

Evaluates: LT80602 in a 5V Output-Voltage Application at 2.1MHz Switching Frequency

Description

The LT80602EVKITA# (EV kit) is a proven 5V design to evaluate the LT80602 synchronous step-down [*Silent Switcher*](#)[®]. The EV kit is designed for a 5V output. The wide input range up to 65V allows a variety of input sources, such as automotive batteries and industrial supplies. The LT80602 is a compact, ultralow electromagnetic interference (EMI) emission, high-efficiency, high-speed synchronous monolithic step-down switching regulator that consumes only 8 μ A of quiescent current when the output is regulated at 5V. The top and bottom power switches, compensation components, and other necessary circuits within the LT80602 minimize the need for external components and simplify the design. The EV kit can also evaluate the LT80603, LT80603A, LT80603HV, LT80602HV, and LT80603AHV. Refer to the IC data sheet guidelines when modifying the schematic to achieve optimal performance.

The application circuit demonstrated in the evaluation board is suitable for a wide range of automotive, telecom, industrial, and other applications.

The LT80602 data sheet provides a complete description of the part, its operation, and application information. Consult the data sheet in conjunction with this EV kit.

Design files for this circuit board are available at <https://www.analog.com/en/products/LT80602.html>.

Features and Benefits

- Silent Switcher Architecture, Ultralow EMI Emissions
- Spread-Spectrum Frequency Modulation
- Input Voltage Range up to 65V
- 2.1MHz Switching Frequency
- High 89.1% Efficiency ($V_{IN} = 24V$, $I_{OUT} = 2.5A$)
- 8 μ A I_Q Regulating 24V_{IN} to 5V_{OUT}
- On-the-Fly Mode Change Among Burst Mode, Pulse-Skipping Mode (PSM), and Forced Continuous Mode (FCM)
- 99% Duty-Cycle Operation
- 0.75 μ A Shutdown Current
- Bias Bootstrap Input for Improved Efficiency
- Burst and Pulse-Skipping Modes to Enable Enhanced Light-Load Efficiency
- Programmable Soft-Start and Tracking
- Built-In Output-Voltage Monitoring and Die Temperature Monitoring with PG/T_J
- Overtemperature and Overcurrent Protection
- External Clock Synchronization
- Proven PCB Layout
- Fully Assembled and Tested
- Complies with CISPR 25 Class 5 Conducted and Radiated Emissions

[Ordering Information](#) appears at end of data sheet.

Quick Start

Required Equipment

- 65V, 2.5A DC power supply
- Digital multimeter (DMM)
- Load resistors capable of sinking up to 2.5A

Procedure

The EV kit is fully assembled and tested. See [Figure 1](#) for proper measurement equipment setup, use the following procedure.

1. Set an input power supply capable of 65V/2.5A, then turn off the supply.
2. Connect the input power supply to the input terminals V_{IN_EMI} and PGND to check the EMI performance of the EV kit. Connect the input power supply to the input terminals V_{IN} and PGND to operate without the EMI filter.
3. Place a voltmeter across the input voltage sense terminals V_{IN_SENSE} and PGND to get an accurate input voltage measurement.
4. Connect a variable load capable of sinking 2.5A at 5V to the output terminals V_{OUT} and PGND, and set the current to 0A.

5. Place a voltmeter across the output voltage sense terminals V_{OUT_SENSE} and PGND to get an accurate output voltage measurement.
6. Verify that the shunts are not installed across pins on jumper JU1. See [Table 1](#) for more details.
7. Verify that the shunts are properly installed across pins on jumper JU2. See [Table 2](#) for more details.
8. Verify that the shunts are properly installed across pins on jumper JU3. See [Table 3](#) for more details.
9. Turn on the power at the input.

Note: Ensure that the input voltage never exceeds 65V.

10. Check that the output voltage is properly set to 5V.

11. Adjust the load and/or input within the operating range and observe the output voltage regulation, ripple voltage, efficiency, and other desired parameters.

Note: When measuring the input or output voltage ripple, take care to avoid using a long ground lead on the oscilloscope probe. Measure the output voltage ripple by touching the probe tip directly across the output capacitor. See [Figure 2](#) for the proper scope technique.

