EVAL-LTC7878-AZ

70V Parallel Dual Phase 4-Switch Buck-Boost Controller

General Description

Evaluation circuit EVAL-LTC7878-AZ features the LTC®7878: a 70V parallelable buck-boost controller with inductor DCR current sensing. The LTC7878 is a four-switch buck-boost switching regulator designed to operate above, below, or equal to the output voltage safely and easily. The constant-frequency, peak-current mode architecture allows phase-lockable switching frequency up to 600kHz. A programmable input or output current loop regulates the average input or output current loop, making it suitable for battery charging applications. Additionally, with a wide 5V to 70V input and output range and seamless, low-noise transition between operating regions, the LTC7878 is ideal for industrial and telecom systems.

The EVAL-LTC7878-AZ operates from a 18V to 65V input voltage range and generates an output of 24V and at least a 20A load. The board features two LTC7878's in parallel to achieve very high power. The parallel operation is set to a switching frequency of 100kHz, which results in an efficient circuit. Both phases are set 180° offset to interleave the switching while still providing great current sharing.

The LTC7878 has a precision voltage reference that can generate an output voltage with a 1% tolerance over the full operating conditions. The converter achieves over 98% efficiency with a 20A load at full operating V_{IN}.

This board can be easily modified to regulate output voltages from 1V to 70V. Its multiphase/multi-ICs parallel operation feature allows for simple alterations for higher power.

The EVAL-LTC7878-AZ provides a high-performance, cost-effective solution for generating a 24V output. The LTC7878 data sheet gives a complete description of this part, its operation, and applications information. The data sheet must be read in conjunction with this user guide for EVAL-LTC7878-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	18		65	V
Output Voltage	V_{IN} = 18V to 65V		24		V
Maximum Output Current	V_{IN} = 18V to 65V, No Heatsink, No Airflow	20	25		A
Switching Frequency			100		kHz
Run Rising Threshold			17.4		V
Run Falling Threshold			16.2		V
Typical Efficiency	V_{IN} = 18V, I_{OUT} = 20A		98.2		%
	V_{IN} = 24V, I_{OUT} = 20A		98.2		%
	V_{IN} = 48V, I_{OUT} = 20A		98.3		%

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Quick Start Procedure

Evaluation circuit EVAL-LTC7878-AZ is easy to set up to evaluate the performance of the LTC7878. For a proper measurement equipment setup, see Figure 1 and follow the procedure below.

1. Set the input power supply to a voltage between 18V and 65V. Disable the power supply.

   NOTE: Make sure that the input voltage V_{IN} does not exceed 65V.

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. Turn the input power supply on and adjust the input voltage to 48V.
5. Verify that the output voltage is 24V 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.
6. 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.

Adjusting the Output Voltage

The LTC7878 supports an adjustable output voltage range from 1V to 70V. To change the output voltage from the programmed 24V, change R35, R36, R65, and R66. 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 100kHz is chosen for 24V output. R18 and R48 program the desired switching frequency. The switching frequency is set using the FREQ and PLLIN/SPREAD pins. Refer to the Setting the Operating Frequency section on the LTC7878 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-LTC7878-AZ includes a resistive voltage divider (R7/R8 and R37/R38) connected between the V_{IN} and SGND pins to turn on the device at the required input voltage. The EVAL-LTC7878-AZ is designed to turn on LTC7878 at around 18V. However, this threshold can be easily adjusted by changing R7 and R8.

$EXTV_{CC}$ Linear Regulator

The $EXTV_{CC}$ pin allows the $INTV_{CC}$ power to be derived from a high-efficiency external source. On EVAL-LTC7878-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 R67 and R70. An external supply can then be added to C20 and C53.

Parallel Dual Phase with Interleaved Switching

The LTC7878 is designed to easily be paralleled for even higher output power. The EVAL-LTC7878-AZ features two LTC7878s in parallel by connecting the SS, ITH, VFB, and RUN pins of the two controllers together. The CLKOUT pin of the first phase is connected to the SYNC pin of the second phase.

For an interleaved dual-phase operation, the first phase is set to send a CLKOUT signal 180° out of phase. If a different phase offset is required, refer to the data sheet and change resistors around the PHASMD pin. If a single-phase operation is wanted, disconnect R1, R2, R3, R4, and R5, and short the RUN2 turret to GND.

