User's Guide
SNVU592C–July 2018–Revised April 2019

# LM5180-Q1 Single-Output EVM User's Guide

The LM5180EVM-S05 evaluation module (EVM) is a flyback DC/DC converter that employs primary-side regulation (PSR) based on sampling of the transformer's primary winding voltage to achieve high efficiency in a small footprint. It operates over a wide input voltage range of 10 V to 65 V providing a regulated 5-V output using a transformer with 3 : 1 turns ratio. Operating without an optocoupler or transformer auxiliary winding, the converter delivers an output voltage with ±1.5% regulation.

The EVM design uses the LM5180-Q1 65-V PSR flyback converter. An integrated 100-V, 1.5-A power MOSFET provides ample margin for line transients and switch (SW) node voltage spikes related to transformer parasitic leakage inductance. Load regulation errors related to transformer secondary winding resistance are avoided by virtue of the quasi-resonant boundary conduction mode (BCM) control scheme. Additional features includes current-mode control with internal compensation, hiccup-mode fault protection, programmable soft-start, and optional output voltage temperature compensation. Input UVLO protects the converter at low input voltage conditions, and the EN/UVLO pin supports adjustable UVLO with user-defined hysteresis for application specific power-up and power-down requirements.

The LM(2)5180 and LM(2)5180-Q1 converters are available in a 8-pin WSON package with 4-mm × 4-mm footprint and 0.8-mm pin pitch to enable isolated DC/DC solutions with high density and low component count. Wettable flank pins provide a visual indicator of solderability, which reduces inspection time and manufacturing costs in high-reliability industrial and automotive applications. See the LM5180 and LM5180-Q1 data sheets for more information. Use the LM5180-Q1 with WEBENCH® Power Designer to create a custom regulator design. Furthermore, the user can download the *LM5180 Quickstart Calculator* to optimize component values and examine predicted efficiency performance across line and load ranges.

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# 1 High Density EVM Description

The LM5180-Q1 single-output EVM is designed to use a regulated or non-regulated high-voltage input rail ranging from 10 V to 65 V to produce a tightly-regulated, isolated output voltage of 5 V at load currents of 1 A (or higher depending on $V_{IN}$). This wide $V_{IN}$ range isolated DC/DC solution offers outsized voltage rating and operating margin to withstand supply rail voltage transients.

The power-train passive components selected for this EVM, including flyback transformer, flyback rectifying diode, and ceramic input and output capacitors, are available from multiple component vendors. Transformers with functional or basic grade isolation are available with isolation voltages of 1.5 kV and greater.

## *1.1 Typical Applications*

- Isolated bias power rails
- IGBT gate drive supplies for BDC and BLDC motor drives
- Industrial and commercial vehicles
- Automotive body and powertrain

## *1.2 Features and Electrical Performance*

- Tightly-regulated, isolated output voltage of 5 V with ±1.5% load regulation from 1% to 100% load
- Wide $V_{IN}$ operating range of 10 V to 65 V
- Rated full load current of 1 A at $V_{IN}$ = 24 V
- Maximum switching frequency of 350 kHz remains below the AM band
- High efficiency across wide load current range
  - Full load efficiency of 86% and 85.5% at $V_{IN}$ = 24 V and 48 V, respectively
  - 86% efficiency at half-rated load, $V_{IN}$ = 24 V
- 1.3-mA and 1-mA no-load supply current at $V_{IN}$ = 24 V and 48 V, respectively
- Input $\pi$-stage EMI filter with damping from electrolytic capacitor ESR
  - Meets EN55025 / CISPR 25 class 5 EMI specifications
- BCM control architecture provides fast line and load transient response
  - Peak current-mode control
  - Quasi-resonant switching for reduced power loss
  - Internal loop compensation
- Integrated 100-V flyback power MOSFET
  - Provides large margin for input voltage transients
- Cycle-by-cycle overcurrent protection (OCP)
- Monotonic prebias output voltage start-up
- User-adjustable soft-start time using capacitor connected between SS/BIAS and GND
  - Option for external bias using auxiliary winding connected to SS/BIAS
- Resistor-programmable input voltage UVLO with customizable hysteresis for applications with wide turnon and turnoff voltage difference
  - Input UVLO set to turn on and off at $V_{IN}$ of 9.5 V and 6.5 V, respectively
- Fully assembled, tested, and proven PCB layout with 50-mm × 35-mm total footprint


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## 2 EVM Performance Characteristics

### Table 1. Electrical Performance Characteristics

| PARAMETER | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **INPUT CHARACTERISTICS** | | | | | | |
| Input voltage range, $V_{IN}$ | Operating | | 10 | 24 | 65 | V |
| Input voltage turnon, $V_{IN-ON}$ | Adjusted using EN/UVLO divider resistors | | | 9.5 | | V |
| Input voltage turnoff, $V_{IN-OFF}$ | Adjusted using EN/UVLO divider resistors | | | 6.5 | | V |
| Input voltage hysteresis, $V_{IN-HYS}$ | Adjusted using EN/UVLO divider resistors | | | 3 | | V |
| Input current, no load, $I_{IN-NL}$ | $I_{OUT}$ = 0 A | $V_{IN}$ = 24 V | | 1.3 | | mA |
| | | $V_{IN}$ = 48 V | | 1 | | mA |
| | | $V_{IN}$ = 65 V | | 1 | | mA |
| Input current, disabled, $I_{IN-OFF}$ | $V_{EN}$ = 0 V | $V_{IN}$ = 24 V | | 10 | | µA |
| **OUTPUT CHARACTERISTICS** | | | | | | |
| Output voltage, $V_{OUT}$ [(1)] | | | 4.95 | 5.025 | 5.1 | V |
| Output current, $I_{OUT}$ [(2)] | $V_{IN}$ = 12 V | | | | 0.8 | A |
| | $V_{IN}$ = 24 V | | | | 1.2 | A |
| | $V_{IN}$ = 48 V | | | | 1.4 | A |
| Output voltage regulation, $\Delta V_{OUT}$ | Load regulation, $V_{IN}$ = 24 V | $I_{OUT}$ = 10 mA to 1 A | | 1% | | |
| | Line regulation, $I_{OUT}$ = 500 mA | $V_{IN}$ = 10 V to 65 V | | 1% | | |
| Output voltage ripple, $V_{OUT-AC}$ | $V_{IN}$ = 24 V, $I_{OUT}$ = 1 A | | | 50 | | mVrms |
| Output overcurrent protection, $I_{OCP}$ | $V_{IN}$ = 24 V | | | 1.55 | | A |
| | $V_{IN}$ = 48 V | | | 1.55 | | A |
| Soft-start time, $t_{SS}$ | | | | 8 | | ms |
| **SYSTEM CHARACTERISTICS** | | | | | | |
| Switching frequency, $F_{SW-NOM}$ | $V_{IN}$ = 24 V, $I_{OUT}$ = 0.5 A | | | 350 | | kHz |
| Half-load efficiency, $\eta_{HALF}$ [(1)] | $I_{OUT}$ = 0.5 A | $V_{IN}$ = 12 V | | 86% | | |
| | | $V_{IN}$ = 24 V | | 86% | | |
| | | $V_{IN}$ = 48 V | | 84% | | |
| | | $V_{IN}$ = 65 V | | 82% | | |
| Full load efficiency, $\eta_{FULL}$ | $I_{OUT}$ = 1 A | $V_{IN}$ = 24 V | | 86% | | |
| | | $V_{IN}$ = 36 V | | 86% | | |
| | | $V_{IN}$ = 48 V | | 85.5% | | |
| | | $V_{IN}$ = 65 V | | 84.5% | | |
| Isolation rating [(3)] | | | | | 1500 | V |
| LM5180 junction temperature, $T_J$ | | | –40 | | 150 | °C |

(1) The default output voltage of this single-output EVM is 5 V. Efficiency and other performance metrics can change based on operating input voltage, load current, externally-connected output capacitance, and other parameters.

(2) The maximum output power delivered by the LM5180-Q1 PSR flyback converter increases with input voltage.

