       | 2        | 0             | RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603                                                                                                    | 603               | ERJ-3GEY0R00V                                        | Panasonic               |
| R14                            | 1        | 5.76 k        | RES, 5.76 k, 1%, 0.1 W, 0603                                                                                                                 | 603               | RC0603FR-075K76L                                     | Yageo                   |

**Table 8-1. LM5158EVM-FLY Bill of Materials (continued)**

| DESIGNATOR              | QUANTIT<br>Y | VALUE        | DESCRIPTION                                                                                      | PACKAGE<br>REFERENCE          | PART NUMBER         | MANUFACTURER                    |
|-------------------------|--------------|--------------|--------------------------------------------------------------------------------------------------|-------------------------------|---------------------|---------------------------------|
| R15                     | 1            | 100 k        | RES, 100 k, 0.1%, 0.1 W, AEC-Q200 Grade 0, 0603                                                  | 603                           | ERA-3AEB104V        | Panasonic                       |
| R16                     | 1            | 86.6 k       | RES, 86.6 k, 1%, 0.1 W, 0603                                                                     | 603                           | RC0603FR-0786K6L    | Yageo                           |
| R23                     | 1            | 10.0 k       | RES, 10.0 k, 1%, 0.1 W, 0603                                                                     | 603                           | RC0603FR-0710KL     | Yageo                           |
| T1                      | 1            |              | FLYBACK TRANSFORMER                                                                              | SMT_TRANSFORMER_17MM20_21MM97 | ZB1324-AL           | Coilcraft                       |
| U1                      | 1            |              | 2.2-MHz Wide VIN 85-V Boost/Sepic/Flyback Converter with Dual Random Spread Spectrum             | WQFN16                        | LM5158QRTERQ1       | Texas Instruments               |
| C1, C11, C16, C21       | 0            | 100 pF       | CAP, CERM, 100 pF, 100 V, $\pm 1\%$ , C0G/NP0, 0603                                              | 603                           | C1608C0G2A101F080AA | TDK                             |
| C7                      | 0            | 47 $\mu$ F   | 47- $\mu$ F 50-V Aluminum - Polymer Capacitors Radial, Can - SMD 30 m $\Omega$ 4000 Hrs at 125°C | SMD2                          | EEH-ZC1H470P        | Panasonic                       |
| C30, C32, C33           | 0            | 1000 pF      | CAP, CERM, 1000 pF, 50 V, $\pm 5\%$ , X7R, 0603                                                  | 603                           | C0603C102J5RACTU    | Kemet                           |
| C35                     | 0            | 0.01 $\mu$ F | CAP, CERM, 0.01 $\mu$ F, 16 V, $\pm 10\%$ , X7R, 0603                                            | 603                           | C0603C103K4RACTU    | Kemet                           |
| D6                      | 0            | 80 V         | Diode, Schottky, 80 V, 0.5 A, SOD-123                                                            | SOD-123                       | MBR0580-TP          | Micro Commercial Components     |
| D8                      | 0            | 30 V         | Diode, Schottky, 30 V, 0.2 A, SOT-323                                                            | SOT-323                       | BAT54SWT1G          | Fairchild Semiconductor         |
| R1, R2, R3, R8          | 0            | 100          | RES, 100, 1%, 0.1 W, 0603                                                                        | 603                           | RC0603FR-07100RL    | Yageo                           |
| R4, R19                 | 0            | 10           | RES, 10.0, 1%, 0.1 W, 0603                                                                       | 603                           | RC0603FR-0710RL     | Yageo                           |
| R17, R18, R20, R21, R24 | 0            | 10.0 k       | RES, 10.0 k, 1%, 0.1 W, 0603                                                                     | 603                           | RC0603FR-0710KL     | Yageo                           |
| R22                     | 0            | 49.9 k       | RES, 49.9 k, 1%, 0.1 W, 0603                                                                     | 603                           | RC0603FR-0749K9L    | Yageo                           |
| R25, R26                | 0            | 0            | RES, 0, 5%, 0.25 W, AEC-Q200 Grade 0, 1206                                                       | 1206                          | ERJ-8GEY0R00V       | Panasonic                       |
| R27, R29, R30, R31      | 0            | 1.00 k       | RES, 1.00 k, 1%, 0.25 W, AEC-Q200 Grade 0, 1206                                                  | 1206                          | ERJ-8ENF1001V       | Panasonic                       |
| R28                     | 0            | 5.62 k       | RES, 5.62 k, 1%, 0.1 W, 0603                                                                     | 603                           | RC0603FR-075K62L    | Yageo                           |
| R32                     | 0            | 0            | RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603                                                        | 603                           | ERJ-3GEY0R00V       | Panasonic                       |
| U2                      | 0            |              | Optocoupler, 2.5 kV, 100-200% CTR, SMT                                                           | PS2811-1                      | PS2811-1-M-A        | California Eastern Laboratories |
| U3                      | 0            |              | Low-Voltage (1.24V) Adjustable Precision Shunt Regulators, 3-pin SOT-23, Pb-Free                 | DBZ0003A                      |                     | Texas Instruments               |