Thermal Performance

The LTC7878 features excellent thermal performance due to the high efficiency of the synchronous buck-boost circuit operation. The component temperatures of EVAL-LTC7878-AZ with a typical 24V 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.

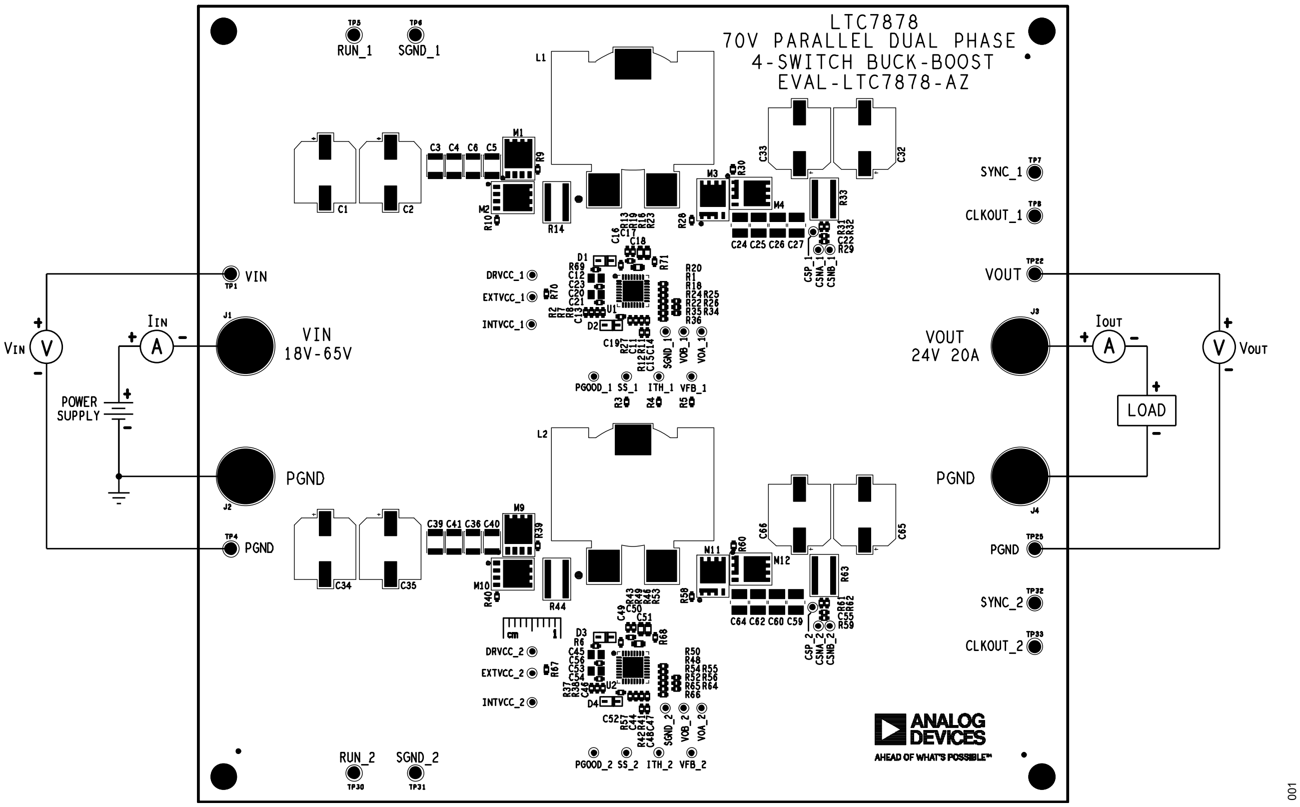


Figure 1. EVAL-LTC7878-AZ Board Connections

Performance

(V_{IN} = 24V, V_{OUT} = 24V, I_{OUT} = 20A, f_{SW} = 100kHz, T_A = +25°C, unless otherwise noted.)

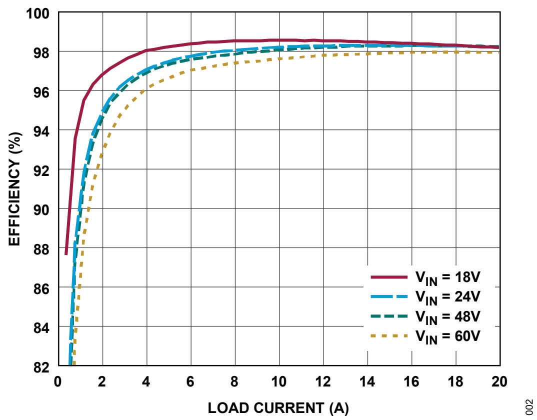


Figure 2. Efficiency vs. Load Current. EVAL-LTC7878-AZ performs with an efficiency of over 97% across all input voltage range.