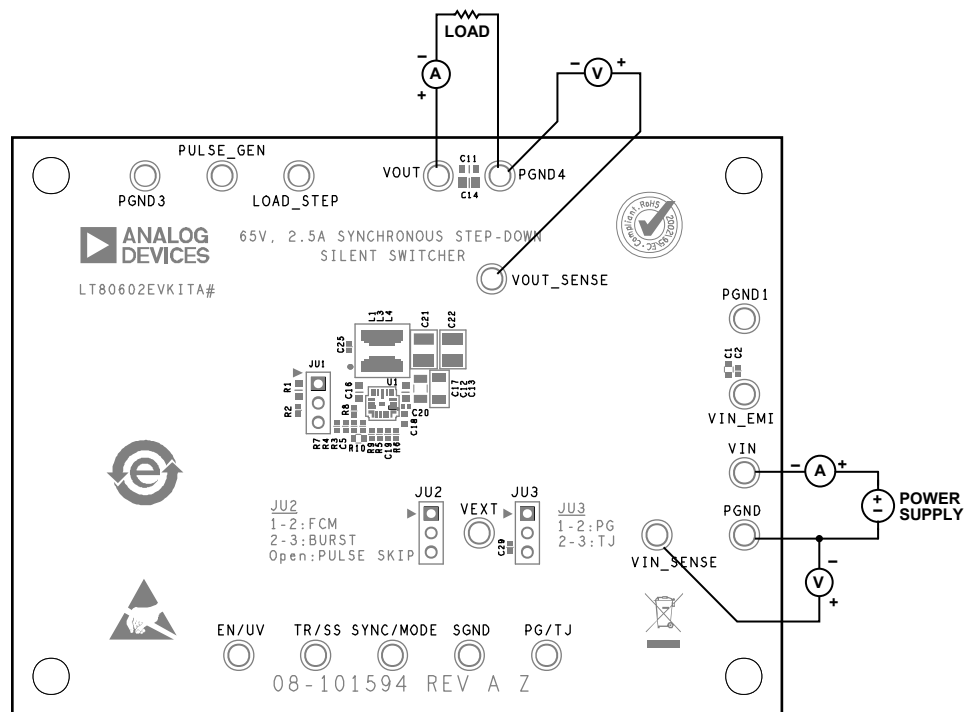


Figure 1. Proper Measurement Equipment Setup

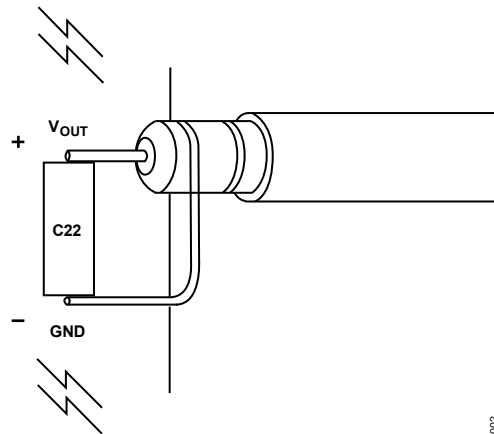


Figure 2. Measuring Output Ripple

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Typical Performance Characteristics

($V_{IN} = V_{EN/UV} = 24V$, $C_{INTVCC} = 2.2\mu F$, $V_{GND} = V_{GND1} = V_{GND2} = 0V$, $V_{BIAS/VOUT} = V_{OUT}$, $C_{SS} = 8.2nF$, $T_A = +25^\circ C$, unless otherwise noted.)

