High Frequency Step-Down Controller with 40V GaN FETs

General Description

The evaluation circuit EVAL-LTC7891-BZ features the LTC®7891, which is a 100V capable step-down synchronous gallium nitride (GaN) field effect transistor (FET) controller. In this application, the IC is optimized with 40V GaN FETs to operate within the 15V–36V input range at 800kHz. The LTC7891 is specifically designed to drive GaN FETs safely and easily through internally optimized bootstrap switches and smart dead time control. Split gate drivers allow FETs to be turned on or off easily. Additionally, the IC features low I_Q, up to 3MHz programmable/synchronizable switching frequency, spread spectrum, and a small 28-lead (4mm x 5mm) side wettable QFN package. These features promote a wide variety of applications, including industrial, military, medical, and telecommunications systems.

The EVAL-LTC7891-BZ operates from a 15V–36V input range and generates a maximum 12V, 25A output. The LTC7891 has a precision voltage reference that can generate an output voltage with 2% tolerance over the full operating conditions. The EVAL-LTC7891-BZ is set to 800kHz switching frequency, resulting in a small and efficient circuit. The converter achieves over 97% efficiency with 25A load at full operating V_{IN}, with a peak efficiency near 99%.

This board can be easily modified to regulate output voltages from 0.8V to 15V. Various FETs of a similar footprint can be used to fit an array of applications. An alternate molded core inductor footprint can be utilized for lower-profile designs. For higher input voltage applications, refer to the EVAL-LTC7891-AZ version designed for wider input and output voltage ranges at a lower switching frequency.

The EVAL-LTC7891-BZ provides a high-performance, cost-effective solution for generating a 12V output. The LTC7891 data sheet gives a complete description of the part, its operation, and application information. Use the data sheet in conjunction with this user guide.

Design files for this circuit board are available at *www.analog.com*.

Performance Summary (T_A = 25°C)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range		15		36	V
Output Current Range	V_{IN} = 15V to 32V, heatsink			25	A
	V_{IN} = 36V, heatsink*			23.5	A
	V_{IN} = 15V to 25V, no heatsink, maximum FET temperature < 100°C			25	A
	V_{IN} = 36V, no heatsink, maximum FET temperature < 100°C*			20	A
Output Voltage	V_{IN} = 15V to 36V	11.76	12	12.24	V
Output Voltage Ripple (Peak-to-Peak)	V_{IN} = 24V, I_{OUT} = 25A			100	mV_{P-P}
Run Rising Threshold			14.9		V
Run Falling Threshold			13.6		V
Switching Frequency	JP2 = Disable SS (Spread spectrum frequency modulation (SSFM) off)		800		kHz
	JP2 = Enable SS (SSFM on)	700		900	kHz
Typical Efficiency	V_{IN} = 15V, I_{OUT} = 25A		98.4		%
	V_{IN} = 24V, I_{OUT} = 25A		97.8		%
	V_{IN} = 36V, I_{OUT} = 25A**		97.2		%

**See the Performance section for thermal limit curves.*

***Thermal limits are maintained with airflow.*

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Quick Start Procedure

The evaluation circuit EVAL-LTC7891-BZ is easy to set up to evaluate the performance of the LTC7891. For a proper measurement equipment setup, see *Figure 1* and use the following procedure.

1. Set the input power supply to a voltage between 15V and 36V. Disable the power supply.
   Note: Make sure that the input voltage V_{IN} does not exceed 36V.
2. Connect the positive terminal of the power supply to V_{IN} and the negative terminal to GND.
3. Connect the load (< 25A) between V_{OUT} and GND.
4. Verify that the RUN switch (SW1) is set to the ON position.
5. Turn the input power supply on and adjust the input voltage to 24V.
6. Verify that the output voltage is 12V on the DMM connected to V_{OUT}. If there is no output, temporarily disconnect the load to make sure that the load is not set too high.
7. Once the proper output voltage is established, adjust the load and observe the output voltage regulation, ripple voltage, efficiency, and other parameters.

