EVAL-LTC7891-AZ

High Frequency Step-Down Supply with EPC GaN FETs

General Description

Evaluation circuit EVAL-LTC7891-AZ features the LTC®7891: a 100V Step-Down Synchronous GaN FET controller. The LTC7891 is specifically designed to drive up to 100V GaN FETs safely and easily through internally optimized bootstrap switches and smart dead time control. Split gate drivers allow for easily adjustable turn-on and turn-off of FETs. 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 allow for a wide variety of applications including industrial, military, medical, and telecommunications systems.

The EVAL-LTC7891-AZ operates from a 15V to 72V input voltage range and generates a 12V, 20A output. The LTC7891 has a precision voltage reference which can generate an output voltage with 2% tolerance over the full operating conditions. The EVAL-LTC7891-AZ is set to 500kHz switching frequency, which results in a small and efficient circuit. The converter achieves over 96% efficiency with 20A load at full operating V_{IN}, with a peak efficiency of over 99%.

This board can be easily modified to regulate output voltages from 0.8V to 60V. The evaluation circuit has been specially designed with 100V EPC GaN FET form factor. Various FETs of similar footprint can be replaced to fit a wide array of applications.

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

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	I_{OUT} = 0A to 20A, Heatsink	15		72	V
	I_{OUT} = 0A to 20A, No Heatsink, Maximum Board Temperature < 100°C	15		52	V
Output Voltage	V_{IN} = 15V to 72V	11.76	12	12.24	V
Output Voltage Ripple (Peak-to-Peak)	V_{IN} = 48V, I_{OUT} = 20A			50	mV_{P-P}
Run Rising Threshold			15.4		V
Run Falling Threshold			13.9		V
Switching Frequency	JP2 = Disable SS (SSFM Off)		500		kHz
	JP2 = Enable SS (SSFM On)	500		600	kHz
Typical Efficiency	V_{IN} = 24V, I_{OUT} = 20A		98		%
	V_{IN} = 48V, I_{OUT} = 20A		97		%

One Analog Way, Wilmington, MA 01887-2356, U.S.A. | Tel: 781.329.4700

Quick Start Procedure

Evaluation circuit EVAL-LTC7891-AZ is easy to set up to evaluate the performance of the LTC7891. For a proper measurement equipment setup, see Figure 1 and follow the procedure below.

1. Set the input power supply to a voltage between 15V and 72V. Disable the power supply.

   NOTE: Make sure that the input voltage V_{IN} does not exceed 72V.
2. Connect the positive terminal of the power supply to V_{IN} and the negative terminal to GND.
3. Connect the load (< 20A) 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 48V.
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, care must be taken 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-AZ is a fully assembled and tested board that demonstrates the performance of the LTC7891. The evaluation circuit is designed to deliver 12V output at load current up to 20A from a 15V to 72V input supply. The board is programmed at 500kHz switching frequency for optimum efficiency and component size.

Adjusting the Output Voltage

The LTC7891 supports an adjustable output voltage range, from 0.8V to 60V. To change the output voltage from the programmed 12V, change R18 and R19. Refer to the Setting the Output Voltage section on the data sheet for how to calculate the V_{FB} resistor divider values for the desired output voltage. All the corresponding power components will also need to be changed to meet the desired output voltage.

Setting the Switching Frequency

Selecting the switching frequency is a trade-off between efficiency and component size. For optimal performance, a switching frequency of 500kHz is chosen for 12V output. R37 programs the desired switching frequency. The switching frequency is set using the FREQ and PLLIN/SPREAD pins. Refer to the Setting the Operating Frequency section in the LTC7891 data sheet for 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-AZ 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-AZ is designed to turn on LTC7891 at around 15V. However, this threshold can be easily adjusted 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's 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 TRK/SS turret to make the startup of the V_{OUT} track an external supply. Typically, this requires connecting to the TRK/SS turret through an external resistor divider from the external supply to GND. Refer to the Soft-Start and Tracking section on the data sheet.