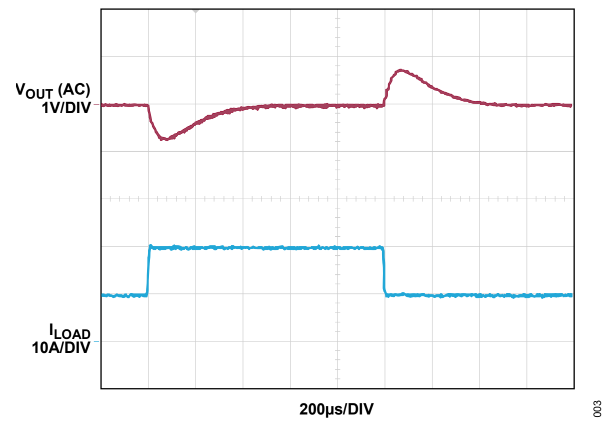


Figure 3. Load Step Response. EVAL-LTC7878-AZ has a good load step response with small output capacitor.

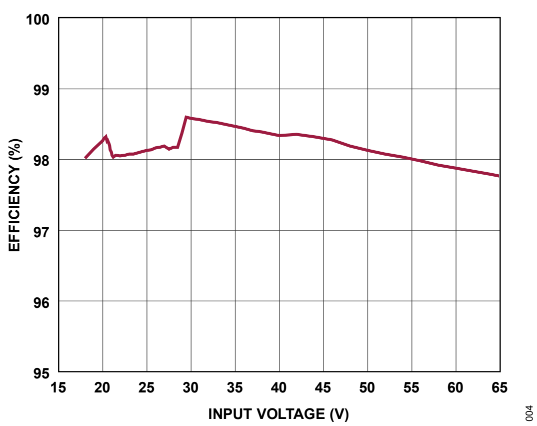


Figure 4. Efficiency vs. Input Voltage at 20A load. At an output current of 20A, the EVAL-LTC7878-AZ can operate at an efficiency of at least 98% for most of the input voltage range.

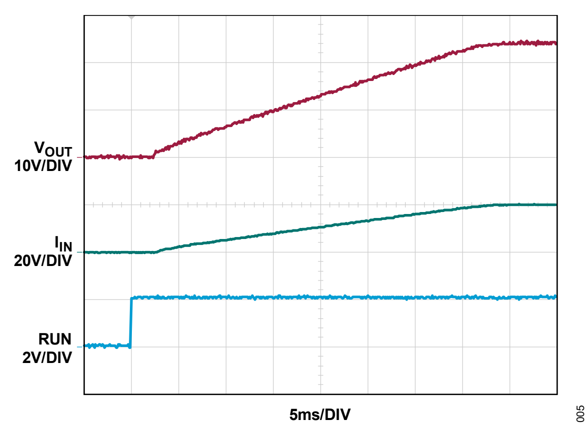


Figure 5. Soft-Start Behavior. EVAL-LTC7878-AZ ramps the output slowly at start-up without output voltage overshoot.

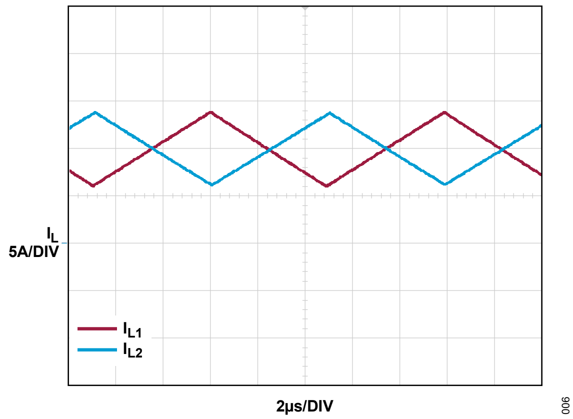


Figure 6. Inductor currents at 48V input at 20A load. Looking at the inductor currents of each phase, the EVAL-LTC7878-AZ shows great current sharing between two phases.

