ADP1071-2EBZ3.3V User Guide

UG-1117

One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A. • Tel: 781.329.4700 • Fax: 781.461.3113 • www.analog.com

Evaluating the ADP1071-2 Isolated Synchronous Flyback Controller

FEATURES

Full support evaluation kit for the ADP1071-2
10 W flyback topology
3.3 V output voltage (Vdc)
3 A steady state
Auxiliary output of 8.0 Vdc, 10 mA
Forced CCM operation
Integrated drivers primary side MOSFET and secondary side synchronous rectifier
External reference signal tracking
Precision enable undervoltage lockout with hysteresis
Short-circuit, output overvoltage, and overtemperature protection
Cycle by cycle input overcurrent protection
Frequency synchronization
Soft start and soft stop functionality

EVALUATION KIT CONTENTS

ADP1071-2EBZ3.3V

ADDITIONAL EQUIPMENT

DC power supply capable of 36 Vdc to 60 Vdc, 20 W
Electronic load capable of 3.3 V, 5 A input
Oscilloscope capable of 500 MHz bandwidth or above, 2 channels to 4 channels
Precision digital multimeters (Agilent 34401A multimeter or equivalent)

GENERAL DESCRIPTION

The ADP1071-2EBZ3.3V evaluation board allows users to evaluate the ADP1071-2 in a power supply application.

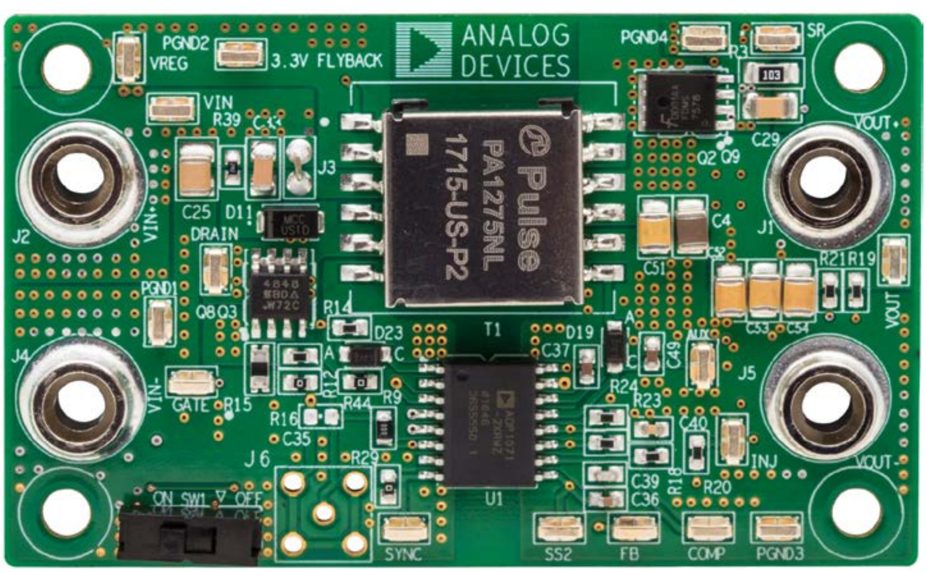
The ADP1071-2EBZ3.3V evaluation board is set up to act as an isolated power supply unit (PSU), with a rated load of 3.3 Vdc 3 A from a 36 Vdc to 60 Vdc source. There is also an auxiliary output of 8.0 Vdc, 10 mA. The operation of the converter is in continuous conduction mode (CCM).

All connectors and multiple test points allow easy access to all critical circuit nodes and pins of the ADP1071-2.

Multiple test points allow easy access to all critical circuit nodes and pins of the ADP1071-2.

Full data on the ADP1071-2 can be found in the ADP1071-2 data sheet, available from Analog Devices, Inc., which must be consulted in conjunction with this user guide when using the evaluation board.

EVALUATION BOARD PHOTOGRAPH



15651-001

Figure 1.

TABLE OF CONTENTS

REVISION HISTORY

10/2018—Revision 0: Initial Version

EVALUATION BOARD OVERVIEW

The ADP1071-2EBZ3.3V evaluation board features the ADP1071-2 in a dc-to-dc switching power supply in flyback topology with synchronous rectification operating at a 200 kHz switching frequency.

Figure 2 shows the block diagram of the evaluation board. The dimensions of the evaluation board are 75 mm × 45 mm × 20 mm. The circuit is designed to provide a rated load of 3.3 Vdc, 3 A from a dc input voltage source of 36 Vdc to 60 Vdc. The ADP1071-2 operates in CCM and provides features including precision enabled undervoltage lockout (UVLO) regulation, synchronization, prebias start up, frequency synchronization, and comprehensive protection functions.

POWER TRAIN OVERVIEW

The evaluation board is shown in Figure 1. The circuit components are as follows:

- The input filter consists of a capacitor bank including C25, C26, and C28.
- Q3 is an N-channel metal-oxide semiconductor field effect transistor (MOSFET), used as the main switch on the primary side.
- The primary current is sensed using a current sensing resistor, R15.
- Transformer, T1, provides the isolation.
- The secondary side has a N-channel MOSFET, Q2, as the synchronous rectifier (SR).
- The output filter consists of a capacitor bank (C4, C20 to C22, C51 to C54). The components listed previously are the main power stage.

Refer to the Evaluation Board Schematic and Artwork section for the complete schematic.

Additional circuitry around the power train are as follows:

- The resistor capacitor diode (RCD) snubber for main switch is made up of R39, C33, and D11.
- The RCD snubber for SR is made up of R3, C29, and D21.
- Component U1 is the isolated synchronous flyback controller. The ADP1071-2 provides gate drive for driving the primary switch and synchronous rectifier based on the Analog Devices *i*Coupler® technology.
- During start up, U1 is powered by the J2 and J4 input dc source via an external start-up circuit (Q7, R17, D5, and C38). When switching starts, the transformer T1 has two auxiliary windings that provide power to the V_{REG1} and V_{DD2} pins.

APPLICATIONS

High efficiency, high power density, and isolated dc-to-dc power supplies include the following:

- Intermediate bus converters, bricks
- Paralleled power supply systems
- Power over Ethernet (PoE)
- Server, storage, industrial, and networking infrastructure

CONNECTORS

The connections to the ADP1071-2EBZ3.3V evaluation board are shown in Table 1.