(3) The selected flyback transformer provides functional isolation to 1500 V DC.



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## 3 Application Circuit Diagram

Figure 1 shows the schematic of an LM5180 PSR flyback converter (EMI filter stage not shown). Soft start (SS), temperature compensation (TC), and UVLO (EN/UVLO) components are shown that are configurable as required for the specific application.

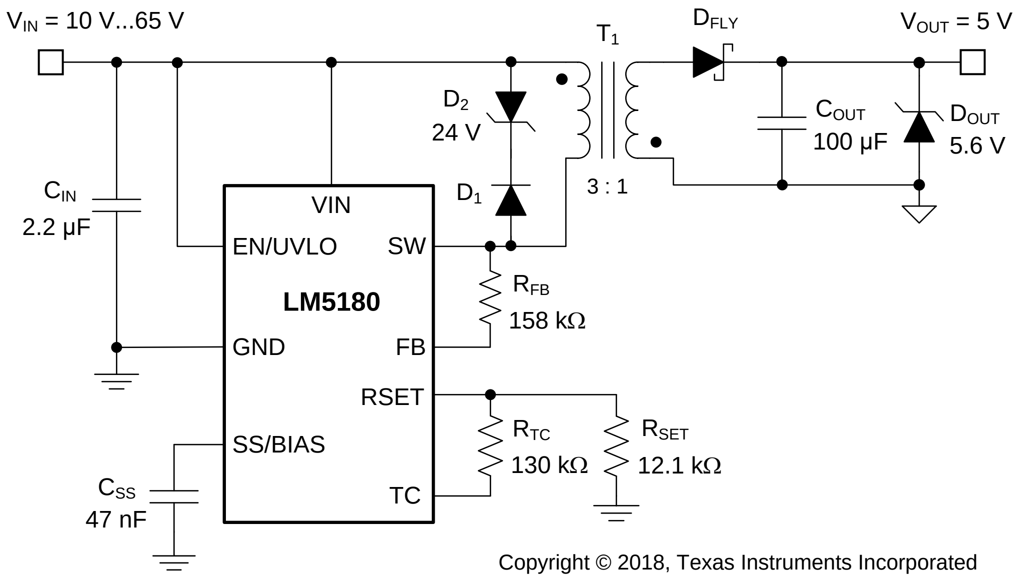


**Figure 1. LM5180 PSR Flyback Converter Simplified Schematic**

## 4 EVM Photo

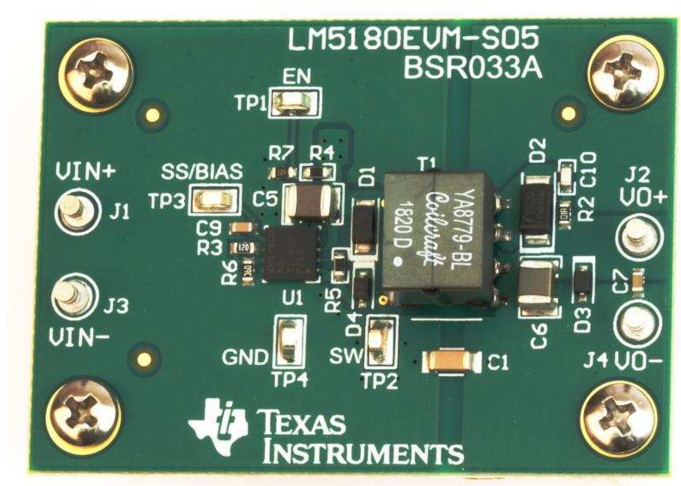


**Figure 2. LM5180 EVM Photo (Top Side)**

**CAUTION**

Caution Hot surface.
Contact may cause burns.
Do not touch.


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# 5 Test Setup and Procedure

## 5.1 Test Setup

**Table 2. EVM Connections**

| LABEL | DESCRIPTION |
|---|---|
| VIN+ | Positive input voltage power and sense connection |
| VIN– | Negative input voltage power and sense connection |
| VOUT+ | Positive output voltage power and sense connection |
| VOUT– | Negative output voltage power and sense connection |
| EN | ENABLE input. Tie to GND to disable converter |
| SW | SW node connection |

Referencing the EVM connections described in Table 2, the recommended test setup to evaluate the LM5180EVM-S05 is shown in Figure 3. Working at an ESD-protected workstation, make sure that any wrist straps, boot straps, or mats are connected and referencing the user to earth ground before power is applied to the EVM.

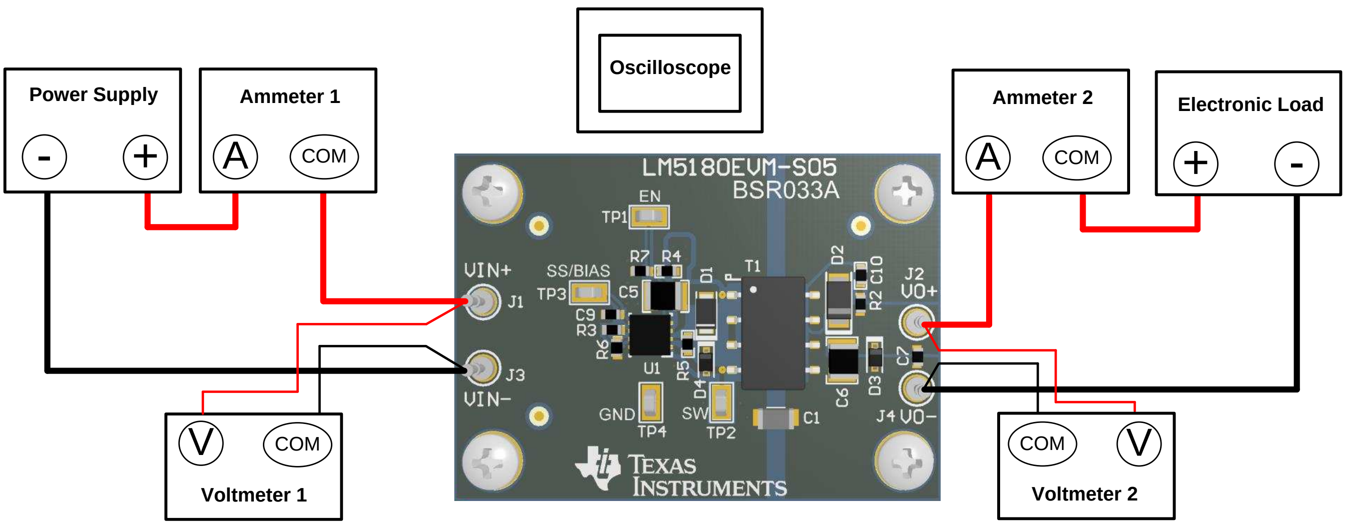


**Figure 3. EVM Test Setup**

**CAUTION**

Refer to the LM5180 datasheet, LM5180 Quickstart Calculator and WEBENCH® Power Designer for additional guidance pertaining to component selection and converter operation.


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## 5.2 Test Equipment

**Voltage Source:** The input voltage source $V_{IN}$ should be a 0–65-V variable DC source capable of supplying 0.5 A.

**Multimeters:**

- **Voltmeter 1:** Input voltage at VIN+ to VIN–. Set the voltmeter to an input impedance of 100 MΩ.
- **Voltmeter 2:** Output voltage at VOUT+ to VOUT–. Set the voltmeter to an input impedance of 100 MΩ.
- **Ammeter 1:** Input current. Set the ammeter to 1-second aperture time.
- **Ammeter 2:** Output current. Set the ammeter to 1-second aperture time

**Electronic Load:** The load should be an electronic constant-resistance (CR) or constant-current (CC) mode load capable of 0 Adc to 1 Adc at 5 V. For a no-load input current measurement, disconnect the electronic load as it may draw a small residual current.

**Oscilloscope:** With the scope set to 20-MHz bandwidth and AC coupling, measure the output voltage ripple directly across an output capacitor with a short ground lead normally provided with the scope probe. Place the oscilloscope probe tip on the positive terminal of the output capacitor, holding the probe's ground barrel through the ground lead to the capacitor's negative terminal. TI does not recommend using a long-leaded ground connection because this may induce additional noise given a large ground loop. To measure other waveforms, adjust the oscilloscope as needed.