## 9 EVM Layout

Figure 9-1 through Figure 9-4 illustrate the EVM

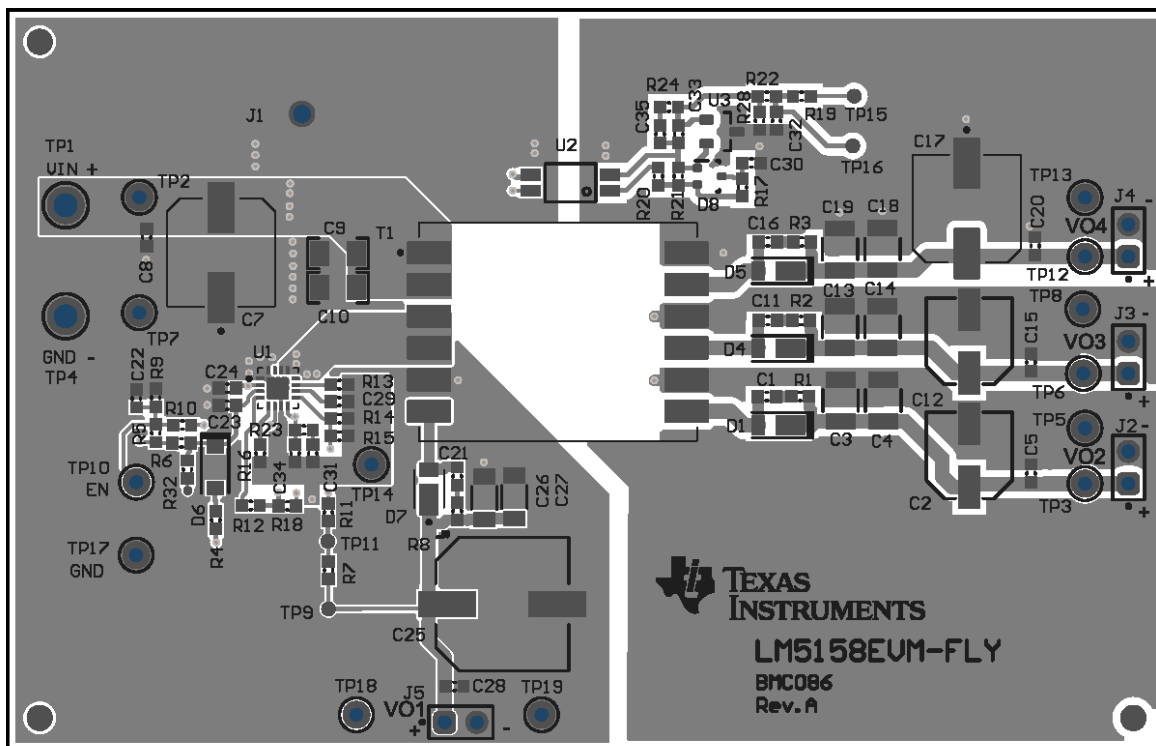


Figure 9-1. Top Layer with Silkscreen