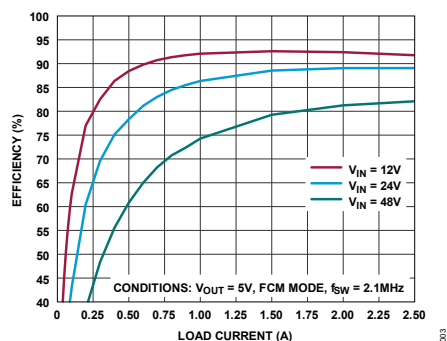


Figure 3. Efficiency vs. Load Current

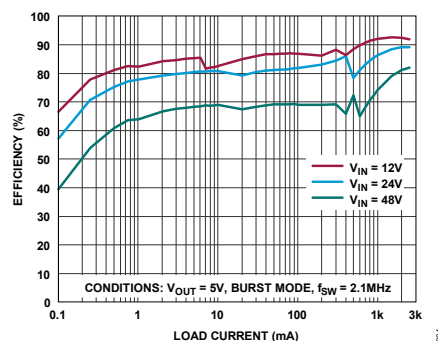


Figure 4. Efficiency vs. Load Current

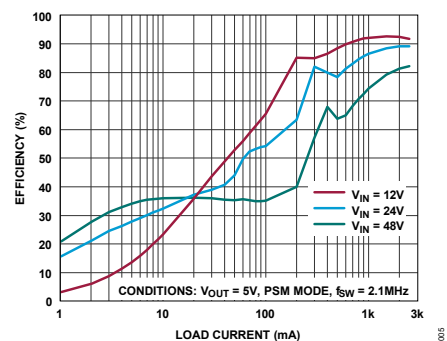


Figure 5. Efficiency vs. Load Current

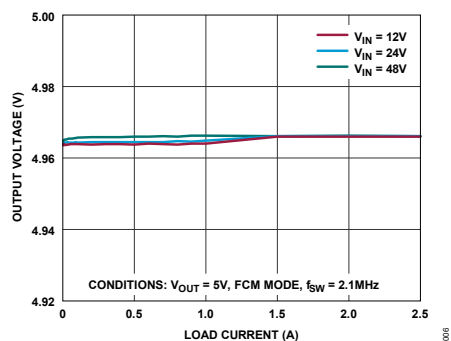


Figure 6. Output Voltage vs. Load Current

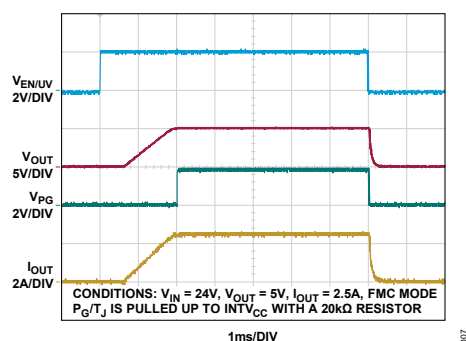


Figure 7. Startup/Shutdown through EN/UV

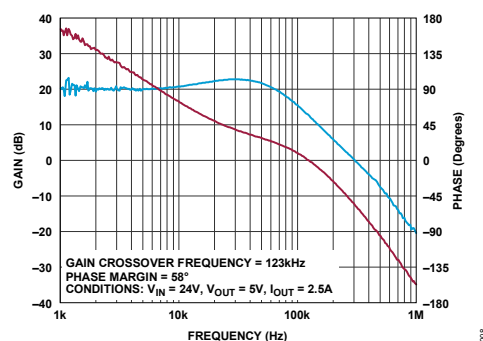


Figure 8. Gain/Phase vs. Frequency

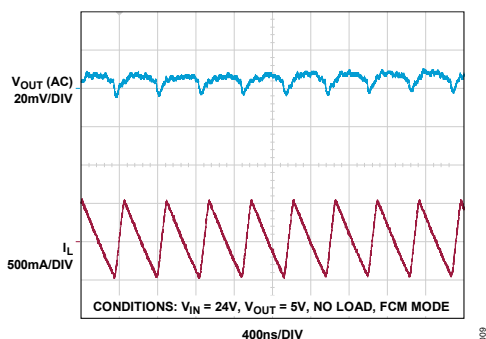


Figure 9. Steady-State Switching Waveform

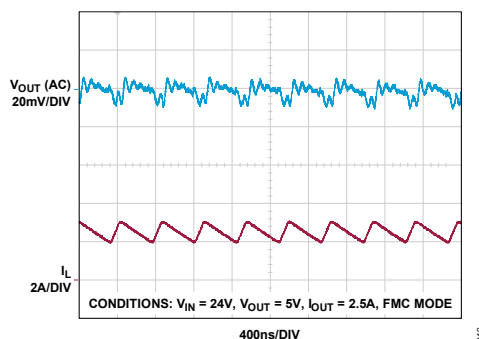


Figure 10. Steady-State Switching Waveform

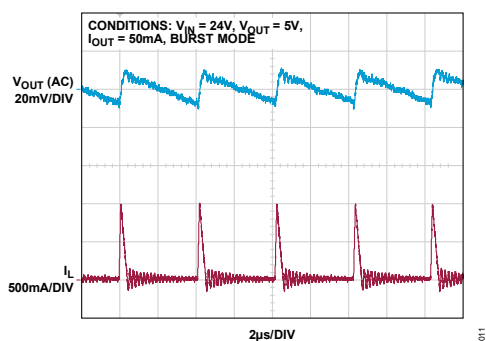


Figure 11. Steady-State Switching Waveform

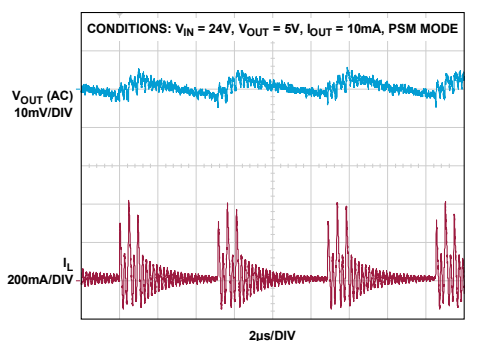


Figure 12. Steady-State Switching Waveform

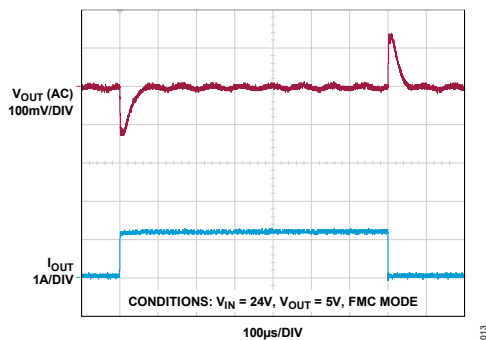


Figure 13. Load Current Stepped from 10mA to 1.25A

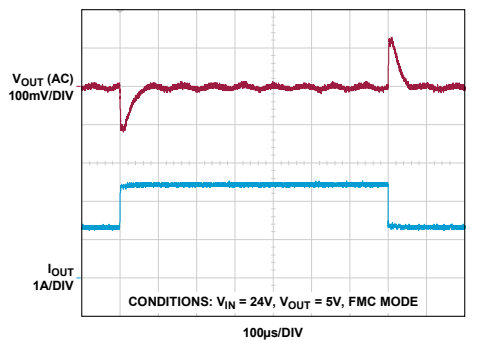


Figure 14. Load Current Stepped from 1.25A to 2.5A