Table 1. Evaluation Board Connections

Connector	Function
J2	VIN+, dc input
J4	VIN−, ground return for dc input
J1	VOUT+, dc return
J5	VOUT−, return for dc output

CAUTION

The ADP1071-2EBZ3.3V evaluation board uses high voltages. Extreme caution must be taken, especially on the primary side, to ensure safety. It is strongly advised to switch off the evaluation board when not in use. Use a current limited, isolated dc source at the input.

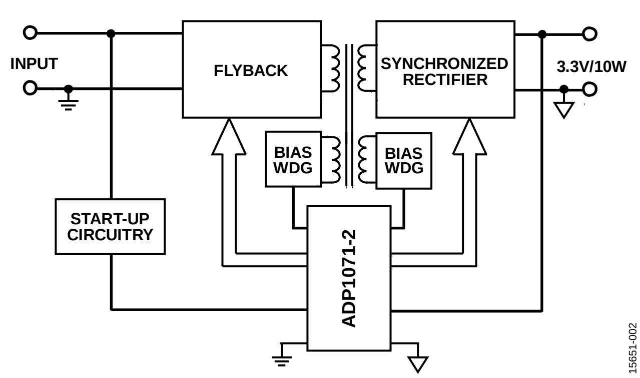


Figure 2. ADP1071-2EBZ3.3V Evaluation Board Block Diagram

EVALUATION BOARD HARDWARE

EVALUATION BOARD CONFIGURATIONS

The ADP1071-2EBZ3.3V evaluation board is shipped preconfigured with the default settings to operate the power supply at the rated load. No additional configuration is necessary other than to turn on the hardware PSON switch that is described in the Powering Up section. J3 must be replaced with a wire to monitor the primary current.

POWERING UP

1. To power up the evaluation board, connect a dc source at 48 V at the input terminals and an electronic load at the output terminals.
2. Connect voltmeters on the input terminals and output terminals as needed.
3. Connect the voltage probes at different test pins. Ensure that the differential probes are used and that the ground of the probes are isolated if the measurements are made on the primary and secondary sides of the transformer (T1) simultaneously.
4. Set the electronic load to 3 A.
5. Turn the PSON switch (SW1) to the on position.

The evaluation board is up and running, and ready for evaluation. The output must read 3.3 Vdc.

EVALUATING THE ADP1071-2EBZ3.3V

This user guide describes the operation of the ADP1071-2 and the ADP1071-2EBZ3.3V evaluation board and describes the functions available with the ADP1071-2. Several test points on the evaluation board allow easy monitoring of the various signals. The following sections provide a description of the typical features and results achieved when evaluating this device.

GATE AND SR

The gate signals, GATE and SR, are generated by isolated gate drivers within ADP1071-2. The logic high level is V_{REG1} for GATE, and V_{REG2} for SR, and both logic low levels are 0. An example of GATE and SR waveforms is shown in Figure 3. All the signals in Figure 3 represent the signals at the output pins of the integrated circuit (IC).

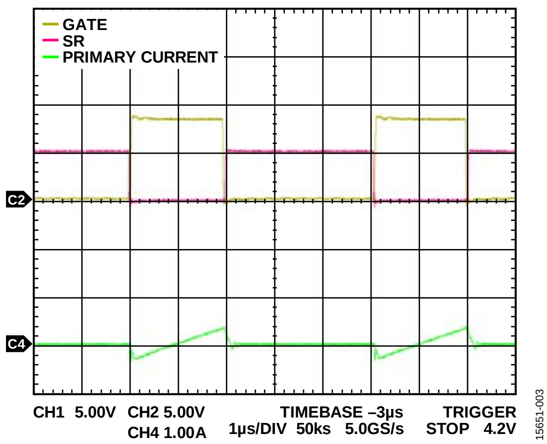


Figure 3. GATE and SR Example at 48 Vdc Input and No Load

Deadtime

The deadtime between GATE and SR signals is measured at 48 Vdc input and no load. All the signals in Figure 4 represent the signals at the output pins of the IC. Figure 5 shows an example of the pulse width modulation (PWM) deadtime at the specified line and load condition.

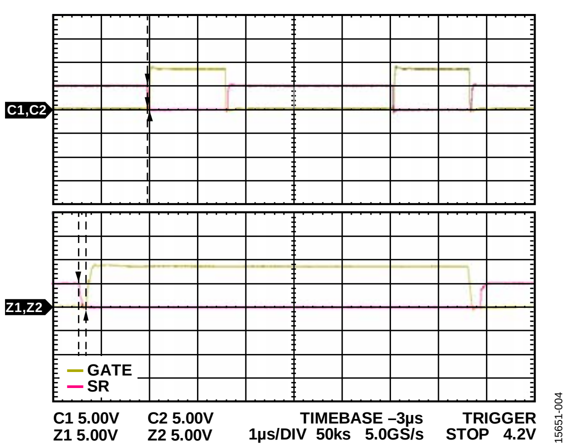


Figure 4. Deadtime Example at 48 Vdc Input and No Load

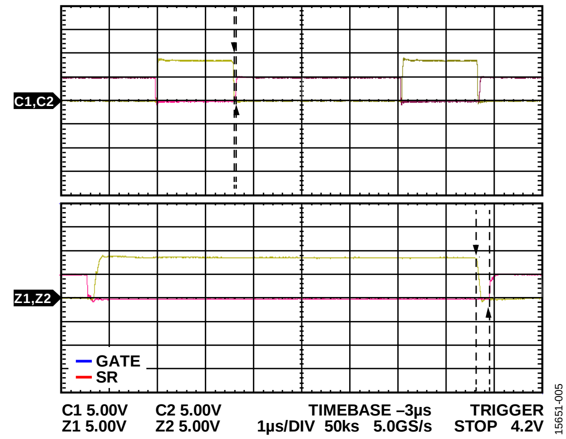


Figure 5. Deadtime Example at 48 Vdc Input and No Load

Frequency Synchronization

The internal oscillator frequency can be programmed by R27. The ADP1071-2EBZ3.3V evaluation board includes a 120 kΩ resistor, corresponding to a 200 kHz switching frequency. The oscillator can also synchronize to an external signal. To synchronize to an external signal, remove R29 and connect a function generator output to the SYNC test point. Be aware that the loop may become instable if the external frequency is set too high. Refer to the ADP1071-2 data sheet for more information.

PWM Jitter

Figure 6 shows the falling edge of the GATE PWM signal at full load.