**Safety:** Always use caution when touching any circuits that may be live or energized.

## 5.3 Recommended Test Setup

### 5.3.1 Input Connections

- Prior to connecting the DC input source, set the current limit of the input supply to 0.1 A maximum. Ensure the input source is initially set to 0 V and connected to the VIN+ and VIN– connection points as shown in Figure 3. An additional input bulk capacitor is recommended to provide damping if long input lines are used.
- Connect voltmeter 1 at VIN+ and VIN– connection points to measure the input voltage.
- Connect ammeter 1 to measure the input current and set to at least 1-second aperture time.

### 5.3.2 Output Connections

- Connect an electronic load to VOUT+ and VOUT– connections. Set the load to constant-resistance mode or constant-current mode at 0 A before applying input voltage.
- Connect voltmeter 2 at VOUT+ and VOUT– connection points to measure the output voltage.
- Connect ammeter 2 to measure the output current.

## 5.4 Test Procedure

### 5.4.1 Line and Load Regulation, Efficiency

- Set up the EVM as described above.
- Set load to constant resistance or constant current mode and to sink 10 mA.
- Increase input source from 0 V to 24 V; use voltmeter 1 to measure the input voltage.
- Increase the current limit of the input supply to 0.5 A.
- Using voltmeter 2 to measure the output voltage, $V_{OUT}$, vary the load current from 10 mA to 1 A DC; $V_{OUT}$ should remain within the load regulation specification.
- Set the load current to 0.5 A (50% rated load) and vary the input source voltage from 10 V to 65 V; $V_{OUT}$ should remain within the line regulation specification.
- Decrease load to 0 A. Decrease input source voltage to 0 V.


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## 6 Test Data and Performance Curves

Figure 4 through Figure 11 present typical performance curves for the LM5180EVM-S05. Because actual performance data may be affected by measurement techniques and environmental variables, these curves are presented for reference and may differ from actual field measurements.