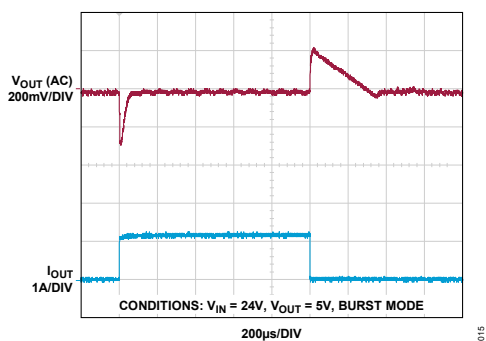


Figure 15. Load Current Stepped from 10mA to 1.25A

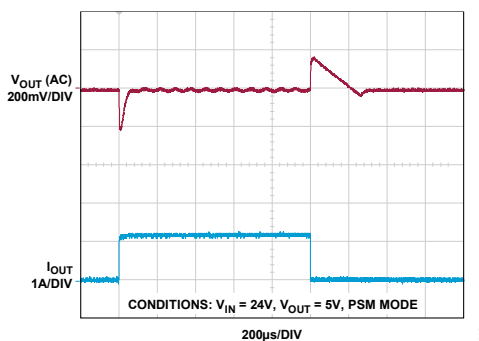


Figure 16. Load Current Stepped from 10mA to 1.25A

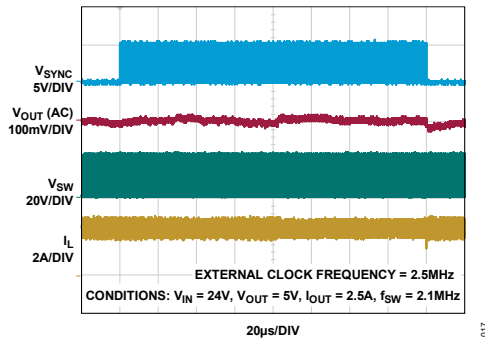


Figure 17. External Clock Synchronization

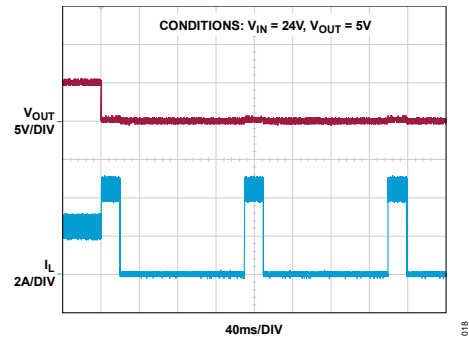


Figure 18. Output Short

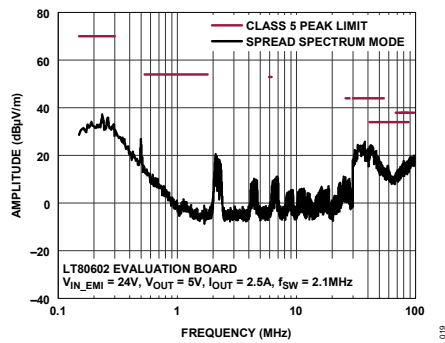


Figure 19. CISPR25 Conducted Emission Test with Class 5 Peak Limits

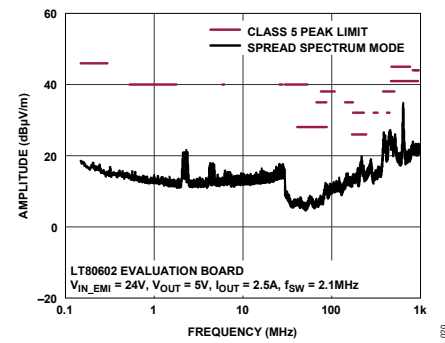
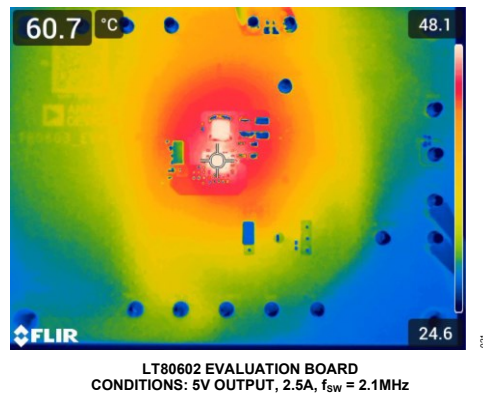


Figure 20. CISPR25 Radiated Emission Test with Class 5 Peak Limits

Figure 21. Thermal Image with $V_{\text{IN}} = 24\text{V}$

Detailed Description

The LT80602EVKITA# is designed to demonstrate the salient features of the LT80602 synchronous step-down Silent Switcher. The EV kit is preset for a 5V output and can handle input voltages up to 65V at load currents up to 2.5A. It also features a 2.1MHz switching frequency for optimum efficiency and component size.