Note: When measuring the input or output voltage ripple, take precautions to minimize the length of the oscilloscope probe ground lead. Measure the input or output voltage ripple by connecting the probe tip directly across the V_{IN} or V_{OUT} and GND terminals, preferably across the input or output capacitors.

The EVAL-LTC7891-BZ is a fully assembled and tested board. The evaluation circuit is designed to deliver 12V output at a load current of up to 25A from a 15V to 36V input supply. The board is programmed at 800kHz switching frequency for optimum efficiency and component size.

Adjusting the Output Voltage

The LTC7891 supports an adjustable 0.8V to 60V output voltage range. To change the output voltage from the programmed 12V, change R18 and R19. Refer to the *Setting the Output Voltage* section in the LTC7891 data sheet to calculate the V_{FB} resistor divider values for the desired output voltage. Note that the V_{PRG} resistor R75 must be removed to use resistor programming. All the corresponding power components must also to be changed to meet the desired output voltage. Typically, the compensation components R20, C14, and C10 need to be optimized as well. The output caps have 16V ratings, so increased output voltage requires capacitors with sufficient ratings.

Setting the Switching Frequency

Selecting the switching frequency is a trade-off between efficiency and component size. For optimal performance with smaller components, an 800kHz switching frequency is chosen for 12V output in 36V applications. R37 programs the desired switching frequency. Use the FREQ and PLLIN/SPREAD pins to set the switching frequency. Refer to the *Setting the Operating Frequency* section in the LTC7891 data sheet for more details.

RUN Control (RUN, SW1)

The RUN turret of the evaluation circuit serves as an external on/off control for the controller. The EVAL-LTC7891-BZ includes a resistive voltage divider (R62 and R63) connected between the V_{IN} and GND pins to turn on the device at the required input voltage. Turn the switch (SW1) to the ON position to connect the RUN pin to the center of this resistor divider. The EVAL-LTC7891-BZ is designed to turn on the LTC7891 at approximately 15V. However, this threshold can be adjusted easily by changing R62 and R63. Turn SW1 to the off position to disable the controller. See *Table 3* to configure SW1.

TRACK and Soft-Start Input (TRACK/SS)

The LTC7891 TRACK/SS pin can be used to program an external soft-start function or to allow V_{OUT} to track another supply during startup. The adjustable soft-start function is used to limit the inrush current during startup. The soft-start time is adjusted by C17. An external supply can be connected to the TRACK/SS turret to make the startup of the V_{OUT} track an external supply. Typically, this requires connecting to the TRACK/SS turret through an external resistor divider from the external supply to GND. Refer to the *Soft-Start and Tracking* section on the LTC7891 data sheet for more details.

Mode Selection (MODE)

The EVAL-LTC7891-BZ provides a jumper (JP1) to allow the LTC7891 to operate in either forced continuous, pulse skipping, or burst modes at lighter loads. Refer to the LTC7891 data sheet for more details on the modes of operation. *Table 1* shows the mode selection JP1 settings that can be used to configure the desired mode of operation.

Spread Spectrum, Phase-Locked Loop, and External Frequency Synchronization (PLLIN/SPREAD, JP2)

The LTC7891 features a spread-spectrum mode operation to improve Electromagnetic interference (EMI). This mode varies the switching frequency within the typical boundaries of the frequency set by the FREQ pin and +20%. Spread-spectrum operation is enabled by tying the PLLIN/SPREAD pin to $INTV_{CC}$. The EVAL-LTC7891-BZ includes a jumper (JP2) to conveniently enable or disable the spread-spectrum operation. See *Table 2* to configure JP2.

The LTC7891 also features a phase-locked loop to synchronize the internal oscillator to an external clock source. The EVAL-LTC7891-BZ provides a SYNC turret to connect an external clock source to synchronize with the device switching. Keep the jumper (JP2) in the external sync position when the external clock signal is applied. Refer to the *external clock synchronization* section in the LTC7891 data sheet for more details.

Open-Drain PGOOD Output (PGOOD)

The EVAL-LTC7891-BZ provides a PGOOD turret to monitor the status of the PGOOD output. PGOOD is high when the V_{FB} voltage is within ±10% of the 0.8V reference. PGOOD is pulled low when the V_{FB} voltage is not within 0.8V ± 10% or the RUN pin is low (shutdown). The voltage on the PGOOD pin should not exceed 6V.