Mode Selection (MODE)

The EVAL-LTC7891-AZ 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 spread-spectrum mode operation to improve 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-AZ 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-AZ 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. For more details about external clock synchronization, refer to the LTC7891 data sheet.

Open-Drain PGOOD Output (PGOOD)

The EVAL-LTC7891-AZ provides a PGOOD turret to monitor the status of the PGOOD output. PGOOD is high when V_{FB} voltage is within ±10% of the 0.8V reference. PGOOD is pulled low when 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-AZ, 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 high efficiency of the synchronous step-down GaN FET controller circuitry. The component temperatures of EVAL-LTC7891-AZ with a typical 48V input and 20A load are shown in Figure 7. The six-layer PCB layout features solid copper planes that provide adequate heat spreading across the whole board.

The board can operate with an input voltage up to 72V at 20A without a heatsink or forced air under transient conditions. If the input voltage above 52V for over a minute is required, the circuit will require 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 the full V_{IN} range of 15V to 72V at 20A for steady state.

Heatsink

The EVAL-LTC7891-AZ features space for a heatsink to extend the power and thermal capabilities significantly. The board is designed for the Wakefield-Vette 567-45AB heatsink and is to be used in conjunction with thermal pads and Wurth Elektronik 9774010243R spacers. The spacers should be soldered onto P1, P2, P3, and P4, and a thermal pad placed between the heatsink and the GaN FETs. Properly screw in the heatsink to fully extend the power capabilities of the board.

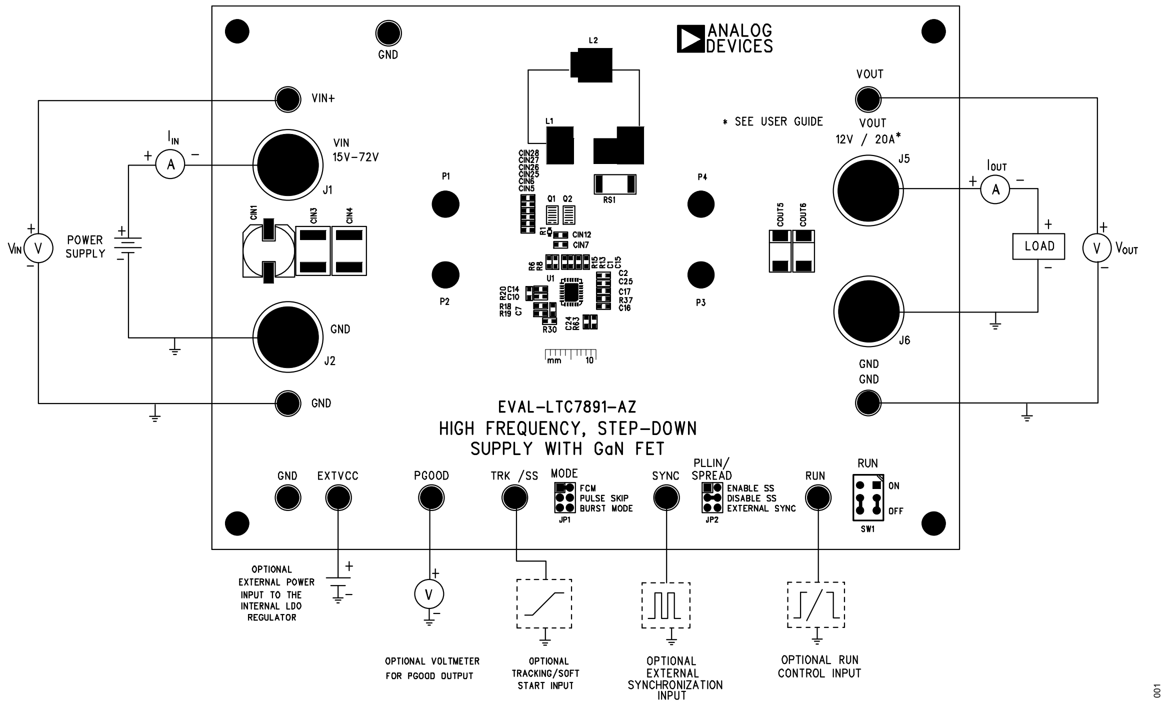


Figure 1. EVAL-LTC7891-AZ Board Connections

Table 1. MODE Selection Jumper (JP1) Settings

SHUNT POSITION	MODE PIN	MODE
1-2*	Connected to $INTV_{CC}$	FCM mode of operation
3-4	Connected to INTVCC with a 100kΩ	Pulse skipping mode of operation
5-6	Connected to GND	Bust mode of operation