### 6.1 Conversion Efficiency

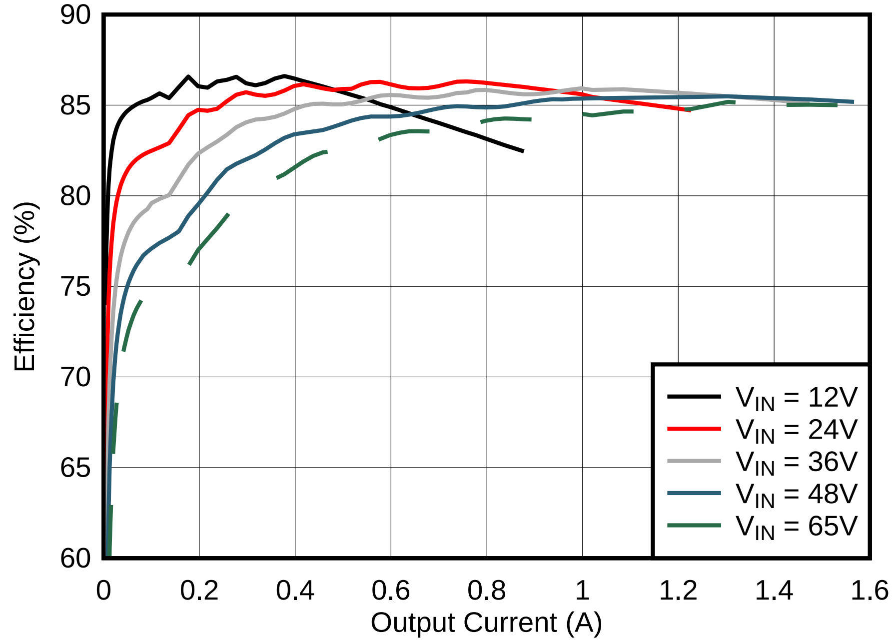


**Figure 4. Conversion Efficiency (Linear Scale)**

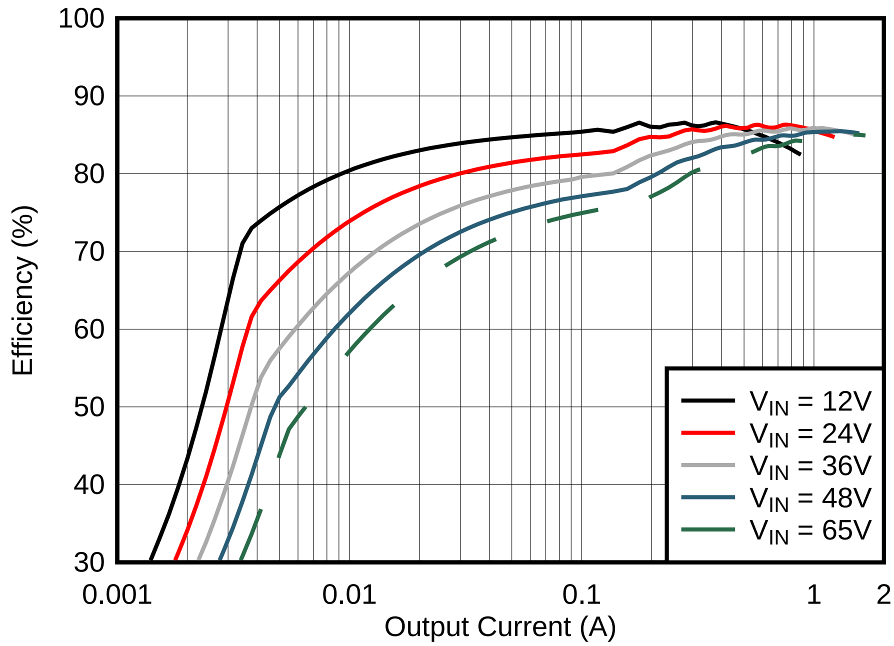


**Figure 5. Conversion Efficiency (Log Scale)**



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### 6.2 Load Regulation

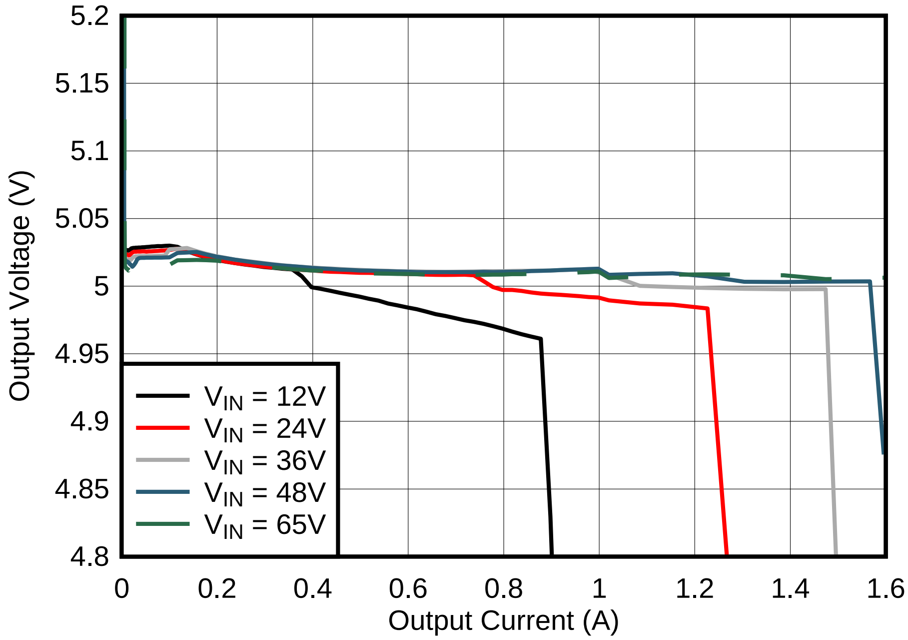


**Figure 6. Load Regulation (Linear Scale)**

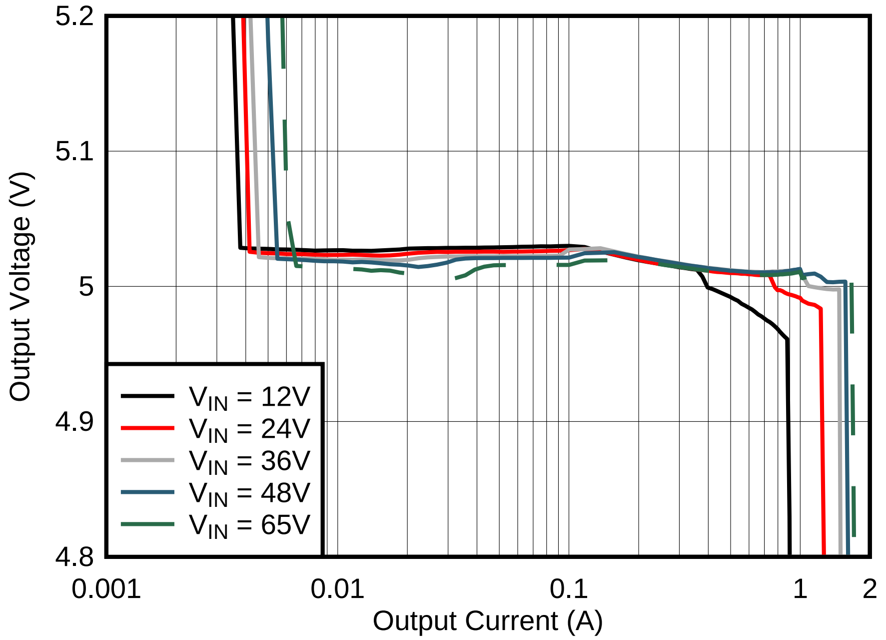


**Figure 7. Load Regulation (Log Scale)**


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## 6.3 Operating Waveforms

### 6.3.1 Switching

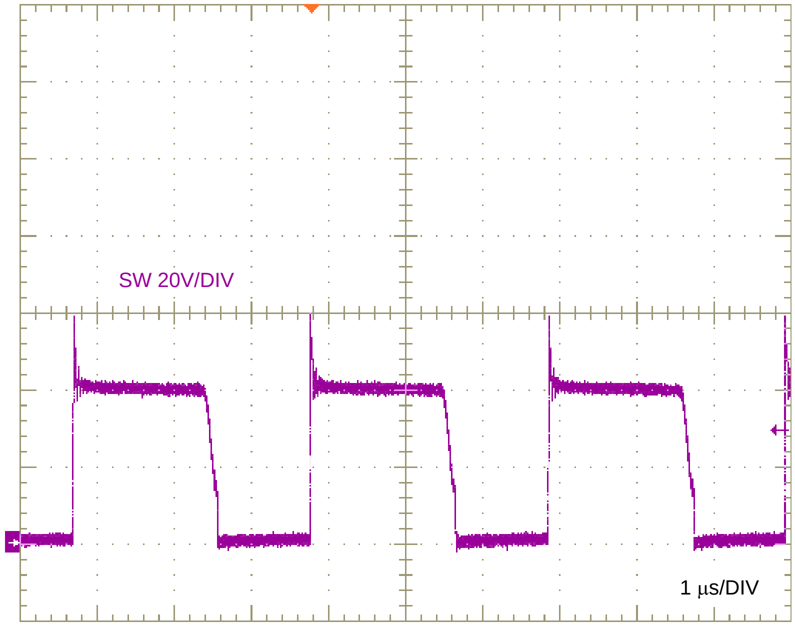


**Figure 8. SW Node Voltage, $V_{IN}$ = 24 V, $I_{OUT}$ = 1 A**

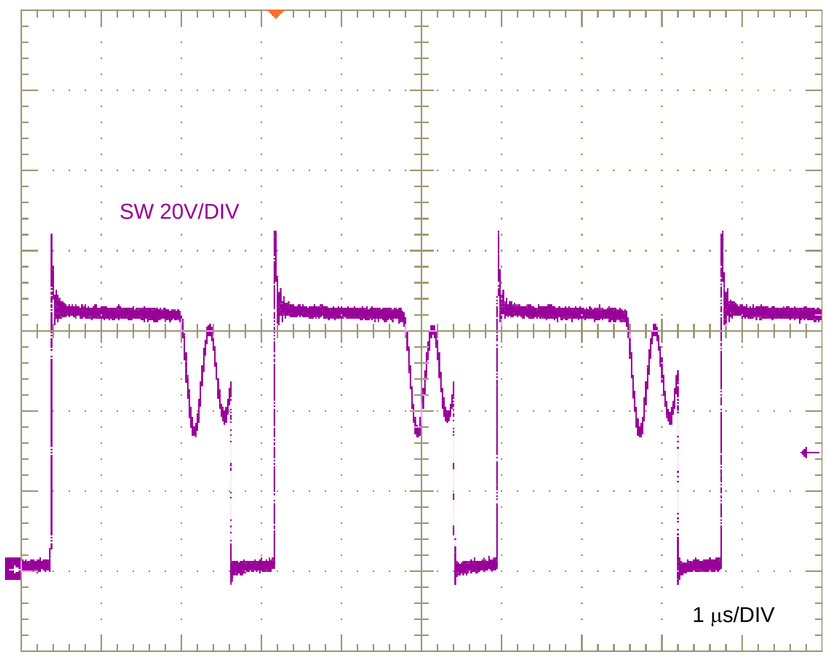


**Figure 9. SW Node Voltage, $V_{IN}$ = 48 V, $I_{OUT}$ = 1 A**


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### 6.3.2 Load Transient Response