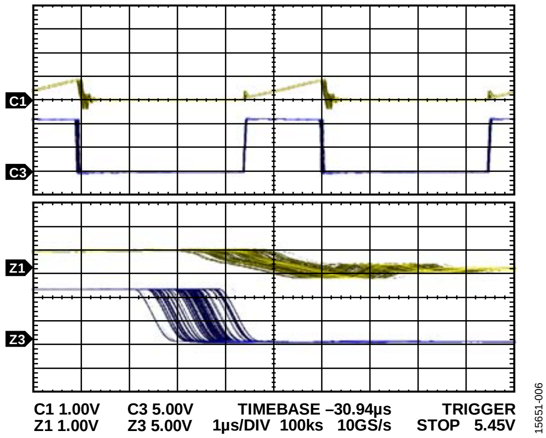


Figure 6. GATE Falling Edge Jitter at 48 Vdc Input and 3 A Load

SOFT START

When the voltage at EN pin exceeds the enable threshold of 1.2 V, the ADP1071-2EBZ3.3V evaluation board enters a two stage soft start sequence allowing the output voltage to ramp up smoothly. Refer to the ADP1071-2 data sheet for more information. Figure 7 and Figure 8 show the soft start performance of the converter at no load and full load, respectively.

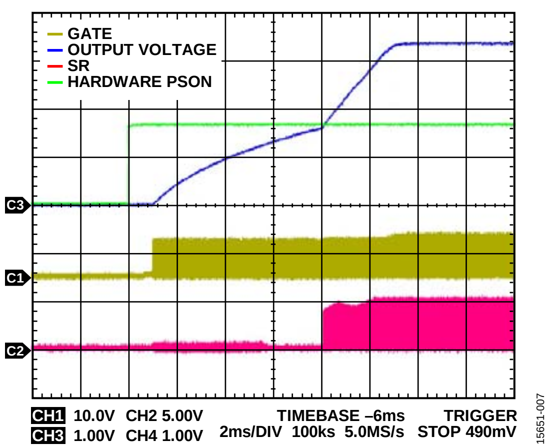


Figure 7. Soft Start at 48 Vdc Input, No Load

When soft starting into a precharged output, the SS2 pin tracks the FB pin and performs a soft start from precharged condition. The SR gate also has a soft start feature that prevents reverse current. This soft start scheme prevents the output from being discharged and prevents reverse current through the SR MOSFETs during soft start.

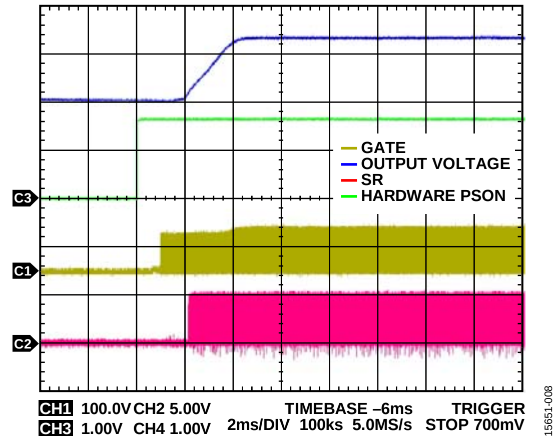


Figure 8. Soft Start from Precharge

SOFT STOP

When the voltage at EN drops below the EN threshold, the secondary drivers shut off immediately while the primary GATE pulse width gradually decreases to the minimum pulse width while the output drops. This soft stop feature prevents any reverse current when the controller shuts down. Figure 9 shows the soft stop performance from full load condition.

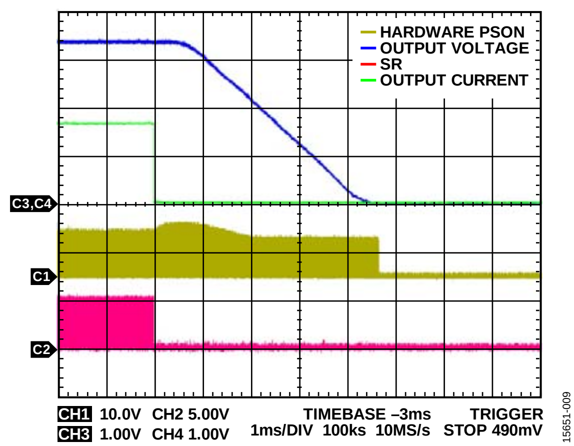


Figure 9. Soft Stop at 48 Vdc Input, 3 A Load

OUTPUT RIPPLE

Output ripple can be measured across C54. The loop area formed by the probe and its grounding must be minimized to achieve clean waveforms. Figure 10 and Figure 11 show the output voltage ripple at no load and full load, respectively.

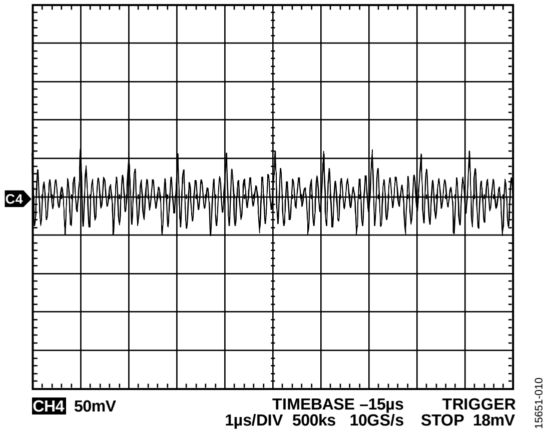


Figure 10. Output Ripple at 48 Vdc Input, No Load

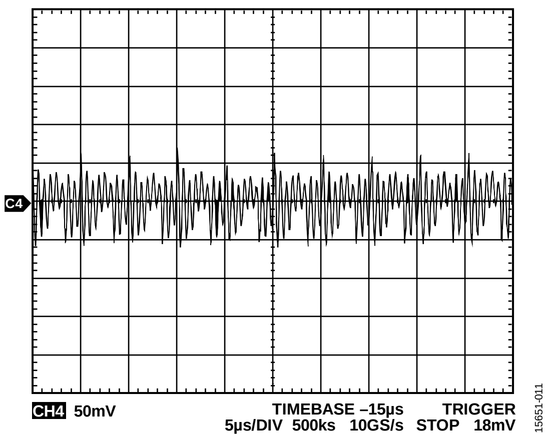


Figure 11. Output Ripple at 48 Vdc Input, 3 A load

CONTROL LOOP

On the secondary side, the output voltage information is sensed by a voltage divider and sent to the FB pin. The FB pin voltage is compared to a 1.2 V reference signal, and the error determines the COMP voltage. The COMP voltage information is sent to the primary side via Analog Devices *i*Coupler technology, allowing closed loop operation.