**Default position*

Table 2. PLLIN/SPREAD Jumper (JP2) Settings

SHUNT POSITION	PLLIN/SPREAD PIN	DESCRIPTION
1-2	Connected to $INTV_{CC}$	Enable 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 startup at the desired input voltage level
OFF*	Connected to GND	Disabled

**Default position*

Performance

(V_{IN} = 48V, V_{OUT} = 12V, I_{OUT} = 20A, f_{SW} = 500kHz, MODE = FCM, T_A = +25°C, unless otherwise noted.)

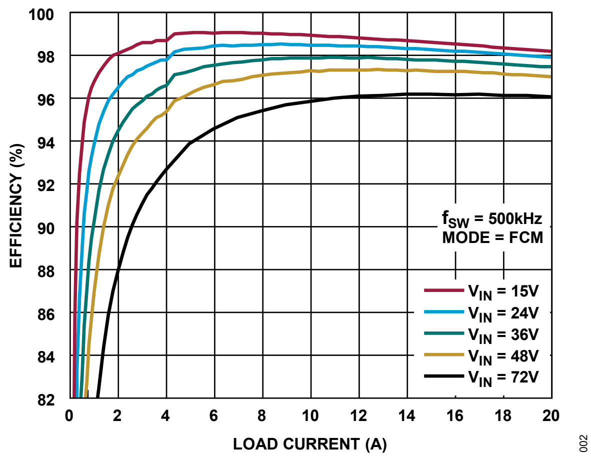


Figure 2. Efficiency vs. Load Current. At V_{IN} = 48V, EVAL-LTC7891-AZ performs with an efficiency of over 98% with 12V Output and 20A Load

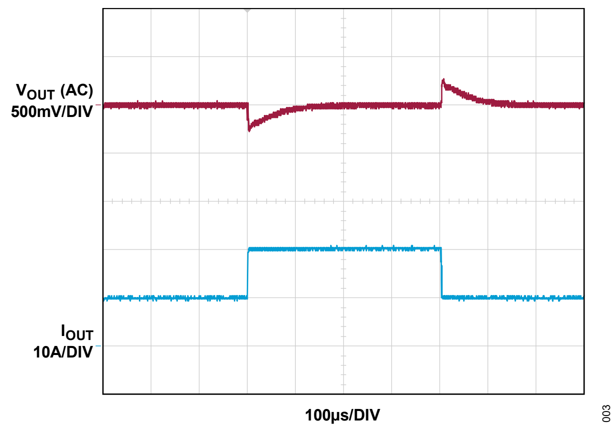


Figure 3. Load Step Response. EVAL-LTC7891-AZ has a Good Load Step Response with Small Output Capacitors

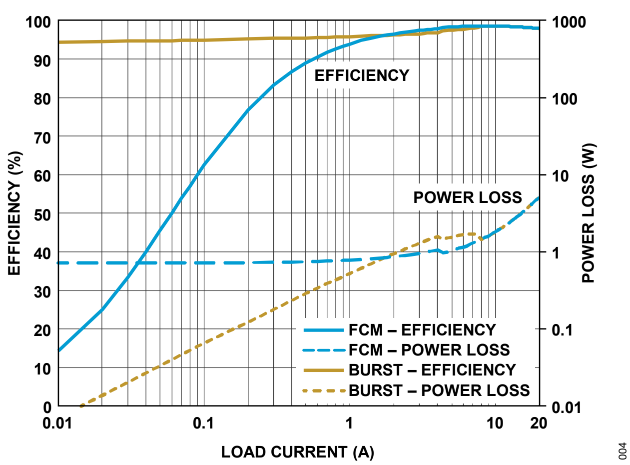


Figure 4. Efficiency and Power Loss vs. Load Current at V_{IN} = 24V. At low load, burst mode significantly improves power loss compared to FCM.