Enable/UVLO (EN/UV) Programming

The LT80602 offers an adjustable input undervoltage lockout feature. When JU1 is left open, the LT80602 is enabled when the input voltage rises above 4.5V. If a shunt is installed across pins 1 to 2 on jumper JU1, the LT80602 is enabled when the input voltage rises above 2.8V (typical V_{IN} rising). To disable the LT80602, install a shunt across pins 2 to 3 on jumper JU1. See [Table 1](#) for JU1 settings. A potential divider formed by R1 and R2 sets the input voltage above which the converter is enabled when JU1 is left open. Refer to the *Enable Pin* section of the *LT80602 data sheet* for more details.

The LT80602 supports external enable/disable control of the device. Leave JU1 open when external enable/disable control is desired.

Table 1. EN/UV Jumper (JU1) Settings

SHUNT POSITION	EN/UV PIN	OUTPUT
1 to 2	Connected to V_{IN}	Enabled
Not installed*	Connected to the center node of resistor-divider R1 and R2	Enabled, UVLO level is set by the resistor-divider between V_{IN} and GND
2 to 3	Connected to GND	Disabled

*Default position.

Mode Selection and External Clock Synchronization (SYNC/MODE)

The EV kit includes a jumper (JU2) that allows the LT80602 to operate in FCM, Burst Mode, and Pulse-Skipping Modes. Refer to the LT80602 data sheet for more details on the modes of operation. [Table 2](#) shows the mode selection (JU2) settings used to configure the desired operating mode.

The internal oscillators of the converter can be synchronized to an external clock signal on the SYNC/MODE pin. The LT80602 also supports on-the-fly mode changes among FCM, Burst Mode, and Pulse-Skipping Modes. Refer to the *Mode Selection and External Clock Synchronization (SYNC/MODE)* section of the *LT80602 data sheet* for more details.

Table 2. Mode Selection Jumper (JU2) Settings

SHUNT POSITION	MODE/SYNC PIN	OUTPUT
1 to 2*	Connected to V_{CC}	Force Continuous Mode of Operation
Not installed	OPEN	Pulse-Skipping Mode of Operation
2 to 3	Connected to GND	Burst Mode of Operation

*Default position.

Setting the Switching Frequency

In the EV kit, a switching frequency of 2.1MHz is chosen for the application circuit. Connecting an 8.66k Ω resistor (R5) from RT to GND programs the device to operate at this switching frequency. Refer to the *Setting the Switching Frequency* section of the *LT80602 data sheet* to select different resistor values for programming the required switching frequency.

BST Capacitor Selection

The BST capacitor must be selected appropriately to hold sufficient charge and supply the BST to the SW rail in sleep mode. In the EV kit, the BST-to-SW capacitance C20 is chosen as 0.22 μ F. Refer to the *BST Capacitor Selection* section of the *LT80602 data sheet* to select the appropriate BST capacitor value based on the programmed switching frequency and operating mode.

Output Voltage Tracking and Soft-Start

The EV kit offers an adjustable soft-start function to limit inrush current during start-up. The soft-start time is adjusted by changing the value of capacitor C19. In this EV kit, the default soft-start time is set to 1.3ms, which is programmed with an 8200pF soft-start capacitor. For output-tracking applications, TR/SS can be externally driven by another voltage source. Refer to the *Output Voltage Tracking and Soft-Start* section of the *LT80602 data sheet* for more details.

FB Resistor Network

The output voltage is programmed using the resistor dividers R3 and R4. The EV kit is programmed to the adjustable 5V output by setting R3 = 1M Ω and R4 = 191k Ω . C5 is added to improve loop stability and transient performance. In the EV kit, for optimal bandwidth and transient performance, C5 is chosen as 5.6pF. Refer to the *FB Resistor Network* section of the *LT80602 data sheet* for more details on the selection of the feedback resistor and phase-lead capacitor.

The EV kit supports fixed 5V and 3.3V output voltage programming using the FB/V_{OS} pin. To program the EV kit to the 5V fixed output, connect a 0 Ω resistor across R7 and open R10, R3, R4, and C5.

Input Capacitors

The input capacitors C6, C12, and C13 minimize EMI emissions, reduce current peaks drawn from the input power supply, and reduce the switching frequency ripple at the input. Refer to the *Input Capacitors and Low EMI PCB Layout* section of the *LT80602 data sheet* for more details.

Output Capacitor and Output Ripple

The output capacitor C21 in the EV kit is populated with 22 μ F. Refer to the *Output Capacitor and Output Ripple* section of the *LT80602 data sheet* for adjusting the output capacitance.