The loop gain, shown in Figure 12, can be measured via a network analyzer. The small signal perturbation must be injected between the INJ and VOUT+ test points. The measurement probes of the network analyzer must be connected between INJ to AGND2 and VOUT+ to ground.

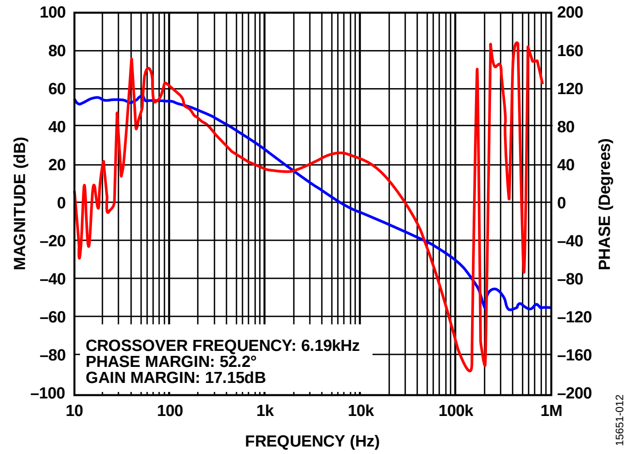


Figure 12. Loop Gain Measurement

Transient Response for Load Step

A dynamic electronic load can connect to the output of the ADP1071-2EBZ3.3V evaluation board to evaluate the transient response. Set up an oscilloscope to capture the transient waveform of the power supply output. Figure 13 shows an example of the load transient response. The user can modify the RC network on the COMP pin to change the transient response.

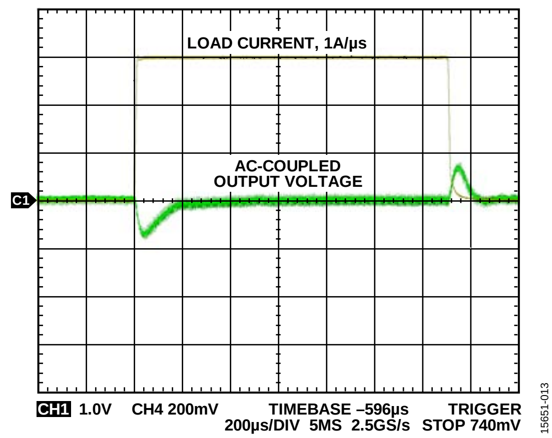


Figure 13. Transient Response with Load Steps: 0% to 100%

EXTERNAL SIGNAL TRACKING

The output voltage can track external signal applied to the SS2 pin. The applied peak value must be lower than 1.2 Vdc. A 5 kHz, 200 mV peak-to-peak sinusoidal signal with 1.1 Vdc offset is applied to the SS2 pin, shown in Figure 14.

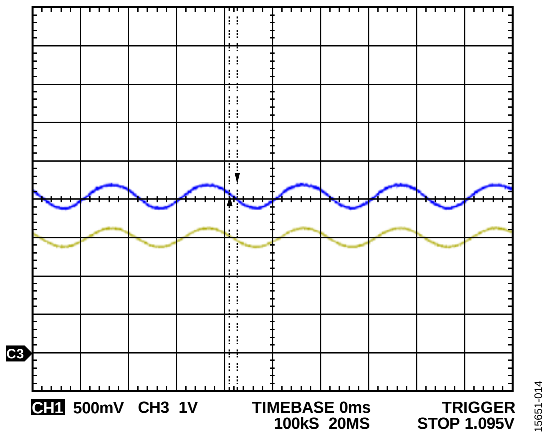


Figure 14. External Signal Tracking

OVERCURRENT PROTECTION

The primary peak current is sensed by the cycle by cycle current sensing resistor, R15. When the sensed input peak current is above the CS pin threshold, the controller operates in cycle by cycle constant current limit mode for 5 ms. After that, the controller immediately shuts down the primary drivers and discharges the SS2 pin. The controller then enters shutdown mode for the next 40 ms and restarts the soft start sequence. Figure 15 and Figure 16 show these protection features.

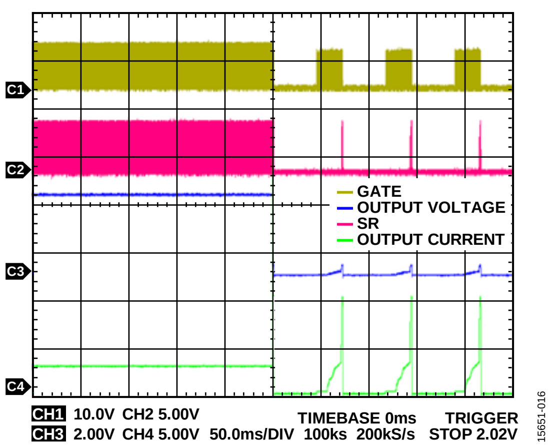


Figure 15. OCP Under Output Short Circuit at 48 Vdc and 3 A Load

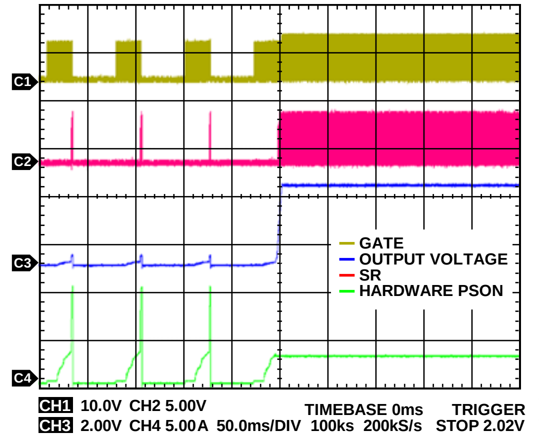


Figure 16. Recovery from Output Short Circuit at 48 Vdc and 3 A Load

VOLTAGE AND CURRENT STRESS

The drain to source voltage of both the main switch and the synchronous rectifiers are clamped by the RCD snubber on the ADP1071-2EBZ3.3V evaluation board. The peak drain to source voltage occurs at maximum input voltage and full load. Figure 17 shows that the peak drain to source voltages of the main switch and synchronous rectifier are 108.5 V and 19.1 V, respectively.