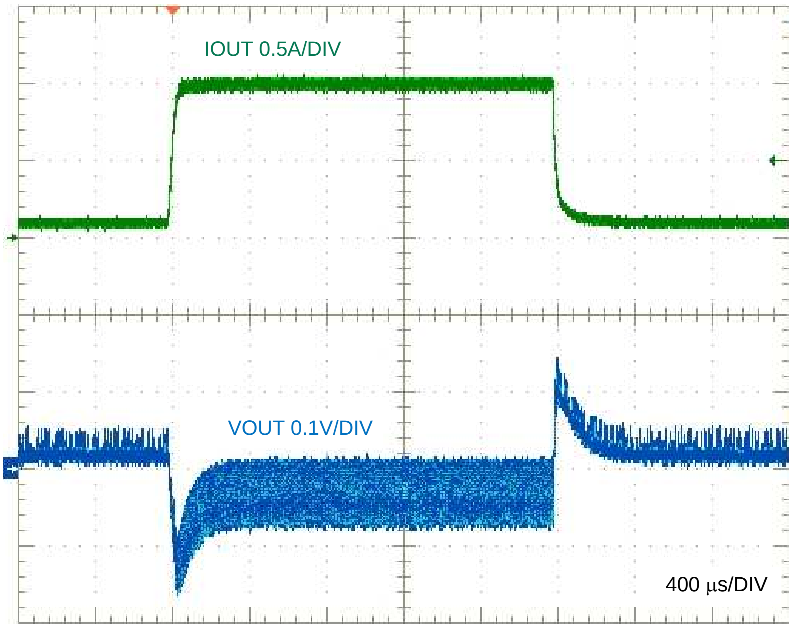


**Figure 10. Load Transient Response, $V_{IN}$ = 24 V, 0.1 A to 1 A at 1 A/µs**

### 6.3.3 Start-Up [(1)]

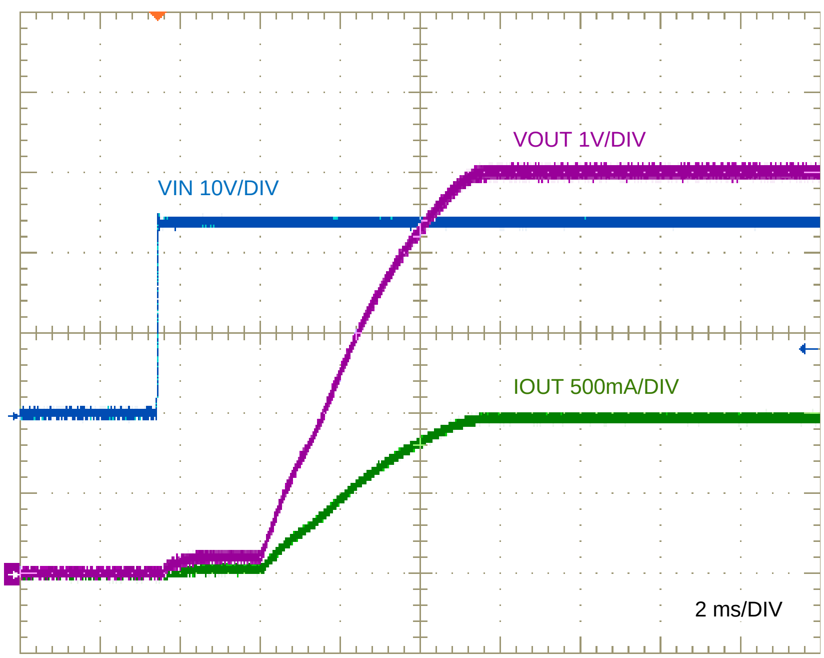


**Figure 11. Start-Up, $V_{IN}$ = 24 V, $I_{OUT}$ = 1 A Resistive**

(1) The internal soft-start timer is applicable here as the SS capacitor was not installed during these start-up tests.



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### *6.4 Enable On*

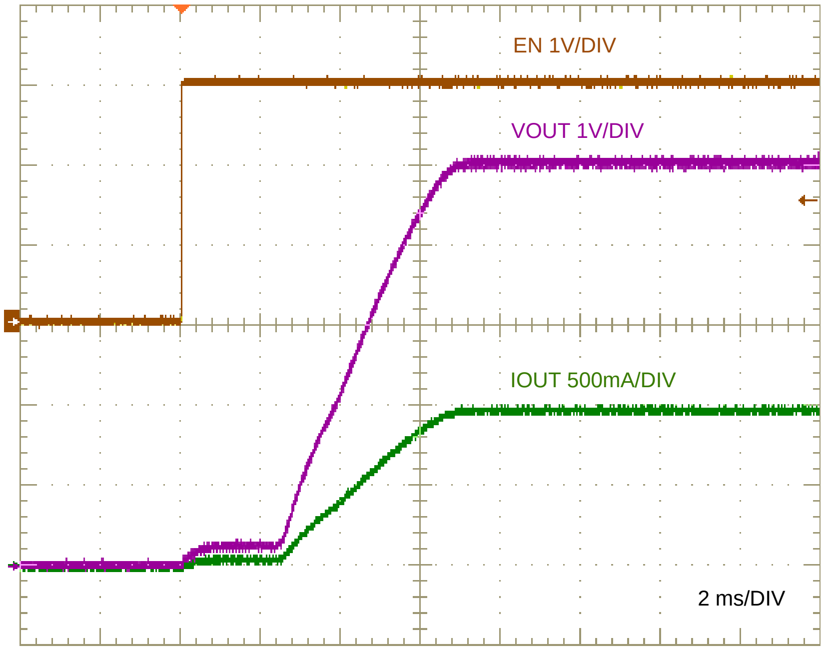


**Figure 12. Enable On, $V_{IN}$ = 24 V, $I_{OUT}$ = 1 A**



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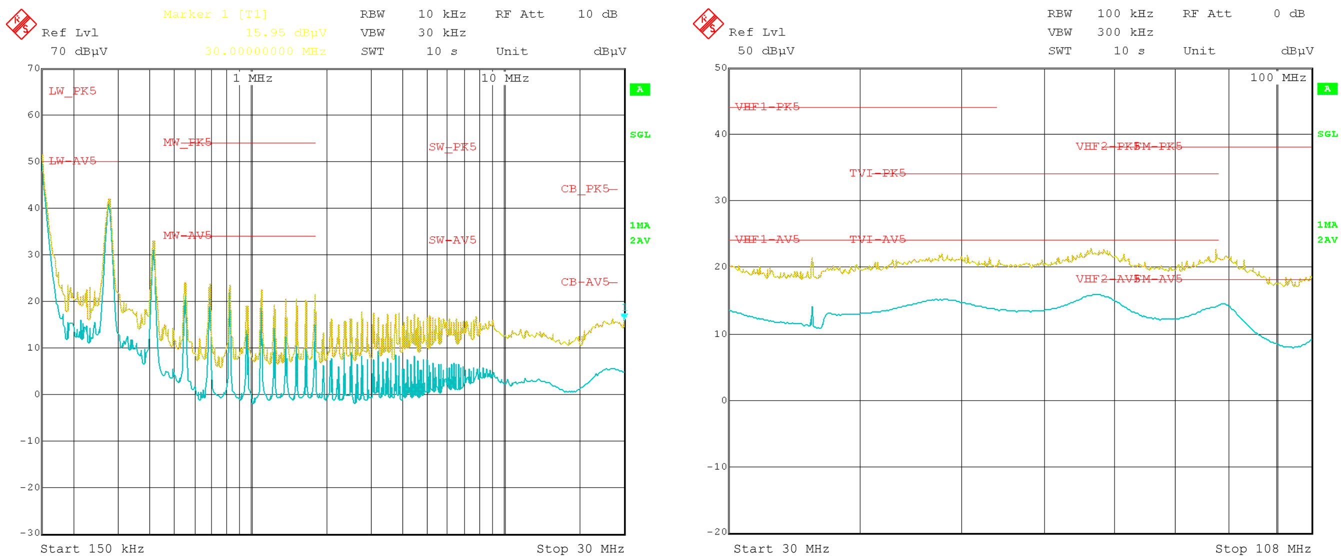
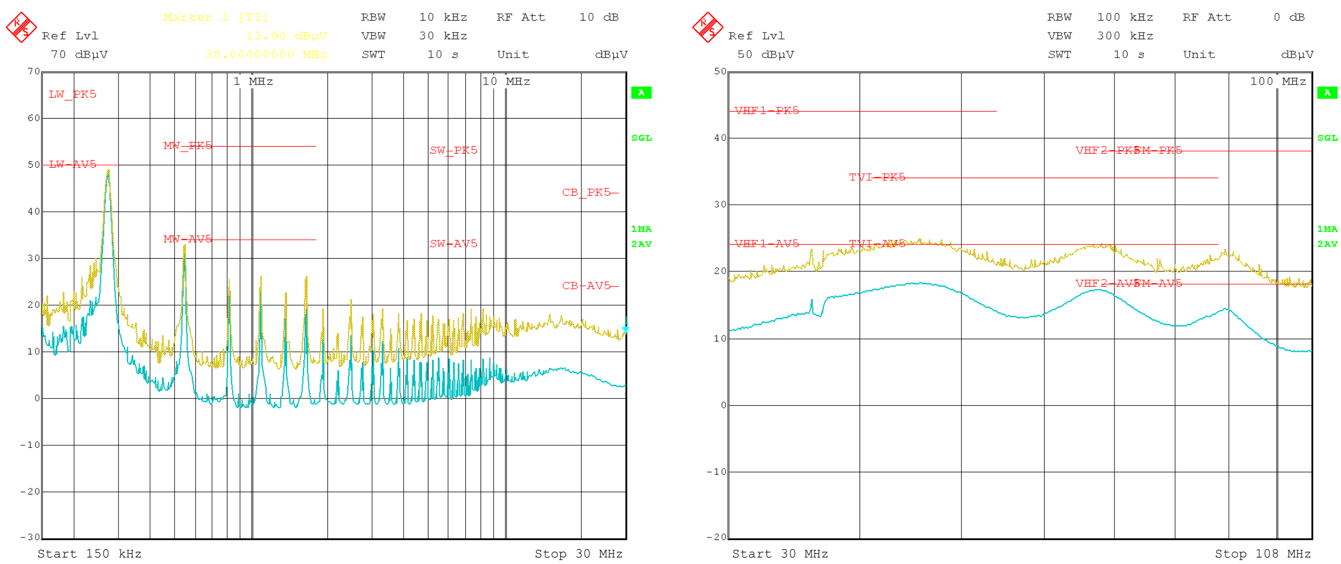
## 6.5 CISPR 25 EMI

Figure 13 and Figure 14 present the EMI performance of the LM5180-Q1 EVM at 12-V and 24-V inputs, respectively. Conducted emissions are measured over a frequency range of 150 kHz to 108 MHz using a 5-µH LISN according to the CISPR 25 specification. CISPR 25 class 5 peak and average limit lines are denoted in red. The yellow and blue spectra are measured using peak and average detection, respectively.