$EXTV_{CC}$ Linear Regulator

The $EXTV_{CC}$ pin allows the $INTV_{CC}$ power to be derived from a high-efficiency external source. On EVAL-LTC7891-BZ, the $EXTV_{CC}$ pin is connected to V_{OUT}. The $EXTV_{CC}$ turret can be used to connect an external power supply to source the $EXTV_{CC}$ LDO. When using an external power supply on the $EXTV_{CC}$ turret, make sure to disconnect the V_{OUT} connection to the $EXTV_{CC}$ pin by removing R59. Populate R61 with a 0Ω resistor.

Thermal Performance

The LTC7891 features excellent thermal performance due to the high efficiency of the synchronous step-down GaN FET controller circuitry. The component temperatures of EVAL-LTC7891-BZ with a typical 24V input and 25A load are shown in *Figure 7*. The six-layer Printed circuit board (PCB) layout features solid copper planes to provide adequate heat spreading across the whole board.

The board can operate with an input voltage of up to 36V at 25A without a heatsink or forced air under transient conditions. If the input voltage exceeds 25V for more than several seconds, the circuit requires a heatsink and/or forced air flow to keep the maximum temperature of the board under 100°C at room temperature. With a heatsink, the board can operate at 25A at steady state in still room temperature air up to 32V, or at the full V_{IN} range of 15V to 36V with forced airflow.

Heatsink

The EVAL-LTC7891-BZ features space for a heatsink to extend the power and thermal capabilities significantly. The board is designed for the Wakefield-Vette 567-45AB heatsink, which is to be used in conjunction with thermal pads and Würth Elektronik 9774010243R spacers. Solder the spacers onto P1, P2, P3, and P4 and place a thermal pad between the heatsink and the GaN FETs. Properly screw in the heatsink to extend the power capabilities of the board fully. Exercise care not to overtighten the screws to avoid mechanically damaging the FETs.