Linear Regulator (INTV_{CC} and BIAS/V_{OUT})

Powering INTV_{CC} from BIAS/V_{OUT} increases the efficiency of the converter at higher input voltages. If the applied BIAS/V_{OUT} voltage exceeds 2.3V (typ), internal V_{CC} is powered from BIAS/V_{OUT}. If BIAS/V_{OUT} is lower than 2.2V (typ), internal V_{CC} is powered from V_{IN}. In this evaluation board, BIAS/V_{OUT} is connected to V_{OUT} by connecting a 0 Ω resistor in R8.

Note: Connect the BIAS/V_{OUT} pin to the converter output voltage node only if the output voltage is programmed between 2.35V and 25V.

Output Power Good and Die Temperature Monitor

The LT80602 offers the PG/T_J pin to monitor either the output voltage status or the die temperature. Install a shunt across pins 1 to 2 on jumper JU3 to monitor the converter output status. Install a shunt across pins 2 to 3 on jumper JU3 to monitor the die temperature. See [Table 3](#) for jumper settings. Refer to the *Output Power Good and Die Temperature Monitor* section of the *LT80602 data sheet* for more details.

Table 3. PG/T_J Jumper (JU3) Settings

SHUNT POSITION	PG/T _J PIN	OUTPUT
1 to 2*	Connected to V _{CC}	PG functionality
2 to 3	Connected to GND	Die temperature monitor

*Default position.

Hot Plug-in and Long Input Cables

The LT80602 EV kit provides an optional electrolytic capacitor (C9, 33 μ F/100V) to dampen input voltage peaks and oscillations that can arise during hot plug-in and/or due to long input cables. These capacitors limit the peak voltage at the input of the DC-DC converters when the EV kit is powered directly from a precharged capacitive source or an industrial backplane printed circuit board (PCB). Long input cables between the input power source and the EV kit circuit can cause input voltage oscillations due to the inductance of the cables. The equivalent series resistance (ESR) of the electrolytic capacitor helps damp out the oscillations caused by long input cables.

Electromagnetic Interference

Compliance with conducted emissions (CE) standards requires an EMI filter at the input of a switching power converter. The EMI filter attenuates high-frequency currents drawn by the switching power converter and limits the noise injected back into the input power source. Power the converter from the V_{IN_EMI} terminal to evaluate EMI performance.

The use of EMI filter components, as shown in the EV kits schematic, results in lower conducted emissions, below CISPR25 Class 5 limits. The manufacturer part numbers of the EMI filter components are listed in the bill of materials (BOM). The PCB layout is also designed to limit radiated emissions from switching nodes of the power converter, resulting in radiated emissions below CISPR25 Class 5 limits. Further, capacitors placed near the input of the board help in attenuating high-frequency noise.

Ordering Information

PART	TYPE
LT80602EVKITA#	EV kit

#Denotes RoHS-compliance.

LT80602EVKITA# Bill of Materials

ITEM	QTY	REFERENCE	DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	1	C12	Capacitor, 1206, 4.7μF, 100V, X7R, 10%	TDK, CGA5L1X7R2A475K160AC
2	2	C16, C17	Capacitors, 0603, 0.1μF, 100V, X7R, 10%	YAGEO, CC0603KRX7R0BB104
3	1	C5	Capacitor, 0402, 5.6PF, 50V, C0G/NPO	Kemet, C0402C569C5GAC
4	1	C18	Capacitor, 0603, 2.2μF, 10V, X7R, 10%	Murata, GRM188R71A225KE15D
5	1	C19	Capacitor, 0402, 8200PF, 50V, X7R, 10%	Venkel, C0402X7R500822KNP
6	1	C20	Capacitor, 0402, 0.22μF, 16V, X7R, 10%	Murata, GRM155R71C224KA12D
7	1	C26	Capacitor, 0402, 0.1μF, 16V, X7R, 10%	TDK, C1005X7R1C104K050BC
8	1	C21	Capacitor, 1210, 22μF, 16V, X7R, 10%	Murata, GRM32ER71C226KEA8L
9	1	L1	Inductor, 1.8μH, 20%	Coilcraft, XGL4025-182MEC
10	1	R1	Resistor, 0603, 3.32MΩ, 1%, 1/10W	Vishay, CRCW06033M32FKEA
11	1	R2	Resistor, 0603, 953kΩ, 1%, 1/10W	Yageo, CRCW0402953KFKEDC
12	1	R3	Resistor, 0402, 1MΩ, 1%, 1/10W	Panasonic, ERJ-2RKF1004X
13	1	R4	Resistor, 0402, 191kΩ, 1%, 1/16W	Vishay, CRCW0402191KFKED
14	1	R6	Resistor, 0402, 20kΩ, 1%, 1/16W	Vishay, CRCW040220K0FKED
15	1	R8	Resistor, 0402, 0, 1/2W	Keystone, 5112
16	1	R5	Resistor, 0402, 8.66kΩ, 1/10W	Panasonic, ERJ-2RKF8661X
17	1	U1	IC, Regulator, FC2QFN17-EP	Analog Devices, LT80602AFOA/VY+T
Additional Demo Board Circuit Components				
18	1	C1	Capacitor, 0603, 0.1μF, 100V, X7R, 10%	Yageo, CC0603KRX7R0BB104
19	1	C2	Capacitor, 0402, 200pF, 100V, X7R, 10%	Murata, GRM155R72A221KA01D
20	1	C9	Capacitor, Aluminium, 33μF, 100V, 20%	Panasonic, EEE-TG2A330P
21	1	C14	Capacitor, 0805	Open
22	1	C22	Capacitor, 1210	Open
23	1	L2	Inductor, 15μH	Open
24	1	L3	Inductor, 8.2μH	Open
25	1	L4	Inductor, 6.8μH	Open
26	1	R10	Resistor, 0603, 0, 0.1%, 1/10W	Samsung, RC1608J000CS
27	1	Q1	MOSFET, N-Channel, 40V, 14A, DPAK	Vishay, SUD50N04-8M8P-4GE3
28	1	R12	Resistor, 2512; 0.1, 1%, 3W	Bourns, CRA2512-FZ-R100ELF
29	1	R13	Resistor, 0805, 10kΩ, 1%, 1/10W	Tyco Electronics, RN73C2A10KBTG
30	1	FB1	Ferrite Bead, 1206, 280 Ohms, 3.5A	Würth Elektronik, 78279221281