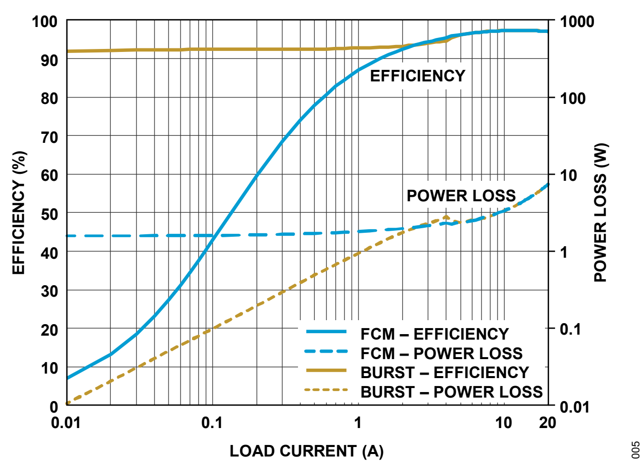


Figure 5. Efficiency and Power Loss vs. Load Current at V_{IN} = 48V. At low load, burst mode significantly improves power loss compared to FCM.

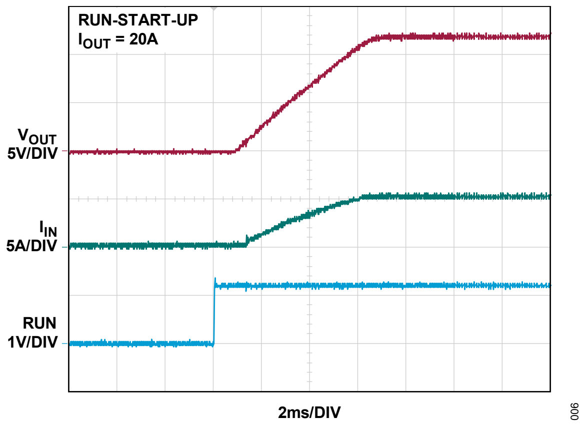


Figure 6. Soft-Start Behavior. EVAL-LTC7891-AZ Ramps the Output Slowly at Start-Up without Output Voltage Overshoot

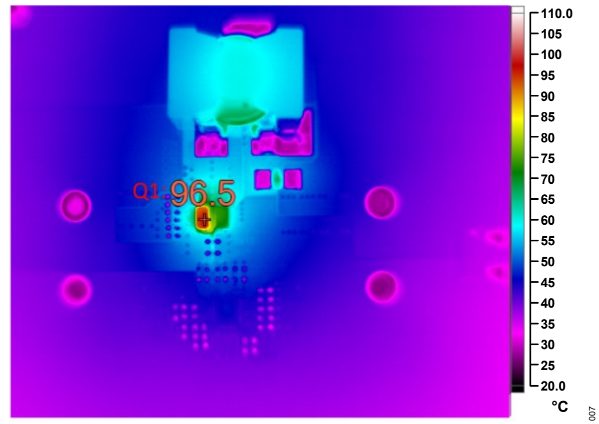


Figure 7. Thermal Performance with 48V Input, 12V Output, and 20A Load. No heatsink or airflow. The hottest component on EVAL-LTC7891-AZ stays under 100°C.