(a) (b)

**Figure 13. CISPR 25 Class 5 Conducted Emissions Plot, $V_{IN}$ = 12 V, $I_{OUT}$ = 0.85 A, (a) 150 kHz to 30 MHz, (b) 30 MHz to 108 MHz**




(a) (b)

**Figure 14. CISPR 25 Class 5 Conducted Emissions Plot, $V_{IN}$ = 24 V, $I_{OUT}$ = 0.85 A, (a) 150 kHz to 30 MHz, (b) 30 MHz to 108 MHz**

Figure 15 presents the radiated emissions from 30 MHz to 1 GHz using a biconical/log antenna with horizontal polarization. CISPR 25 class 5 peak and average limit lines are denoted in purple and red, respectively. The blue and green spectra are measured using peak and average detectors, respectively.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For both conducted and radiated emissions measurements, the transformer core is shielded using a copper strap tied to primary GND.

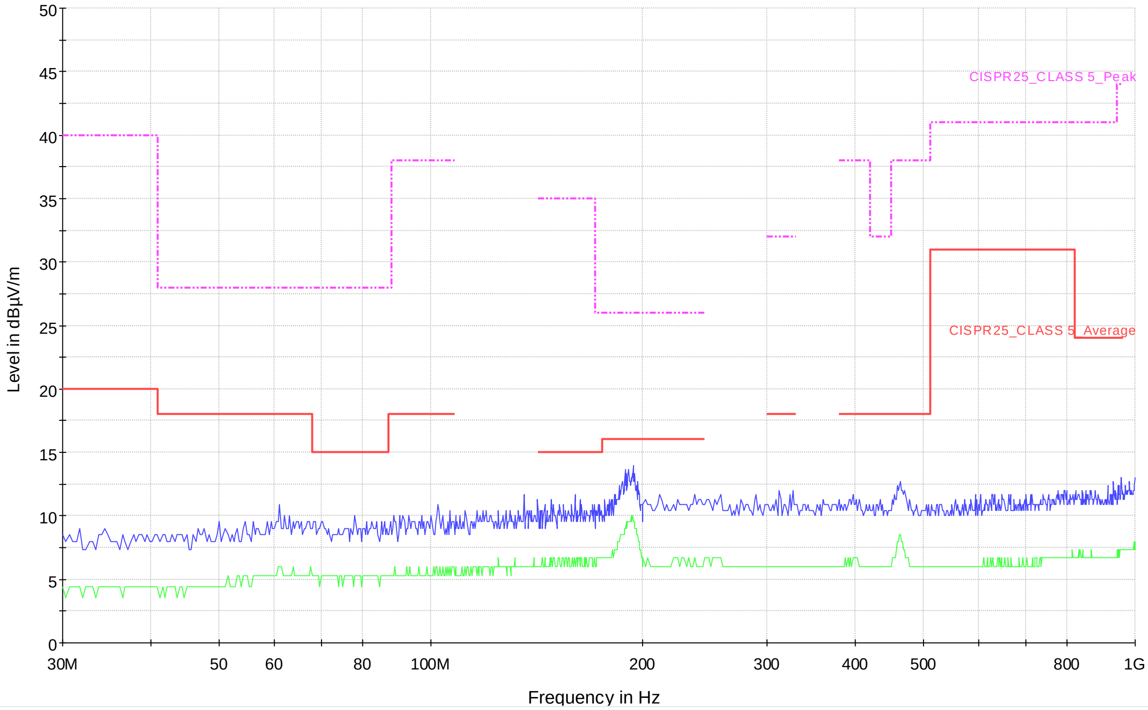


**Figure 15. CISPR 25 Class 5 Radiated Emissions Plot, $V_{IN}$ = 13.5 V, $I_{OUT}$ = 0.5 A**



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# 7 EVM Documentation

## 7.1 Schematic

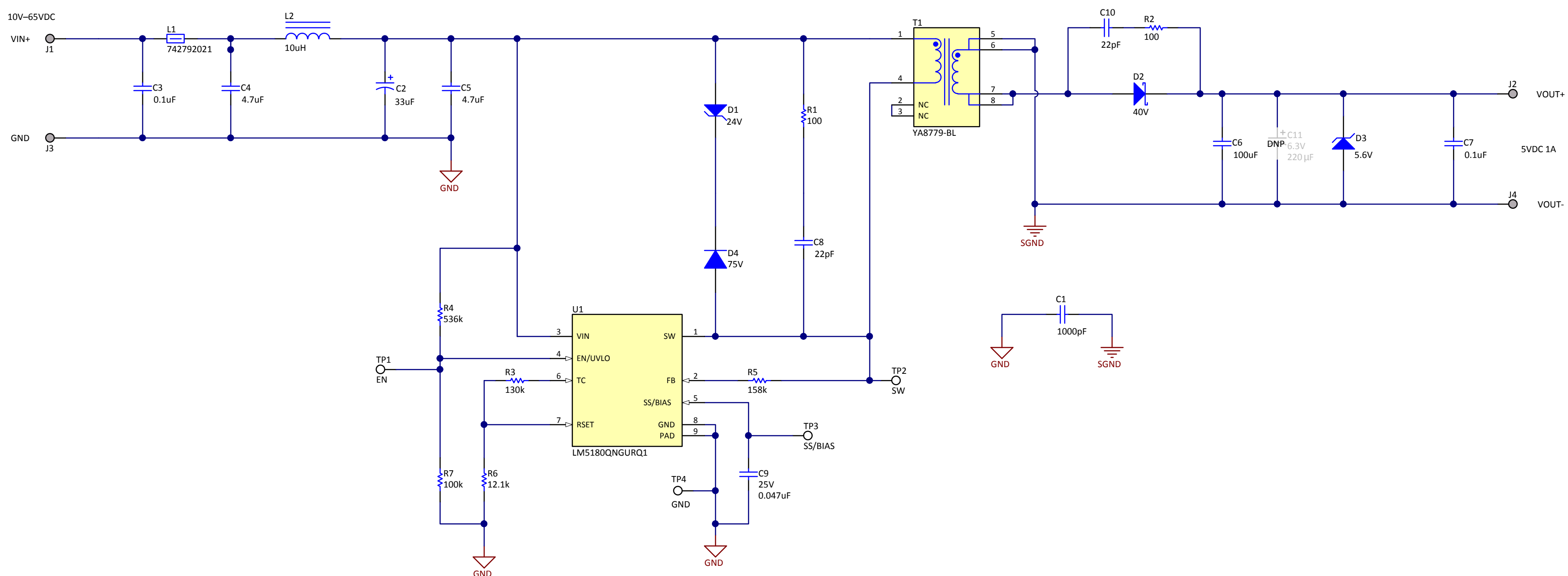


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**Figure 16. PSR Flyback EVM Schematic**