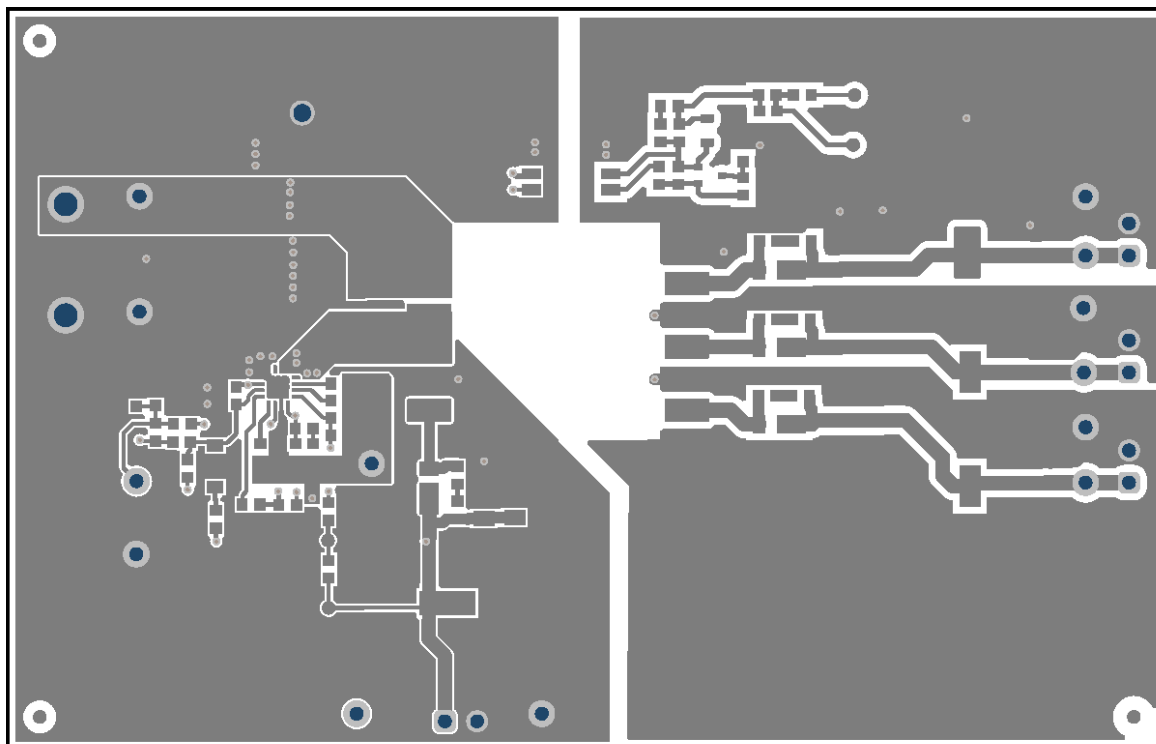


Figure 9-2. Top Layer

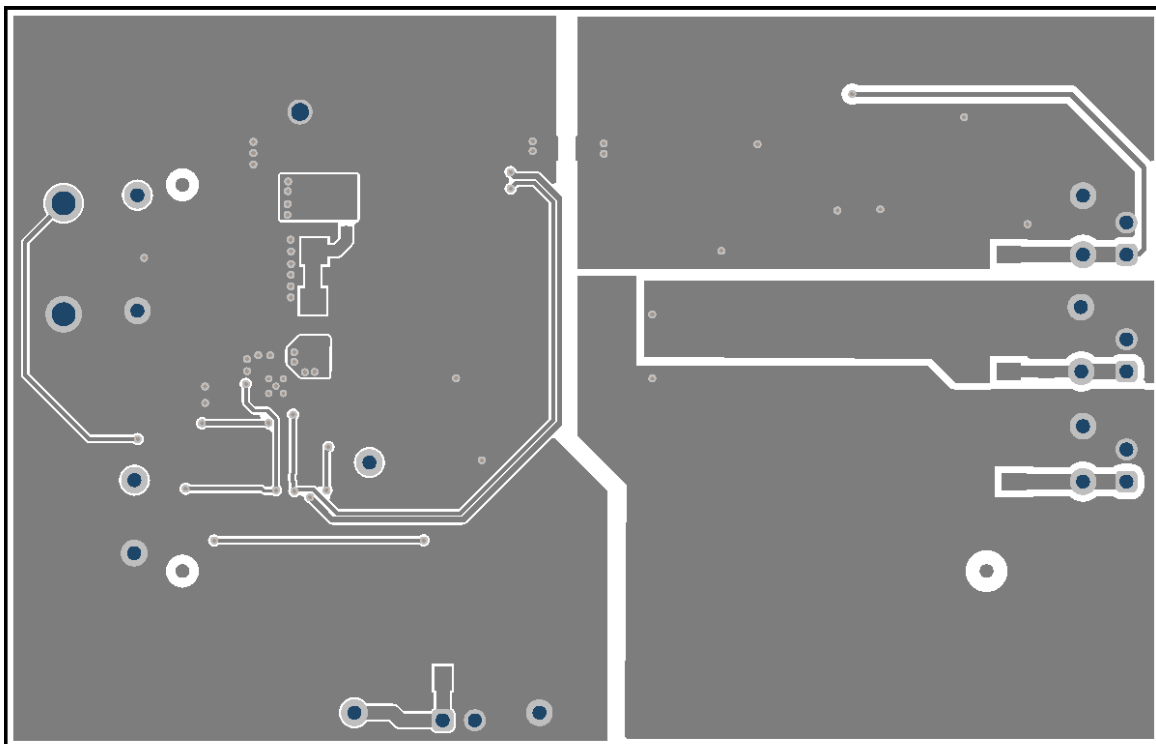


**Figure 9-3. Bottom Layer Viewed From Top**