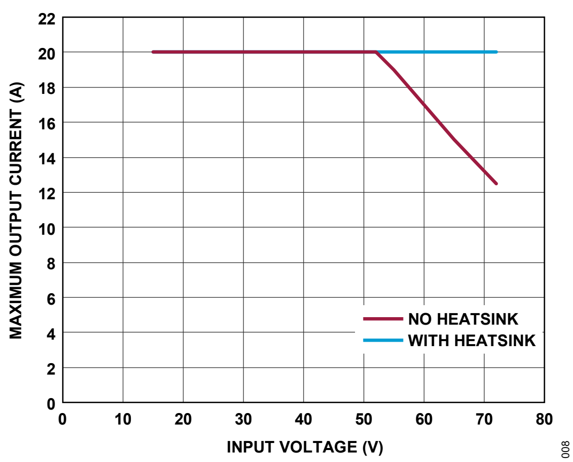


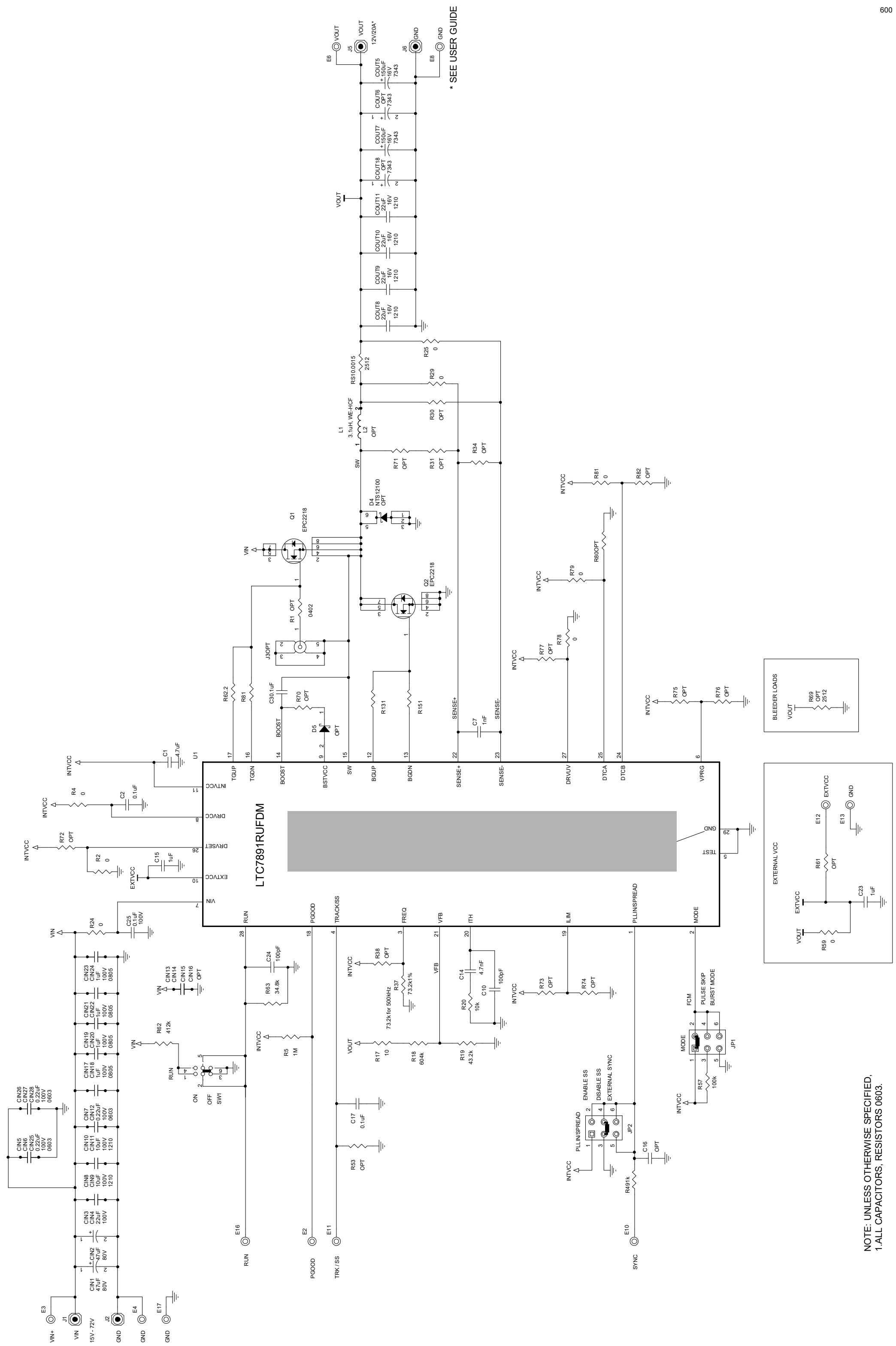
Figure 8. Maximum recommended output current vs. V_{IN} keeping maximum board temperature under 100°C at room temperature. With a heatsink, the board can operate at full 20A output for the entire input range of 15V to 72V.