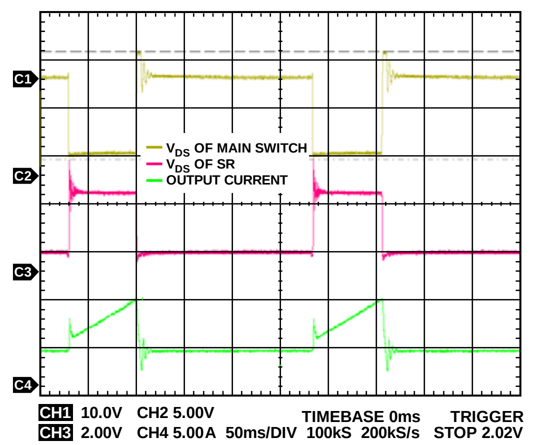


Figure 17. MOSFET Drain to Source Voltages at 60 Vdc Input and 3 A Load

Peak current stress occurs at minimum input voltage and full load, for example, 36 Vdc input and 3 A load. Figure 18 shows that the peak current is at 1.16 A for the primary side. The root mean square (RMS) value of the primary current under such condition is approximately 520 mA.

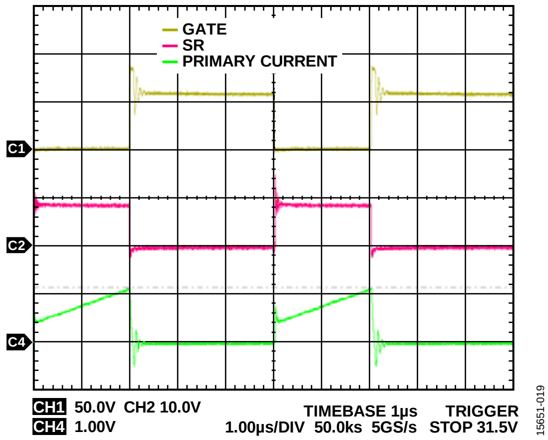


Figure 18. Peak Primary Current at 36 Vdc Input and 3 A Load

EFFICIENCY CURVES

Figure 19 and Figure 20 show the typical efficiency across load and line, respectively. Figure 21 shows the typical load regulation.

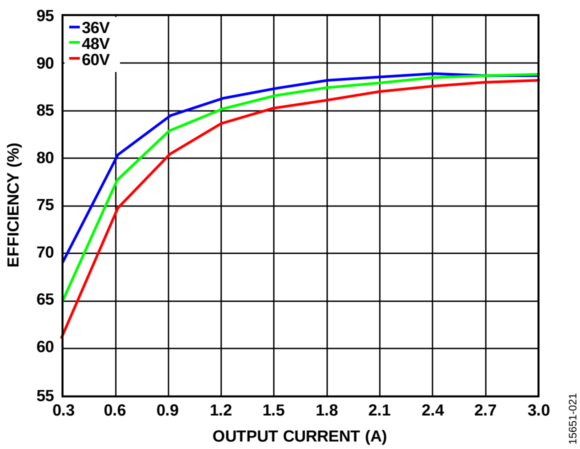


Figure 19. Efficiency Curves at 36 Vdc, 48 Vdc, 60 Vdc Input

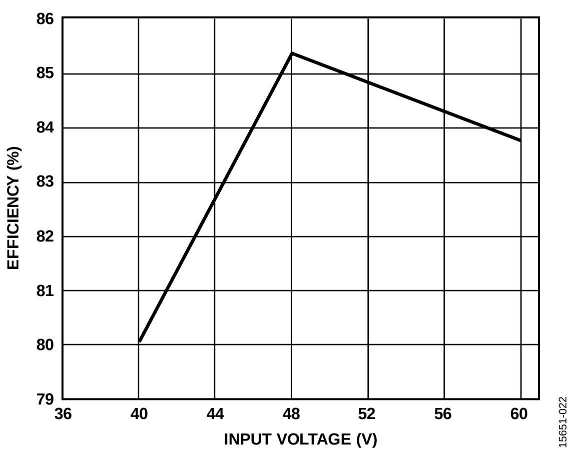


Figure 20. Efficiency vs. Input Voltage

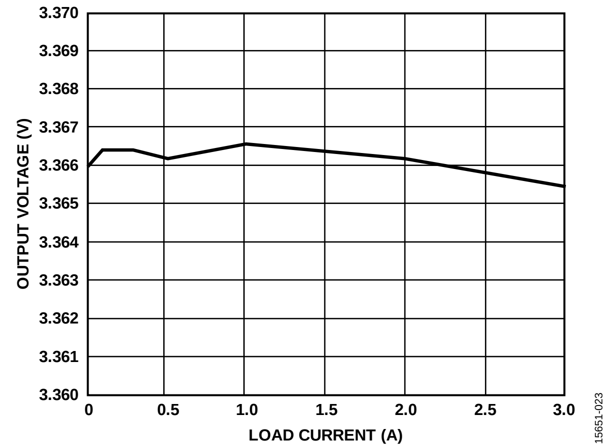


Figure 21. Load Regulation

Table 2. Cross Regulation

3.3 V Load (A)	3.3 V Output (V)	Auxiliary Output (V)
0	3.39	6.86
0.1	3.366	6.79
0.2	3.366	6.72
0.5	3.364	6.64
1	3.362	6.66
2	3.35	7.5
3	3.35	8.41

THERMAL PERFORMANCE

Figure 22 shows the thermal performance of the evaluation board at different operating conditions.

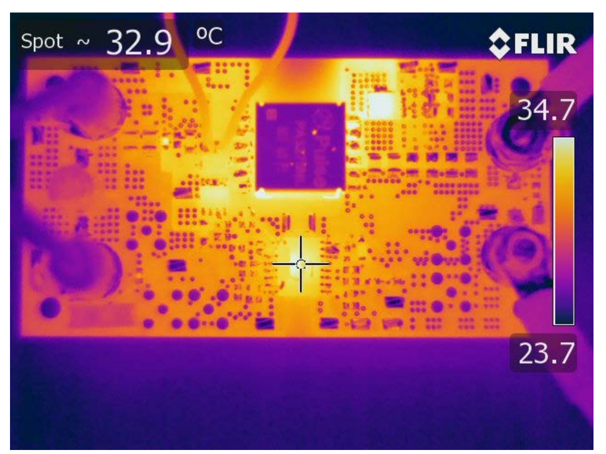


Figure 22. Thermal Image at 48 Vdc Input, 3 A Load, No Airflow, 0.5 Hour Soaking Time