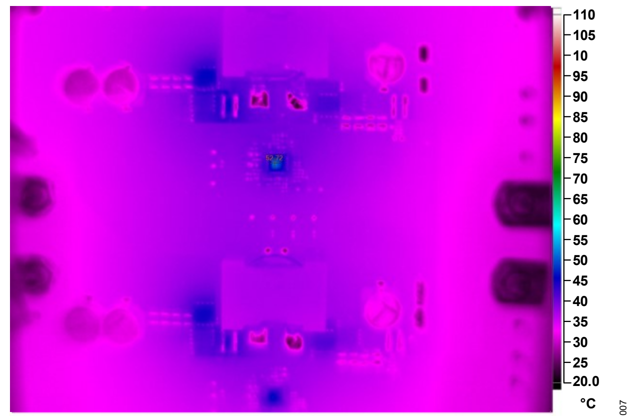


Figure 7. Thermal Performance with 24V Input, 20A Load. No heatsink or airflow. The hottest component on EVAL-LTC7878-AZ stays cool.

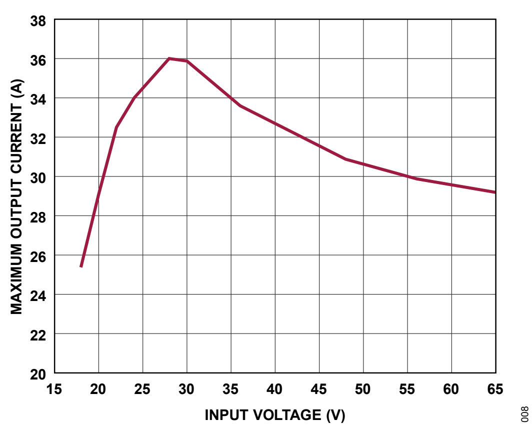


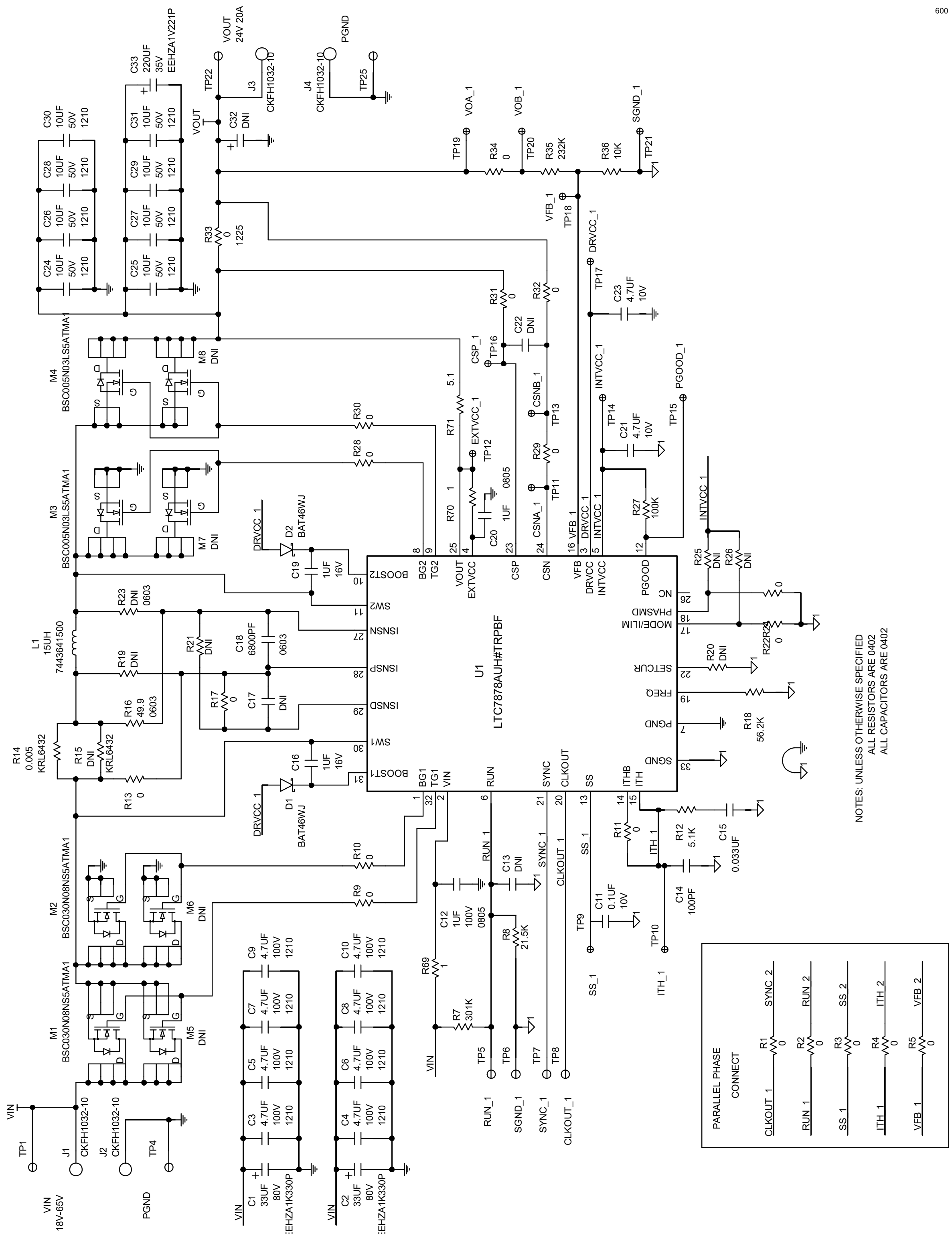
Figure 8. Maximum Output Current vs. V_{IN}. The EVAL-LTC7878-AZ can output over 25A at all V_{IN}, and does not need heatsinks or airflow.