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## 7.2 Bill of Materials

**Table 3. Bill of Materials**

| COUNT | REF DES | DESCRIPTION | PART NUMBER | MFR |
|---|---|---|---|---|
| 1 | C1 | Capacitor, Ceramic, 1nF, 2kV, X7R, 1206 | 202R18W102KV4E | Johanson Dielectrics Inc. |
| 1 | C2 | Aluminum Electrolytic, 33µF, 100V, ±20%, AEC-Q200 grade 2 | EEE-FK2A330P | Panasonic |
| 1 | C3 | Capacitor, Ceramic, 0.1µF, 100V, X7R, 0603 | C1608X7R1A105K080AC | TDK |
| 2 | C4, C5 | Capacitor, Ceramic, 4.7µF, 100V, X7S, 1210 | C3225X7S2A475M200AB | TDK |
| | | | GRJ32DC72A475KE11 | Murata |
| 1 | C6 | Capacitor, Ceramic, 100µF, 6.3V, X5R, 1210 | C3225X5R0J107M250AC | TDK |
| | | | 885012109004 | Würth Electronik |
| | | | GRM32ER60J107ME20 | Murata |
| | | Capacitor, Ceramic, 100µF, 6.3V, X7S, 1210 | GRM32EC70J107ME15 | Murata |
| | | | JMK325AC7107MM-P | Taiyo Yuden |
| 1 | C7 | Capacitor, Ceramic, 0.1µF, 25V, X7R, 0603 | Std | Std |
| 2 | C8, C10 | Capacitor, Ceramic, 220pF, 100V, X7R, 0603 | Std | Std |
| 1 | C9 | Capacitor, Ceramic, 47nF, 16V, X7R, 0603 | Std | Std |
| 1 | D1 | Zener, 24V, 1W, PowerDI-123, AEC-Q101 | DFLZ24-7 | Diodes Inc. |
| | | Zener, 24V, 1W, SOD-123 | DFLZ24-TP | Micro Commercial |
| 1 | D2 | Schottky diode, 40V, 3A, SMA, AEC-Q101 | FSV340AF | Onsemi |
| 1 | D3 | Zener diode, 5.6V, SOD-523 | BZT52C5V6T-7 | Diodes Inc. |
| 1 | D4 | Switching diode, 75V, 0.25A,, SOD-123 | CMDD4448 | Central Semi |
| 4 | H1, H2, H3, H4 | Machine Screw, Round, #4-40 x 1/4, Nylon, Philips Panhead | NY PMS 440 0025 PH | B & F Fastener Supply |
| 4 | H5, H6, H7, H8 | Standoff, Hex, 0.5"L #4-40 Nylon | 1902C | Keystone Electronics |
| 1 | L1 | Ferrite bead, 22Ω at 100MHz, 8mΩ max, 0805 | 742792021 | Würth Electronik |
| 1 | L2 | Inductor, 10µH ±30%, 120mΩ, 1A | 744042100 | Würth Electronik |
| 1 | T1 | Transformer, 30µH, 2A Isat, 3 : 1 turns ratio, 10.2mm × 9.3mm × 10.6mm | YA8779-BLD | Coilcraft |
| | | | 750317605 | Würth Electronik |
| 2 | R1, R2 | Resistor, Chip, 100Ω, 1/8W, 5%, 0805 | Std | Std |
| 1 | R3 | Resistor, Chip, 130kΩ, 1/16W, 1%, 0603 | Std | Std |
| 1 | R4 | Resistor, Chip, 536kΩ, 1/16W, 1%, 0603 | Std | Std |
| 1 | R5 | Resistor, Chip, 158kΩ, 1/16W, 1%, 0603 | Std | Std |
| 1 | R6 | Resistor, Chip, 12.1kΩ, 1/16W, 1%, 0603 | Std | Std |
| 1 | R7 | Resistor, Chip, 100kΩ, 1/16W, 1%, 0603 | Std | Std |
| 1 | U1 | IC, LM5180-Q1, wide $V_{IN}$ PSR flyback converter, WSON-8 | LM5180QNGURQ1 | TI |
| 1 | PCB1 | PCB, FR4, 2 layer, 1 oz, 50 mm x 35 mm | PCB | – |
| 4 | J1, J2, J3, J4 | Turret, PTH, 4.72mm, VIN+, VIN–, VOUT+, VOUT– | 1573-2 | Keystone Electronics |
| 4 | TP1, TP2, TP3, TP4 | Test point for EN, SW, SS/BIAS, GND | 5015 | Keystone Electronics |


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### 7.3 PCB Layout

Figure 17 through Figure 20 show the design of a 2-layer PCB with 1-oz copper thickness. The EVM is a two-sided design with post connections for VIN+, VIN–, VOUT+ and VOUT–.