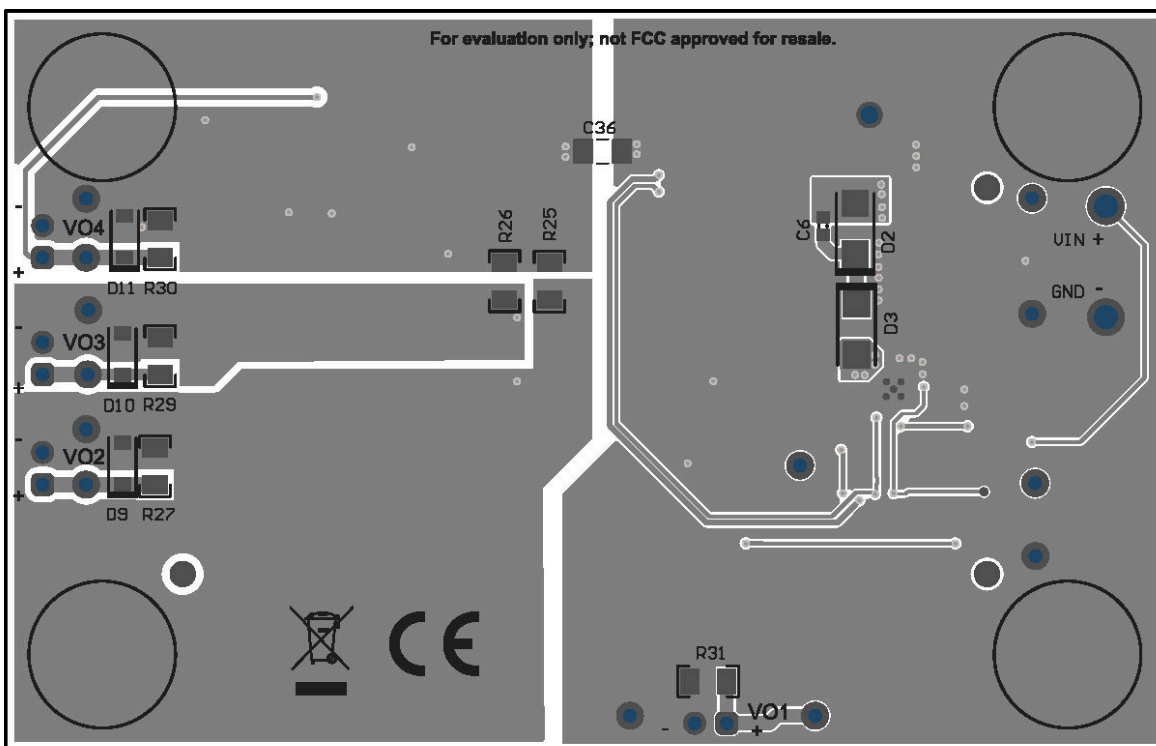


**Figure 9-4. Bottom Layer with Silkscreen Viewed From Bottom**

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