Bill of Materials

ITEM	QTY	DESIGNATOR	DESCRIPTION	MANUFACTURER PART NUMBER
			REQUIRED CIRCUIT COMPONENTS	
1	1	C1	CAP., 4.7µF, X5R, 25V, 10%, 0603	MURATA, GRM188R61E475KE11D
2	3	C2, C3, C17	CAP., 0.1µF, X7R, 25V, 10%, 0603	AVX, 06033C104KAT2A
3	1	C7	CAP., 1000pF, X7R,25V, 10%, 0603	AVX, 06033C102KAT2A
4	2	C10, C24	CAP., 100pF, C0G, 25V, 10%, 0603	AVX, 06033A101KAT2A
5	1	C14	CAP., 4700pF, C0G/NP0, 50V, 5%, 0603	AVX, 06035A472JAT2A
6	1	C15	CAP., 1µF, X5R, 50V, 10%, 0603, AEC-Q200	MURATA, GRT188R61H105KE13D
7	1	C23	CAP.,1µF, X7R, 25V, 10%, 0603, AEC-Q200	MURATA, GCM188R71E105KA64D
8	1	C25	CAP., 0.1µF, X7R, 100V, 10%, 0603	AVX, 06031C104KAT2A
9	2	CIN1, CIN2	CAP., 47µF, AL-POLY., 80V, 20%, AEC-Q200	PANASONIC, EEHZC1K470P
10	2	CIN3, CIN4	CAP., 22µF, X7S, 100V, 20%, 2220, STACKED	TDK, CKG57NX7S2A226M500JH
11	8	CIN5, CIN6, CIN7, CIN12, CIN25, CIN26, CIN27, CIN28	CAP., 0.22µF, X7S, 100V, 10%, 0603, AEC-Q200	TAIYO YUDEN, HMK107C7224KAHTE
12	4	CIN8, CIN9, CIN10, CIN11	CAP., 10µF, X7S, 100V, 10%, 1210	MURATA, GRM32EC72A106KE05L
13	8	CIN17, CIN18, CIN19, CIN20, CIN21, CIN22, CIN23, CIN24	CAP., 1µF, X7S, 100V, 10%, 0805, SOFT TERM	MURATA, GRJ21BC72A105KE11L
14	2	COUT5, COUT7	CAP., 150µF, TANT., 16V, 20%, 7343	PANASONIC, 16TQC150MYF
15	4	COUT8, COUT9, COUT10, COUT11	CAP., 22µF, X7R, 16V, 10%, 1210	MURATA, GRM32ER71C226KEA8L
16	1	L1	IND., 3.1µH, WE-HCF, PWR, 15%, 26A, 2.09mΩ, 2013	WURTH ELEKTRONIK, 7443630310
17	2	Q1,Q2	XSTR., PWR, GaN FET, 100V, 60A/231A, DIE SIZE: 3.5 x 1.95mm	EFFICIENT POWER CONVERSION, EPC2218
18	9	R2, R4, R24, R25, R29, R59, R78, R79, R81	RES., 0Ω, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06030000Z0EA
19	1	R5	RES., 1MΩ, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06031M00FKEA
20	1	R6	RES., 2.2Ω, 5%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3GEYJ2R2V
21	3	R8, R13, R15	RES., 1Ω, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06031R00FKEA
22	1	R17	RES., 10Ω, 1%, 1/10W, 0603	VISHAY, CRCW060310R0FKEA
23	1	R18	RES., 604kΩ, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW0603604KFKEA
24	1	R19	RES., 43.2kΩ, 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3EKF4322V
25	1	R20	RES., 10kΩ, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW060310K0FKEA
26	1	R37	RES., 73.2kΩ, 1%, 1/10W, 0603	NIC, NRC06F7322TRF
27	1	R49	RES., 1kΩ, 1%, 1/10W, 0603	VISHAY, CRCW06031K00FKEA
28	1	R57	RES., 100kΩ, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW0603100KFKEA
29	1	R62	RES., 412kΩ, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW0603412KFKEA
30	1	R63	RES., 34.8kΩ, 1%, 1/10W, 0603	VISHAY, CRCW060334K8FKEA
31	1	RS1	RES., 0.0015Ω, 1%, 3W, 2512, AEC-Q200	VISHAY, WSLP25121L500FEA
32	1	SW1	SWITCH SLIDE DPDT 300MA 6V Through Hole	C&K, JS202011CQN
33	1	U1	IC, Step-Down Controller for GaN FETs, Side Wettable Plastic QFN-28	ANALOG DEVICES, LTC7891RUFDM#PBF