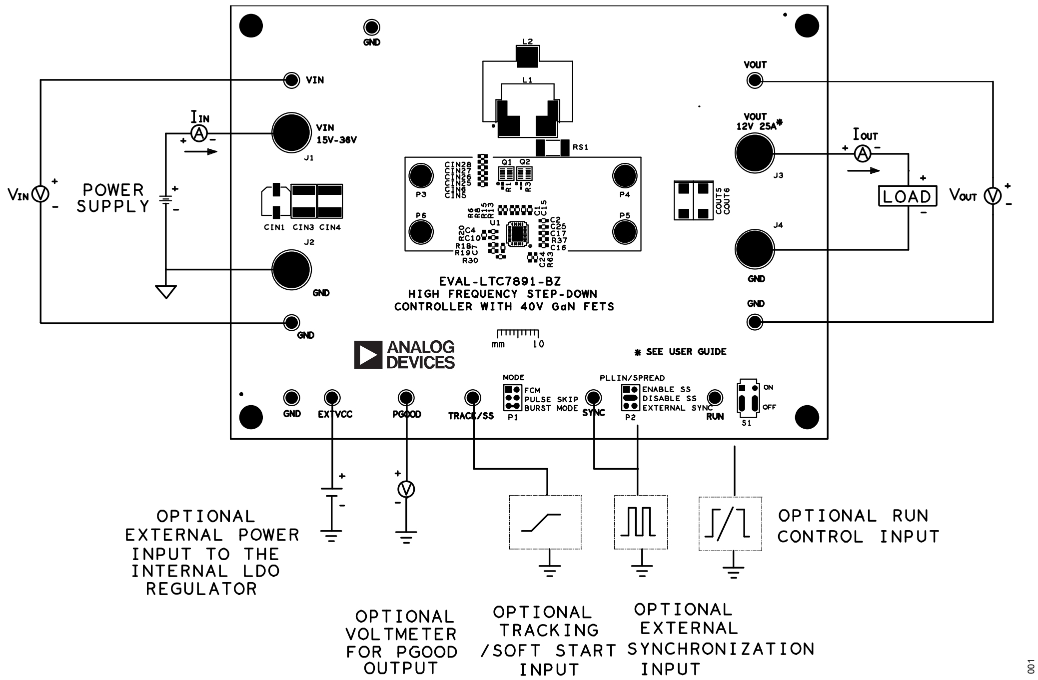


Figure 1. EVAL-LTC7891-BZ Board Connections

Table 1. MODE Selection Jumper (JP1) Settings

SHUNT POSITION	MODE PIN	MODE OF OPERATION
1-2*	Connected to $INTV_{CC}$	Forced continuous mode (FCM)
3-4	Connected to $INTV_{CC}$ with a 100kΩ resistor	Pulse skipping
5-6	Connected to GND	Burst

**Default position*

Table 2. PLLIN/SPREAD Jumper (JP2) Settings

SHUNT POSITION	PLLIN/SPREAD PIN	DESCRIPTION
1-2	Connected to $INTV_{CC}$	Enable Soft-start (SS)
3-4*	Connected to GND	Disable SS
5-6	Connected to the center node of R49 and C16	External SYNC input

**Default position*

Table 3. RUN Switch (SW1) Settings

SWITCH POSITION	RUN PIN	CONTROLLER
ON	Connected to the center node of the resistor-divider R62 and R63	Programmed to start up at the desired input voltage level
OFF*	Connected to GND	Disabled

**Default position*

Performance

(V_{IN} = 24V, V_{OUT} = 12V, I_{OUT} = 20A, f_{SW} = 800kHz, MODE = Burst Mode, T_A = +25°C, unless otherwise noted.)

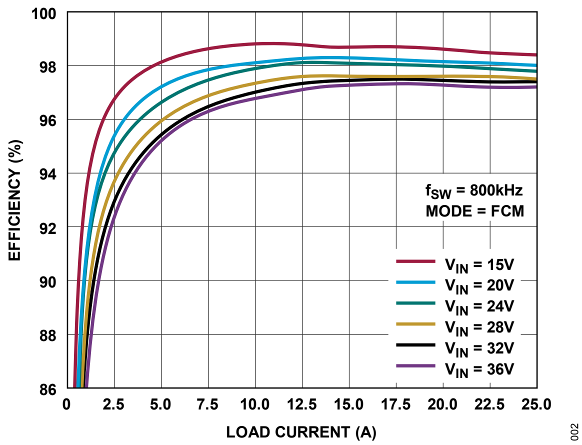


Figure 2. Efficiency vs. Load Current. At V_{IN} = 24V, EVAL LTC7891-BZ Performs with an Efficiency of over 98% with 12V Output and 25A Load.

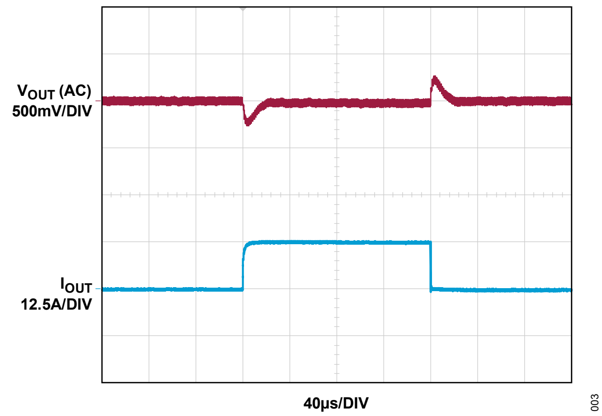


Figure 3. Load Step Response. EVAL-LTC7891-BZ has a Good Load Step Response with Small Output Capacitors.