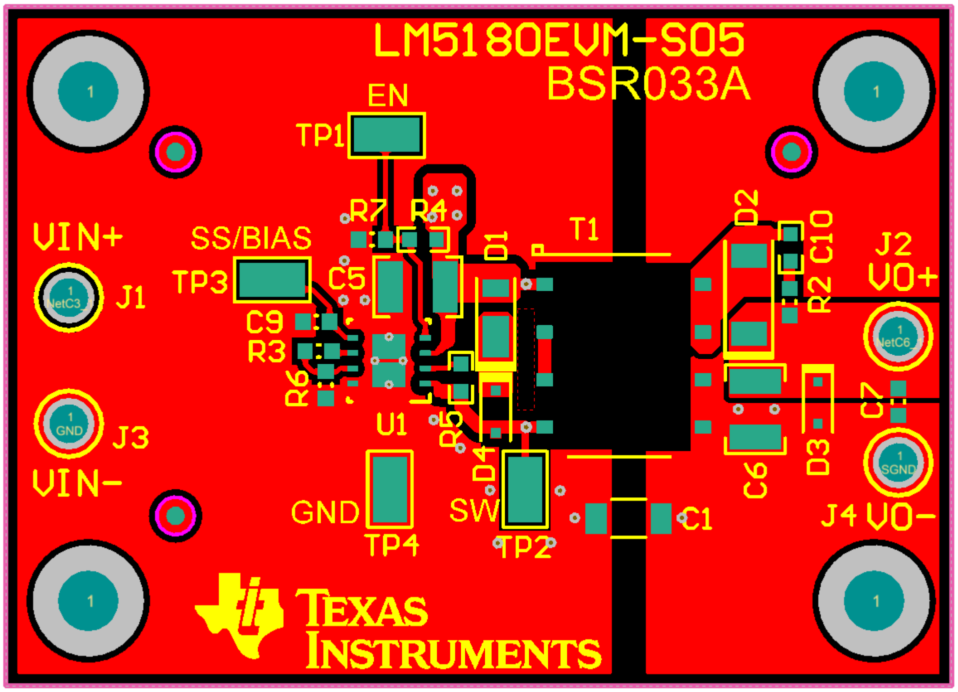


**Figure 17. Top Copper (Top View)**

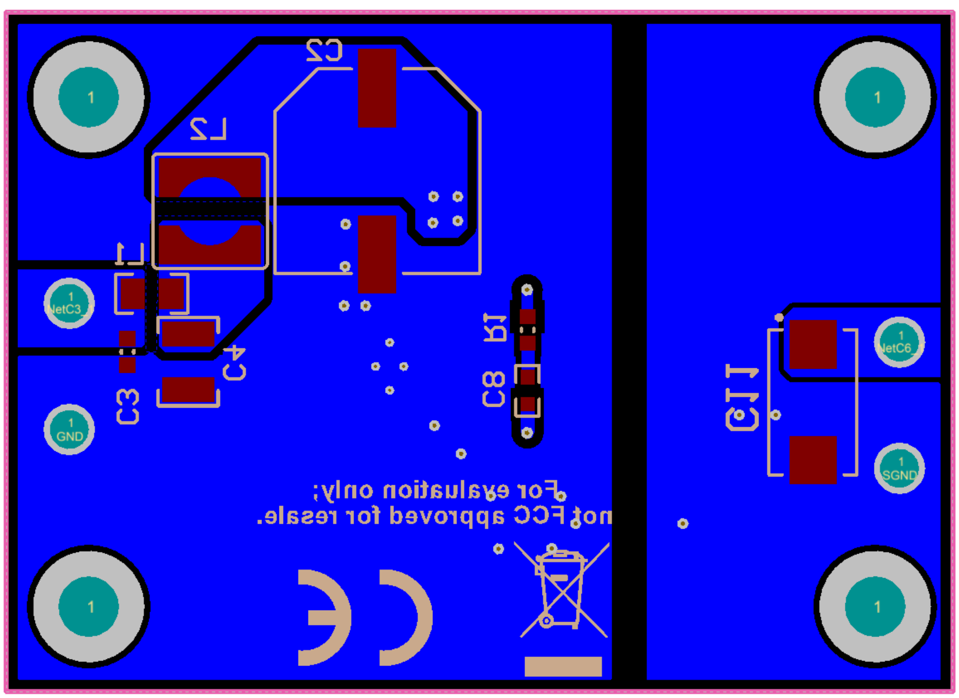

**Figure 18. Bottom Copper (Top View)**


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## 7.4 Assembly Drawings

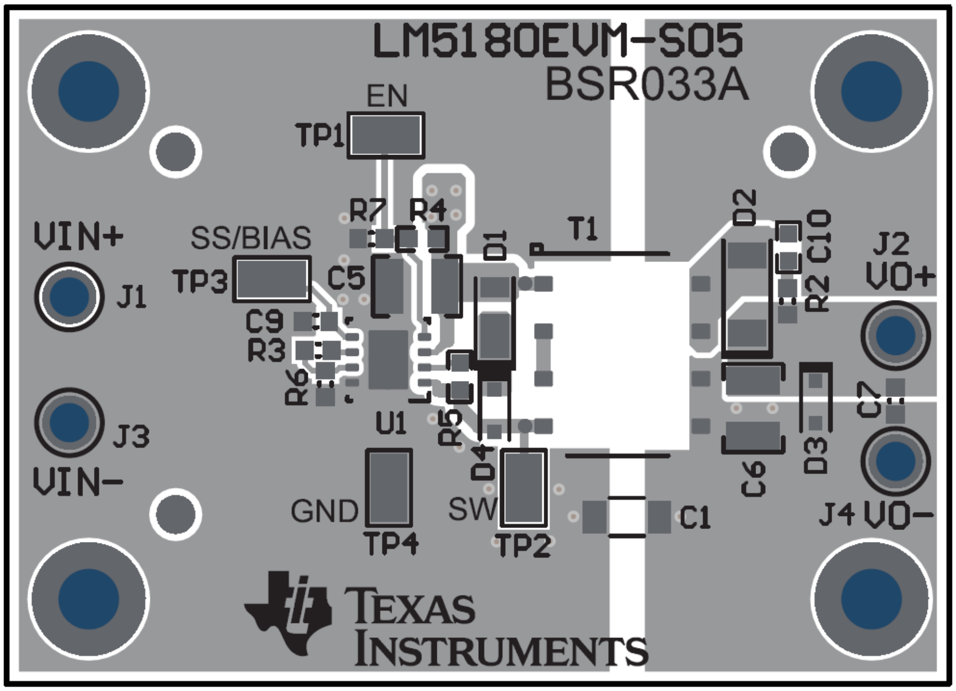


**Figure 19. Top Component Drawing**

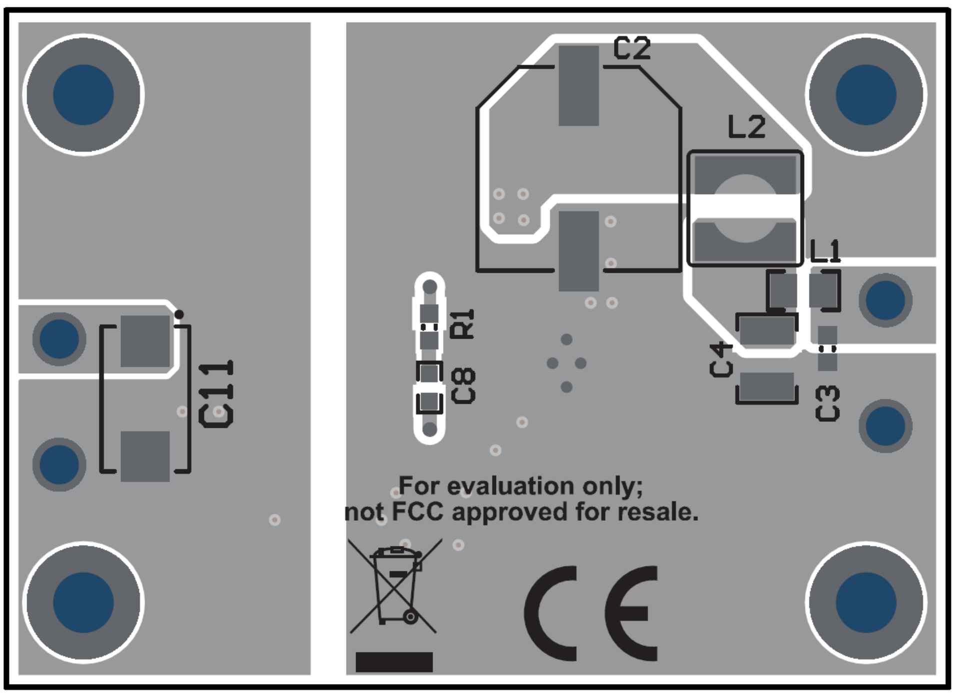


**Figure 20. Bottom Component Drawing**



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# 8 Device and Documentation Support

## 8.1 Device Support

### 8.1.1 Third-Party Products Disclaimer

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### 8.1.2 Development Support

For development support see the following:

- For TI's reference design library, visit TI Designs
- For TI's WEBENCH Design Environments, visit the WEBENCH® Design Center
- LM5180 PSR Flyback Converter Quickstart Calculator and PSPICE simulation model

## 8.2 Documentation Support

### 8.2.1 Related Documentation

For related documentation see the following:

- *LM5180EVM-DUAL EVM User's Guide* (SNVU609)
- *Reduce Buck Converter EMI and Voltage Stress by Minimizing Inductive Parasitics* (SLYT682)
- *AN-2162 Simple Success with Conducted EMI from DC-DC Converters* (SNVA489)
- White Papers:
  - *Valuing Wide VIN, Low EMI Synchronous Buck Circuits for Cost-driven, Demanding Applications* (SLYY104)
  - *An Overview of Conducted EMI Specifications for Power Supplies* (SLYY136)
  - *An Overview of Radiated EMI Specifications for Power Supplies* (SLYY142)
- *Under the Hood of Flyback SMPS Designs* (SLUP261)
- *Flyback Transformer Design Considerations for Efficiency and EMI* (SLUP338)

#### *8.2.1.1 PCB Layout Resources*

- *AN-1149 Layout Guidelines for Switching Power Supplies* (SNVA021)
- *AN-1229 Simple Switcher PCB Layout Guidelines* (SNVA054)
- *Constructing Your Power Supply – Layout Considerations* (SLUP230)
- *Low Radiated EMI Layout Made SIMPLE with LM4360x and LM4600x* (SNVA721)
- Power House Blogs:
  - *High-Density PCB Layout of DC-DC Converters*

#### *8.2.1.2 Thermal Design Resources*

- *AN-2020 Thermal Design by Insight, Not Hindsight* (SNVA419)
- *AN-1520 A Guide to Board Layout for Best Thermal Resistance for Exposed Pad Packages* (SNVA183)
- *Semiconductor and IC Package Thermal Metrics* (SPRA953)
- *Thermal Design Made Simple with LM43603 and LM43602* (SNVA719)
- *PowerPAD Thermally Enhanced Package* (SLMA002)
- *PowerPAD Made Easy* (SLMA004)
- *Using New Thermal Metrics* (SBVA025)


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## Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

**Changes from B Revision (February 2019) to C Revision** **Page**



**Changes from A Revision (October 2018) to B Revision** **Page**



**Changes from Original (July 2018) to A Revision** **Page**




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1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

## WARNING

**Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.**

**User shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.**

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

**FCC NOTICE:** This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

**CAUTION**

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

**FCC Interference Statement for Class A EVM devices**

*NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.*

**FCC Interference Statement for Class B EVM devices**

*NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:*

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

**Concerning EVMs Including Radio Transmitters:**

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

**Concernant les EVMs avec appareils radio:**

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

**Concerning EVMs Including Detachable Antennas:**

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

**Concernant les EVMs avec antennes détachables**

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。 http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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2. 実験局の免許を取得後ご使用いただく。
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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

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10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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