OPTIONAL CIRCUIT COMPONENTS				
1	0	C16	CAP., OPTION, 0603	
2	0	CIN13, CIN14, CIN15, CIN16	CAP., 10µF, X7S, 100V, 10%, 1210	MURATA, GRM32EC72A106KE05L
3	0	COUT6, COUT18	CAP., OPTION, 7343	
4	0	D4	DIODE, SCHOTTKY, 100V, 12A, SO-8FL, AEC-101	ON SEMICONDUCTOR, NTS12100EMFST1G
5	0	D5	DIODE, SCHOTTKY BARRIER 100V 200mA SOD-323	ON SEMICONDUCTOR, NSR02100HT1G
6	0	L2	IND., 3.3µH, ERU CHOKE, 10%, 34A, 1.5mΩ, SMD, 22mm x 22.3mm, AEC-Q200	TDK, B82559A5332A020
7	0	MP5	HEATSINK 1/8 BRICK 55X20.7X11.4M	WAKEFIELD-VETTE, 567-45AB
8	0	R1, R30, R31, R34, R38, R53, R61, R70, R71, R72, R73, R74, R75, R76, R77, R80, R82	RES., OPTION, 0603	
9	0	R69	RES., OPTION, 2512	
10	0	J3	CONN., RF/COAX, MMCX, JACK, FEMALE, VERT, ST, SMT	MOLEX, 73415-2063
HARDWARE – FOR EVALUTATION CIRCUIT ONLY				
1	11	E2, E3, E4, E6, E8, E10, E11, E12, E13, E16, E17	TEST POINT, TURRET, 0.094" MTG. HOLE, PCB 0.062" THICK	MILL-MAX, 2501-2-00-80-00-00-07-0
2	4	J1, J2, J5, J6	EVAL BOARD STUD HARDWARE SET, #10-32	ANALOG DEVICES, 720-0010
3	2	JP1, JP2	CONN., HDR, MALE, 2 x 3, 2mm, VERT, STR, THT	WURTH ELEKTRONIK, 62000621121
4	4	MP1, MP2, MP3, MP4	STANDOFF, NYLON, SNAP-ON, 0.625 (5/8"), 15.9mm	KEYSTONE, 8834
5	2	XJP1, XJP2	CONN., SHUNT, FEMALE, 2 POS, 2mm	WURTH ELEKTRONIK, 60800213421
6	4	P1, P2, P3, P4	CONN-PCB 1POS STEEL SPACER WITH M2X0.4 THD	WURTH ELEKTRONIK, 9774010243R

Schematic


LTC7891RUFDM
* SEE USER GUIDE
BLEEDER LOADS
EXTERNAL VCC
NOTE: UNLESS OTHERWISE SPECIFIED,
1.ALL CAPACITORS, RESISTORS 0603.

Revision History

Revision Number	Revision Date	Nature of Change	Page Number
Rev 0	10/23	Initial Release	—