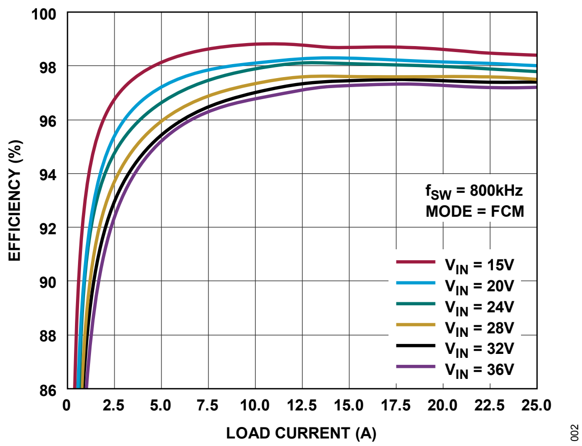


Figure 4. Efficiency and Power Loss vs. Load Current at V_{IN} = 24V. At low load, Burst Mode significantly improves Power Loss compared to FCM.

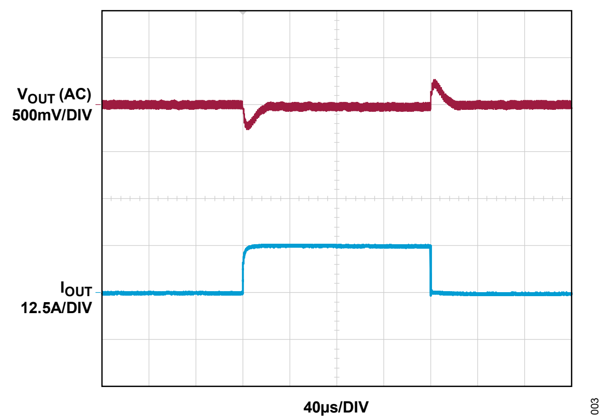
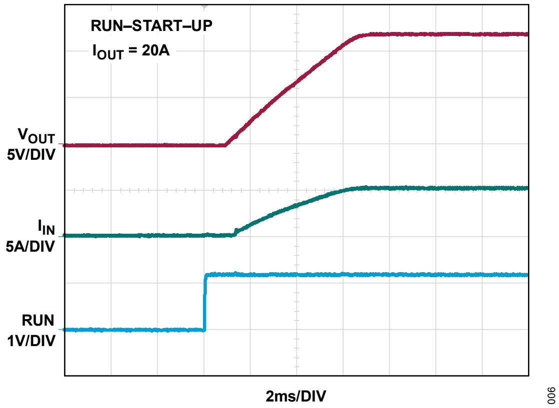


Figure 5. Output Voltage Ripple Magnitude Variation in Burst Mode vs. FCM at V_{IN} = 24V. Burst Mode trades noise spectral density for greatly improved light load efficiency, as shown in [Figure 4](#).



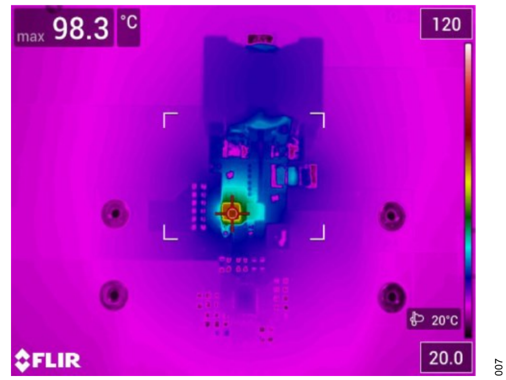


Figure 6. Soft-Start Behavior. EVAL-LTC7891-BZ Ramps the Output Slowly at Startup without Output Voltage Overshoot.

Figure 7. Thermal Performance with 24V Input, 12V Output, and 25A Load. No heatsink or airflow. The hottest component on EVAL-LTC7891-BZ stays under 100°C.