EVALUATION BOARD SCHEMATIC AND ARTWORK

ADP1071-2EBZ3.3V SCHEMATIC

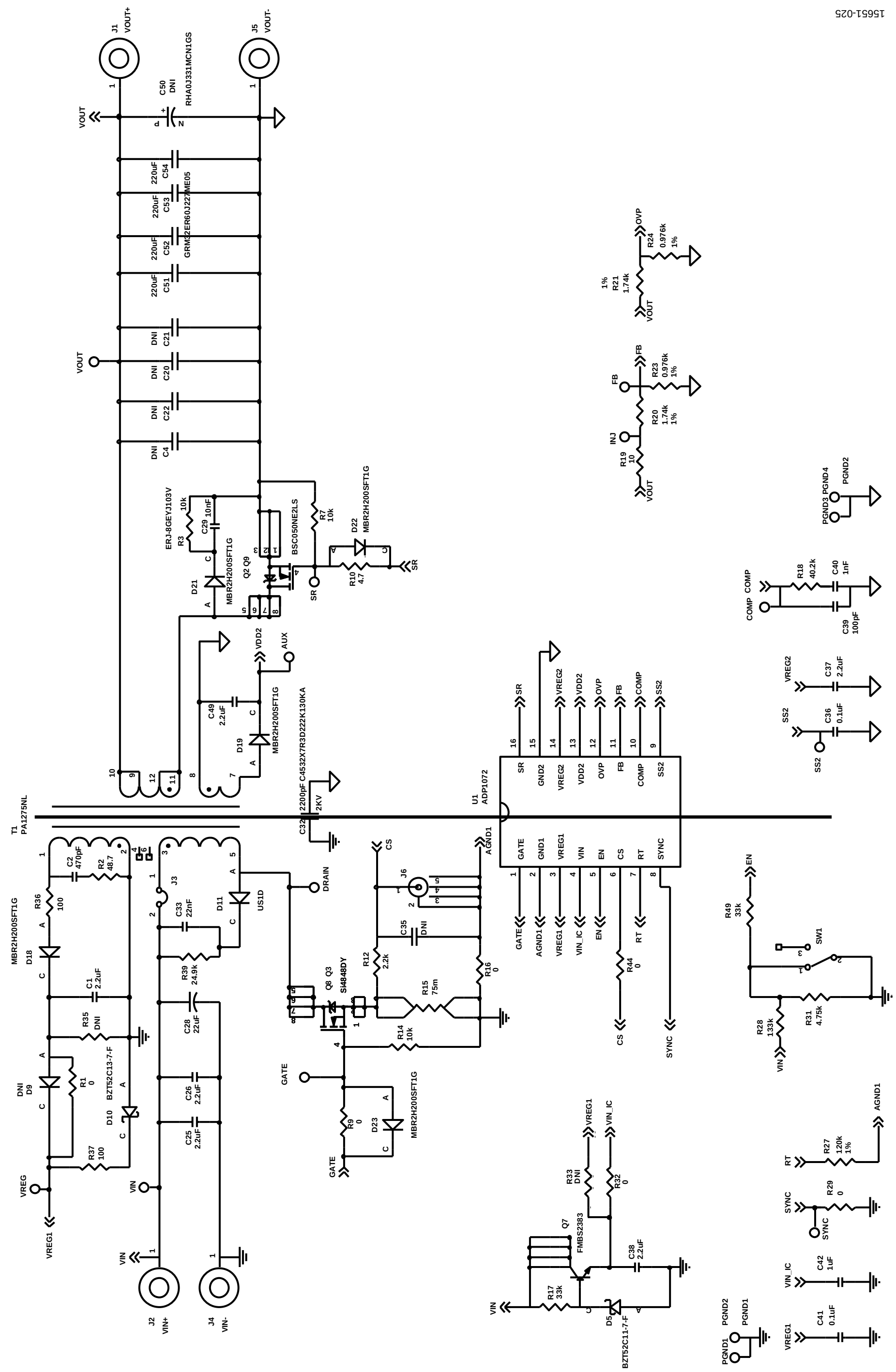


Figure 23. ADP1071-2EBZ3.3V Evaluation Board Schematic

ADP1071-2EBZ3.3V LAYOUT

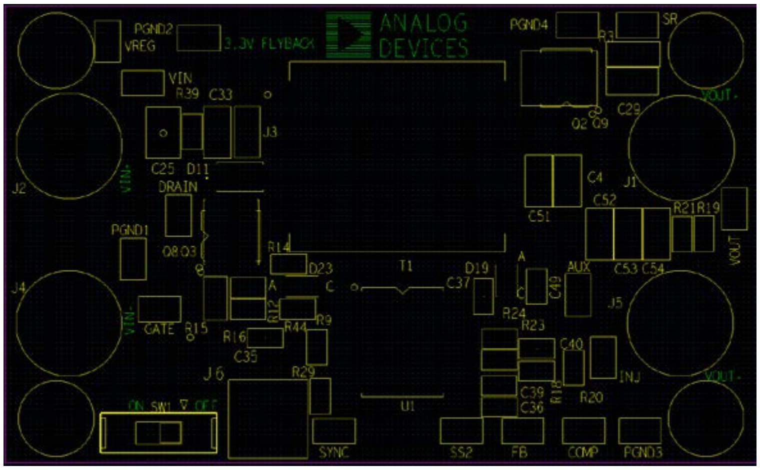