LT80602EVKITA# Bill of Materials (continued)

ITEM	QTY	REFERENCE	DESCRIPTION	MANUFACTURER/PART NUMBER
31	2	C3, C11	Capacitors, 0603	Open
32	3	C10, C25, C29	Capacitors, 0402	Open
33	1	C4	Capacitor, 1206, 4.7μF, 100V, X7R, 10%	TDK, CGA5L1X7R2A475K160AC
34	1	C6	Capacitor, 1206	Open
35	2	C7, C8	Capacitors, 1206	Open
36	1	C30	Capacitor, 0805	Open
37	1	C13	Capacitor, 1206	Open
38	2	R9, R7	Resistors, 0402	Open
Hardware: For Demo Board Only				
39	17	EN/UV, LOAD_STEP, PG/TJ, PGND, PGND1, PGND3, PGND4, PULSE_GEN, SGND, SYNC/MODE, TR/SS, VEXT, VIN, VIN_EMI, VIN_SENSE, VOUT, VOUT_SENSE	Testpoint, Turret, 0.094"	Mill-Max, 2501-2-00-80-00-00-07-0
40	3	JU1, JU2, JU3	Connector, Male, 3 Pins	Sullins, PBC03SABN
41	3	SU1, SU2, SU3	Connector, Female, 2 Pins	Sullins, QPC02SXGN-RC
42	4	MH1 to MH4	Round-Thru Hole Spacer	Keystone, 9032
43	1	VEXT	Testpoint, Turret, 0.04"	Keystone, 5001