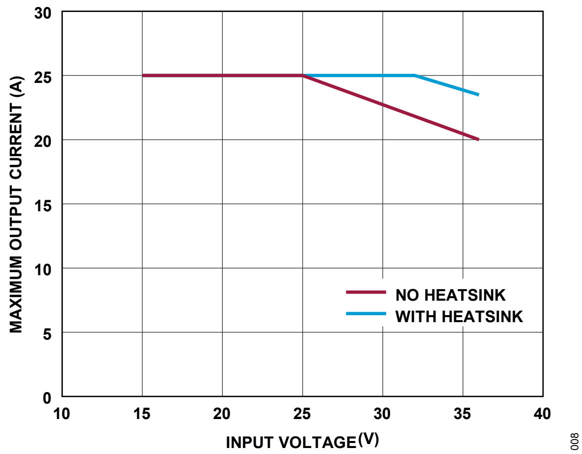


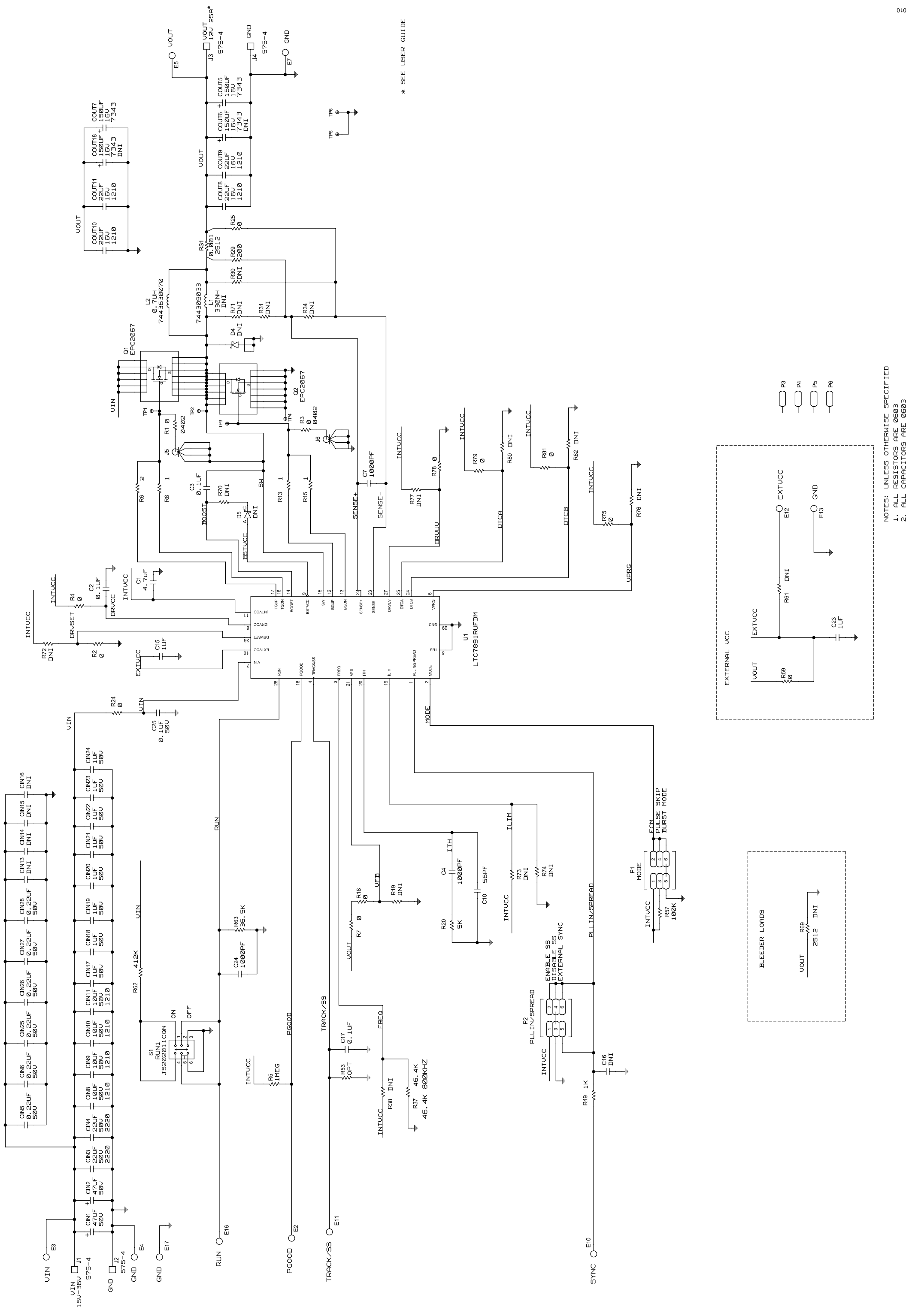
Figure 8. Maximum Recommended Output Current vs. V_{IN} keeping Maximum Board Temperature under 100°C at Room Temperature. With a Heatsink, the Board can Operate at full 25A Output up to 32V continuously without requiring Forced Airflow. Without a Heatsink, Limit Continuous 25A Output at 25V_{IN} at 800kHz.