Figure 24. Silkscreen Top Layer

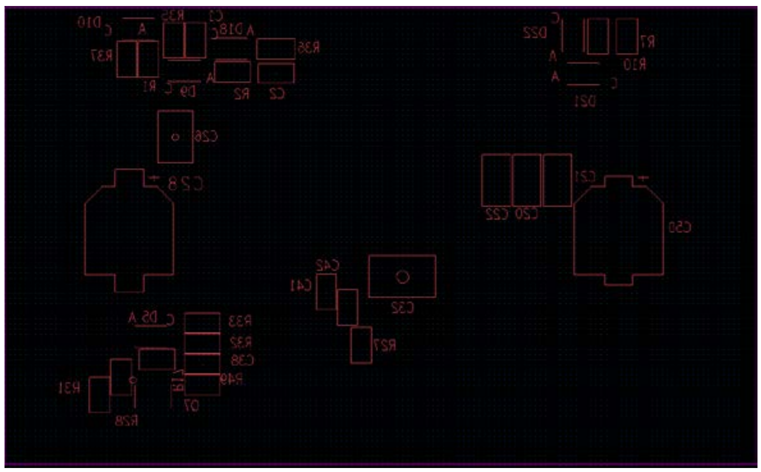


Figure 25. Silkscreen Bottom Layer

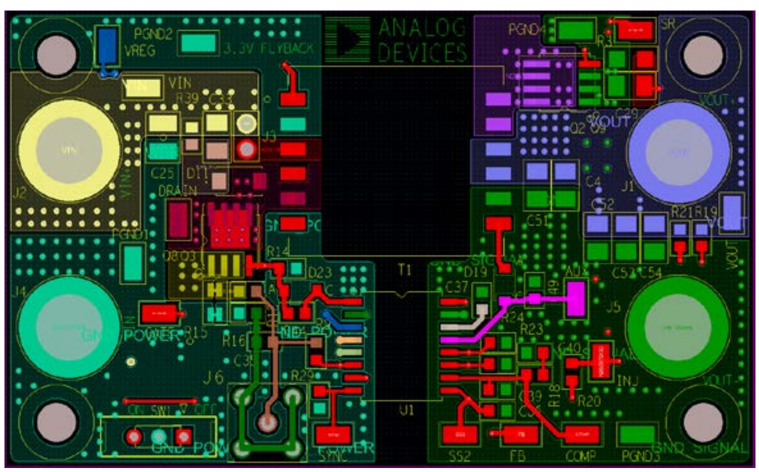
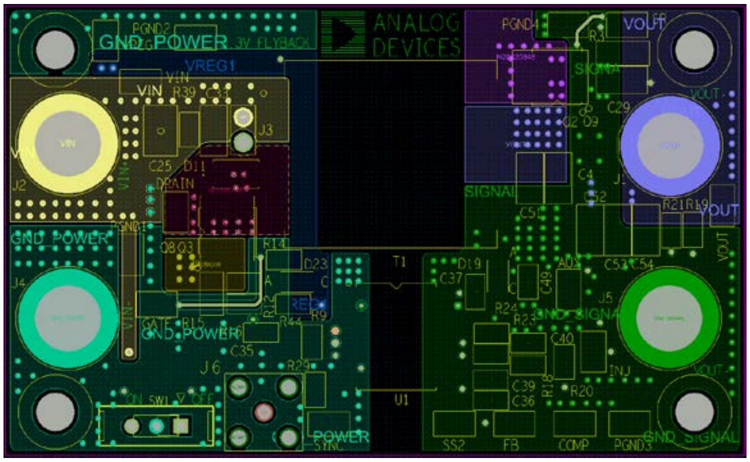
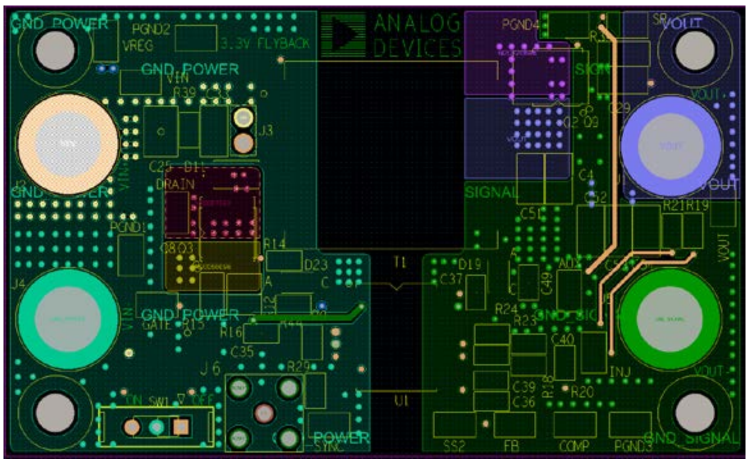