LT80602EVKITA# Schematic Diagram

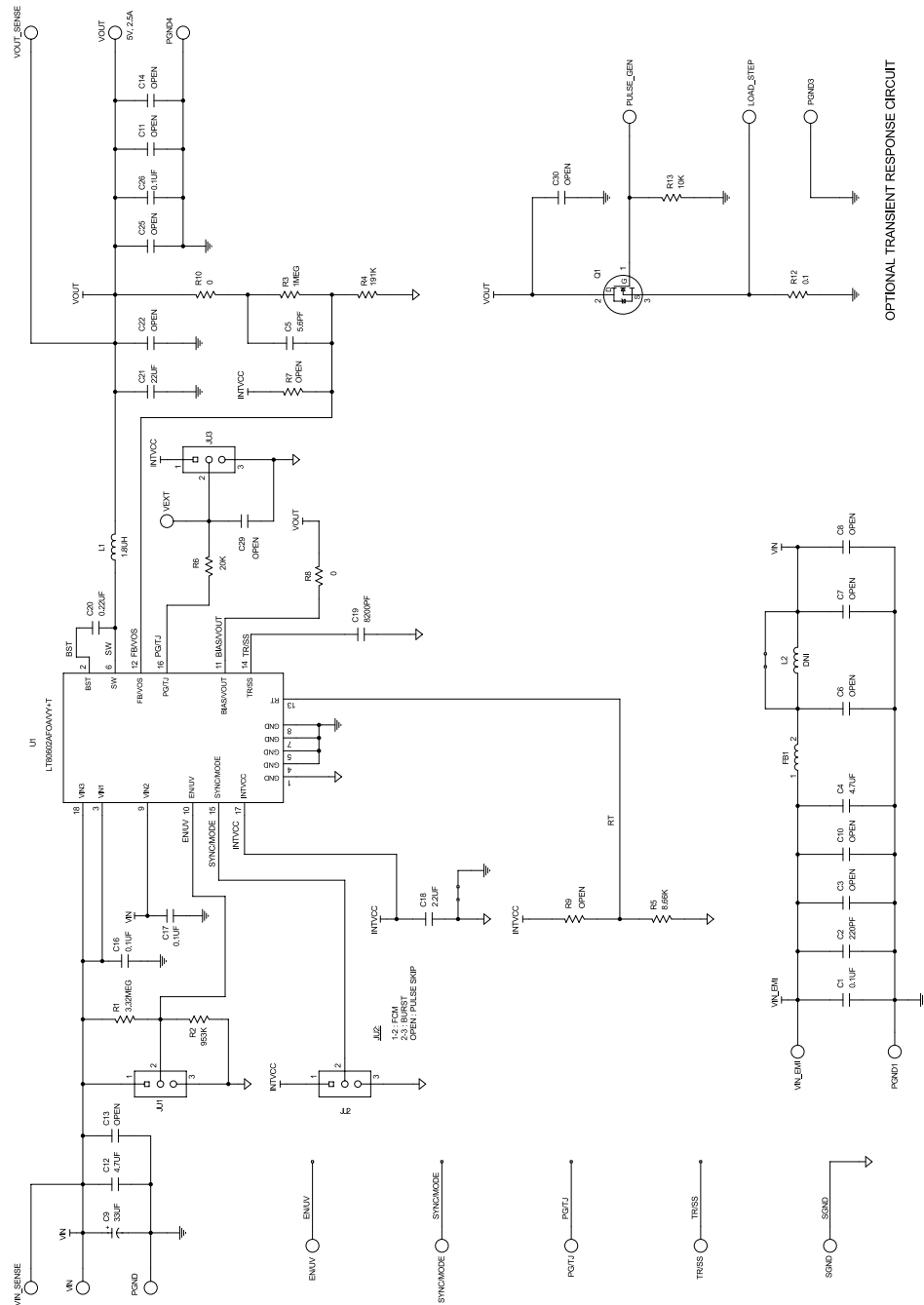


Figure 22. LT80602EVKITA# Schematic Diagram

PULSE_GEN

PGND3

LOAD_STEP

VOUT

C11

C14

PGND4

ANALOG DEVICES

65V, 2.5A SYNCHRONOUS STEP-DOWN SILENT SWITCHER

LT80602EVKITA#

VOUT Sense

PGND1

VIN EMI

VIN

PGND

VOUT Sense

EN/UV

TR/SS

SYNC/MODE

SGND

PG/TJ

08-101594 REV A Z

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LT80602EVKITA# PCB Layout Diagrams (continued)

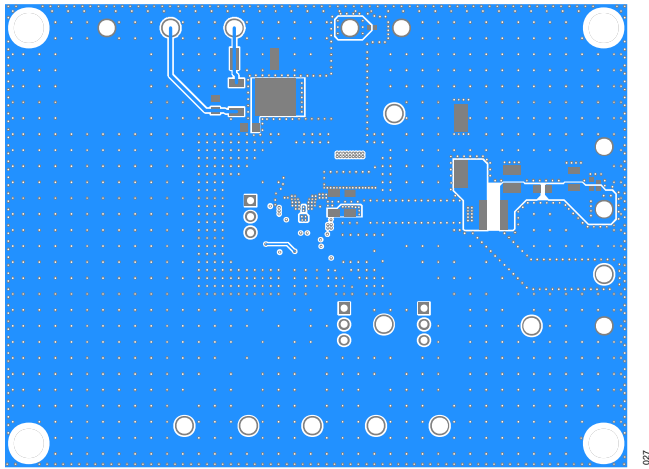


Figure 27. LT80602EVKITA# PCB Layout—Bottom View

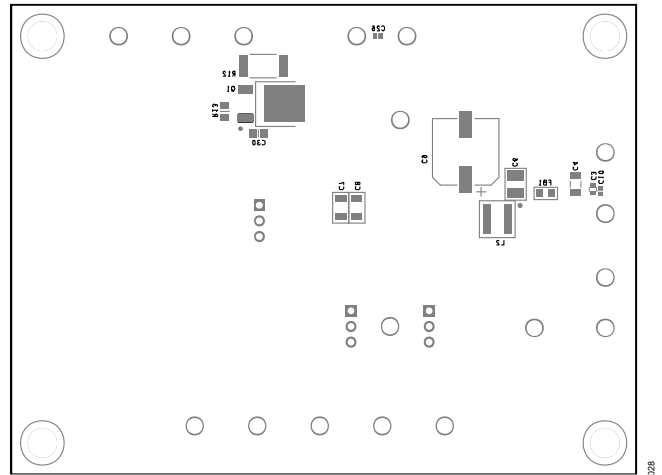


Figure 28. LT80602EVKITA# Component Placement Guide—Bottom Silkscreen

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	8/26	Initial release	—

Notes

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