Bill of Materials

ITEM	QTY	DESIGNATOR	DESCRIPTION	MANUFACTURER PART NUMBER
REQUIRED CIRCUIT COMPONENTS				
1	1	C1	CAP CER 4.7µF 25V 10% X5R 0603 AEC-Q200	MURATA, GRT188R61E475KE13D
2	1	C10	CAP CER 56pF 50V 5% C0G 0603	KEMET, C0603C560J5GACTU
3	2	C15, C23	CAP CER 1µF 25V 10% X7R 0603 AEC-Q200	MURATA, GCM188R71E105KA64D
4	3	C2, C3, C17	CAP CER 0.1µF 25V 10% X7R 0603	KEMET, C0603C104K3RACTU
5	3	C4, C7, C24	CAP CER 1000pF 50V 10% X7R 0603	YAGEO, CC0603KRX7R9BB102
6	1	C25	CAP CER 0.1µF 50V 10% X7R 0603	YAGEO, CC0603KRX7R9BB104
7	2	CIN1, CIN2	CAP ALUM ELECT 47uF 50V 20% 6.3X7.7mm AEC-Q200	PANASONIC, EEE1HA470XP
8	4	CIN8–CIN11	CAP CER 10µF 50V 10% X7R 1210	MURATA, GRM32ER71H106KA12L
9	8	CIN17–CIN24	CAP CER 1µF 50V 10% X7R 0603	TAIYO YUDEN, UMK107AB7105KA-T
10	6	CIN5, CIN6, CIN25–CIN28	CAP CER 0.22µF 50V 10% X7R 0603 AEC-Q200	MURATA, GCM188R71H224KA64D
11	2	CIN3, CIN4	CAP CER 22UF 50V 20% X7R 6.1X5.3MM AEC-Q200 2 STACKED	MURATA, KCM55WR71H226MH01K
12	4	COUT8–COUT11	CAP CER 22µF 16V 10% X7R 1210	MURATA, GRM32ER71C226KEA8L
13	2	COUT5, COUT7	CAP TANT POLY 150UF 16V 20% 7343 0.05Ω	PANASONIC, 16TQC150MYF
14	11	E2–E5, E7, E10–E13, E16, E17	CONN-PCB SOLDER TERMINAL TEST POINT TURRET 0.094" MTG. HOLE PCB 0.062 INCH THK	MILL-MAX, 2501-2-00-80-00-00-07-0
15	4	J1, J2, J3, J4	CONN-PCB BANANA JACK	KEYSTONE ELECTRONICS, 575-4
16	2	J5, J6	CONN-PCB MMCX JACK STR 50Ω 0-6GHZ	MOLEX,734152063
17	1	L2	IND POWER CHOKE SHIELDED WIREWOUND 0.7UH 15% 100KHZ 32A 0.00083 OHM	WÜRTH ELEKTRONIK,7443630070
18	2	P1,P2	CONN-PCB 6POS UNSHROUDED HEADER VERT 2MM PITCH	SAMTEC INC., TMM-103-02-L-D
19	4	P3–P6	CONN-PCB 1POS STEEL SPACER WITH M2X0.4 THD	WÜRTH ELEKTRONIK, 9774010243R
20	2	Q1, Q2	TRAN N-CH EGAN FET ENHANCEMENT MODE POWER 40V 69A	EFFICIENT POWER CONVERSION CORPORATION, EPC2067
21	2	R1, R3	RES SMD 0 Ohm JUMPER 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2GE0R00X
22	3	R8, R13, R15	RES SMD 1Ω 5% 1/10W 0603 AEC-Q200	PANASONIC, ERJ-3GEYJ1R0V
23	11	R2, R4, R7, R18, R24, R25, R59, R75, R78, R79, R81	RES SMD 0Ω JUMPER 1/10W 0603 AEC-Q200 PRECISION POWER	VISHAY, CRCW06030000Z0EA