Figure 26. Printed Circuit Board (PCB) Layout, Top Layer



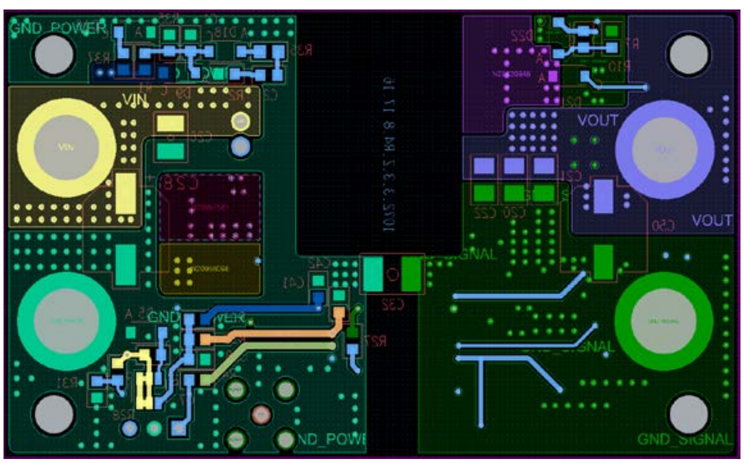
15651-029

Figure 27. PCB Layout, Layer 2



15651-030

Figure 28. PCB Layout, Layer 3



15651-031

Figure 29. PCB Layout, Layer 4

BILL OF MATERIALS

Table 3. ADP1071-2EBZ3.3V Evaluation Board Components List

Reference Designator	Value	Description	Manufacturer	Part Number
C1	2.2 µF	Capacitor, ceramic, 2.2 µF, 25 V, X5R, 0603	Murata	GRM188R61E225ME84D
C2	470 pF	Capacitor, ceramic, 470 pF 50 V, X7R, 0603	Kemet	C0603C471K5RACTU
C4, C22	22 µF	Capacitors, ceramic, 22 µF, 6.3 V, X7R, 1210	TDK	C1210C226K9RACTU
C20, C21	Do not install	Capacitors, ceramic, 22 µF, 6.3 V, X7R, 1210	TDK	C1210C226K9RACTU
C50	Do not install	Capacitor, polymer, aluminum, 330 µF, 6.3 V	Nichicon	RHA0J331MCN1GS
C51 to C54	220 µF	Capacitors, ceramic, 220 µF, 6.3 V, X5R, 1210	Murata	GRM32ER60J227ME05
C25, C26	2.2 µF	Capacitors, ceramic, 2.2 µF, 100 V, X7R, 0603	AVX	12101C225KAT2A
C28	22 µF	Capacitor, aluminum, 22 µF, 20%, 100 V, SMD	Panasonic	EEE-FK2A220P
C29	10 nF	Capacitor, ceramic, 10000 pF, 200 V, X7R, 1206	AVX	12062C103KAT2A
C33	22 nF	Capacitor, ceramic, 0.022 µF, 250 V, X7R, 1206	TDK	C3216X7R2E223K115AA
C32	2200 pF	Capacitor, ceramic, 2200 pF, 2 KV, X7R, 1812	Vishay	C4532X7R3D222K130KA
C35	Do not install	Capacitor, ceramic, 100 pF, 50 V, X7R, 0603	Kemet	C0603C101K5RACTU
C39	100 pF	Capacitor, ceramic, 100 pF, 50 V, X7R, 0603	Kemet	C0603C101K5RACTU
C36, C41	0.1 µF	Capacitors, ceramic, 0.1 µF, 25 V, X7R, 0603	Murata	GRM188R71E104KA01D
C37, C38, C49	2.2 µF	Capacitors, ceramic, 2.2 µF, 25 V, X5R, 0603	Murata	GRT188R61H225KE13D
C40	2 nF	Capacitor, ceramic, 2000 pF, 10 V, X7R, 0603	AVX	0603ZC202JAT2A
C42	1 µF	Capacitor, ceramic, 1 µF, 50V, X7R, 0603	Taiyo Yuden	UMK107AB7105KA-T
D5	Zener diode	Zener diode, 11 V, 500 MW, SOD123	Diodes Inc.	BZT52C11-7-F
D18, D19, D21 to D23	Schottky diode	Schottky diodes, 200 V, 2 A, SOD123FL	ON Semi	MBR2H200SFT1G
D10	Zener diode	Zener diode, 13 V, 500 MW, SOD123	Diode Inc	BZT52C13-7-F
D11	Ultra fast diode general	Diode general purpose 200 V, 1 A, DO214AC	Micro Comm	US1D
J1	VOUT+	Banana jack connector, standard banana threaded, external nut	Emerson	108-0740-001
J2	VIN+	Banana jack connector, standard banana threaded, external (nut)	Emerson	108-0740-001
J3	Jumper	Do not insert (DNI), jumper		
J4	VIN–	Banana jack connector, standard banana threaded, external (nut)	Emerson	108-0740-001
J5	VOUT–	Banana jack connector, standard banana threaded, external (nut)	Emerson	108-0740-001
J6	Do not install	SMB connector jack, male pin, 50 Ω through hole solder	Emerson	131-3701-261
Q3	MOSFET N-CH	MOSFET N-channel, 150 V, 2.7 A	Vishay	SI4848DY
Q2	MOSFET N-CH	MOSFET N-channel, 25 V, 39 A	Infineon	BSC050NE2LS
Q7	Transistor NPN	Transistor, NPN, 160 V 0.8 A, 6-lead SSOT	Fairchild	FMBS2383
R2	48.7 Ω	Resistor, SMD, 48.7 Ω, 1%, 1/10 W, 0603	Panasonic	ERJ-3EKF48R7V
R3	10 kΩ	Resistor, SMD,10 kΩ 5% 1/4 W 1206	Panasonic	ERJ-8GEYJ103V
R7, R14	10 kΩ	Resistors, SMD, 10 kΩ 1% 1/10 W 0603	Panasonic	ERJ-3EKF1002V
R1, R9, R16, R29, R32, R44	0 Ω	Resistors, SMD, 0.0 Ω Jumper 1/10 W 0603	Panasonic	ERJ-3GEY0R00V
R10	4.7 Ω	Resistor, SMD, 4.7 Ω, 5%, 1/10 W, 0603	Panasonic	ERJ-3GEYJ4R7V
R12	2.2 kΩ	Resistor, SMD, 2.2 kΩ, 1% 1/10 W, 0603	Panasonic	ERJ-3EKF2201V
R15	75 mΩ	Resistor, SMD, 0.075 Ω, 1%, 1 W, 1206	Panasonic	ERJ-8BWFR075V
R17, R49	33 kΩ	Resistors, SMD, 33 kΩ, 1%, 1/10 W, 0603	Panasonic	ERJ-3EKF3302V
R18	40.2 kΩ	Resistor, SMD, 40.2 kΩ, 1%, 1/10 W, 0603	Panasonic	ERJ-3EKF4022V
R19	10 Ω	Resistor, SMD, 10 Ω, 1%, 1/10 W, 0603	Panasonic	ERJ-3EKF10R0V
R20, R21	1.74 kΩ	Resistors, SMD, 1.74 kΩ, 1%, 1/10 W, 0603	Panasonic	ERJ-3EKF1741V
R23, R24	0.976 Ω	Resistors, SMD, 976 Ω 1% 1/10 W 0603	Panasonic	ERJ-3EKF9760V

Reference Designator	Value	Description	Manufacturer	Part Number
R27	120 kΩ	Resistor, SMD, 120 kΩ 1% 1/10 W 0603	Panasonic	ERJ-3EKF1203V
R28	133 kΩ, 1%	Resistor, SMD, 133 kΩ 1% 1/10 W 0603	Panasonic	ERJ-3EKF1333V
R39	24.9 kΩ	Resistor, SMD, 24.9 kΩ, 1%,1/4 W, 1206	Panasonic	ERJ-8ENF2492V
R31	4.75 kΩ	Resistor, SMD, 4.75 kΩ, 1%, 1/10 W, 0603	Panasonic	ERJ-3EKF4751V
R22, R33, R35, R45	Do not install	Resistors, SMD, 0.0 Ω, jumper 1/10 W, 0603	Panasonic	ERJ-3GEY0R00V
D9	Do not install	Schottky diode, 200 V, 2 A, SOD123FL	On semi	MBR2H200SFT1G
R36, R37	100 Ω	Resistors, SMD, 100 Ω, 1%, 1/4 W, 0603	Panasonic	ERJ-PA3F1000V
SW1	SW-SPDT	Switch slide SPDT, 200 mA, 30 V	E-Switch	EG1218
T1	PA1275NL	High frequency wire wound transformer	Pulse	PA1275NL
SS2, VIN, INJ, VOUT, PGND1, PGND2, SGND1, SGND2, VREG, SYNC, SR, FB, COMP, GATE, DRAIN, AUX	Test points	PC test points, mini, SMD	Keystone	5019
U1	ADP1072-2	Isolated synchronous flyback controller	Analog Devices	ADP1072-2

UG15651-0-10/18(0)

ANALOG DEVICES

www.analog.com