ITEM	QTY	DESIGNATOR	DESCRIPTION	MANUFACTURER PART NUMBER
24	1	R20	RES SMD 5KΩ 0.1% 1/10W 0603	YAGEO, RT0603BRE075KL
25	1	R29	RES SMD 200Ω 1% 1/10W 0603 AEC-Q200	PANASONIC, ERJ-3EKF2000V
26	1	R37	RES SMD 46.4KΩ 0.1% 1/10W 0603 AEC-Q200 HIGH RELIABILITY	PANASONIC, ERA-3AEB4642V
27	1	R49	RES SMD 1KΩ 1% 1/10W 0603 AEC-Q200	PANASONIC, ERJ-3EKF1001V
28	1	R5	RES SMD 1MEGΩ 5% 1/10W 0603 AEC-Q200	VISHAY, CRCW06031M00JNEA
29	1	R57	RES SMD 100KΩ 1% 1/10W 0603 AEC-Q200	PANASONIC, ERJ-3EKF1003V
30	1	R6	RES SMD 2Ω 1% 1/10W 0603	YAGEO, RC0603FR-072RL
31	1	R62	RES SMD 412KΩ 1% 1/10W 0603 AEC-Q200	VISHAY, CRCW0603412KFKEA
32	1	R63	RES SMD 36.5KΩ 1% 1/10W 0603 AEC-Q200	PANASONIC, ERJ-3EKF3652V
33	1	RS1	RES SMD 0.001Ω 1% 3W CURRENT SENSE AEC-Q200	VISHAY, WSLP25121L000FEA
34	1	S1	SWITCH SLIDE DPDT 300MA 6V	C&K, JS202011CQN
35	1	U1	IC-ADI 100V, LOW IQ, SYNCHRONOUS STEP-DOWN CONTROLLER FOR GAN FET	ANALOG DEVICES, LTC7891RUFDM#PBF
OPTIONAL CIRCUIT COMPONENTS				
1	5	C16, CIN13–CIN16	DO NOT INSTALL (TBD_C0603) PLEASE USE SYM_3 AND/OR SYM_4	TBD0603, TBD0603
2	2	COUT6, COUT18	CAP TANT POLY 150UF 16V 20% 7343 0.05Ω	PANASONIC, 16TQC150MYF
3	1	D4	DIO TRENCH SCHOTTKY RECTIFIER 60V 30A	ONSEMI, NRTS3060MFS
4	1	D5	DIO SCHOTTKY 100V 0.2A 2LD SOD-323	ONSEMI, NSR02100HT1G
5	1	L1	IND POWER CHOKE SHIELDED WIREWOUND 330NH 20% 100KHZ 47.5A 0.000165OHM DCR AEC-Q200	WÜRTH ELEKTRONIK,744309033
6	16	R19, R30, R31, R34, R38, R53, R61, R70–R74, R76, R77, R80, R82	RES., OPTION, 0603	
7	1	R69	RES., OPTION, 2512	
HARDWARE – FOR EVALUATION CIRCUIT ONLY				
1	1	HS1	HEATSINK 1/8 BRICK 55X20.7X11.4M	WAKEFIELD-VETTE, 567-45AB
2	4	MP1–MP4	STANDOFF, NYLON, SNAP-ON, 0.625 (5/8"), 15.9mm	KEYSTONE, 8834
3	2	XJP1, XJP2	CONN., SHUNT, FEMALE, 2 POS, 2mm	WÜRTH ELEKTRONIK, 60800213421
4	4	P1–P4	CONN-PCB 1POS STEEL SPACER WITH M2X0.4 THD	WÜRTH ELEKTRONIK, 9774010243R

Schematic



Revision History

Revision Number	Revision Date	Nature of Change	Page Number
0	9/24	Initial Release	—

Notes