Bill of Materials

ITEM	QTY	DESIGNATOR	DESCRIPTION	MANUFACTURER PART NUMBER
			REQUIRED CIRCUIT COMPONENTS	
1	4	C1, C2, C34, C35	CAP ALUM POLY HYBRID 33µF 80V 20% 10x10.2mm AEC-Q200	PANASONIC, EEHZA1K330P
2	16	C3, C4, C5, C6, C7, C8, C9, C10, C36, C37, C38, C39, C40, C41, C42, C43	CAP CER 4.7µF 100V 10% X7S 1210 AEC-Q200	MURATA, GCM32DC72A475KE02L
3	2	C11, C44	CAP CER 0.1µF 10V 10% X7R 0402	AVX CORPORATION, 0402ZC104KAT2A
4	2	C12, C45	CAP CER 1µF 100V 10% X7S 0805	MURATA, GRJ21BC72A105KE11L
5	2	C14, C47	CAP CER 100PF 10V 20% X7R 0402	KYOCERA, 0402ZC101MAT2A
6	2	C15, C48	CAP CER 0.033µF 16V 10% X5R 0402	AVX, 0402YD333KAT2A
7	4	C16, C19, C49, C52	CAP CER 1µF 16V 10% 0402 LOW ESR	TDK, C1005X6S1C105K050BC
8	2	C18, C51	CAP CER 6800pF 50V 10% X7R 0603	YAGEO, CC0603KRX7R9BB682
9	4	C21, C23, C54, C56	CAP CER 4.7µF 10V 10% X5R 0402 LOW ESR	TDK, C1005X5R1A475K050BC
10	16	C24, C25, C26, C27, C28, C29, C30, C31, C57, C58, C59, C60, C61, C62, C63, C64	CAP CER 10µF 50V 10% X7R 1210	MURATA, GRM32ER71H106KA12L
11	2	C33, C66	CAP ALUM POLYMER 220µF 35V 20% 2.5A 0.02Ω 10000HRS AEC-Q200	PANASONIC, EEHZA1V221P
12	4	D1, D2, D3, D4	DIODE SCHOTTKY SINGLE BARRIER	NXPSEMICONDUCTORS, BAT46WJ, 115
13	2	L1, L2	IND POWER CHOKE SHIELDED 15µH 15% 100KHZ 30A 0.00264Ω AEC-Q200	WURTHELEKTRONIK, 74436415000
14	4	M1, M2, M9, M10	TRAN N-CHANNEL POWER MOSFET 80V 100A	INFINEONTECHNOLOGIES, BSC030N08NS5ATMA1
15	4	M3, M4, M11, M12	TRAN N-CH MOSFET 30V 433A	INFINEONTECHNOLOGIES, BSC005N03LS5ATMA1
16	31	R1, R2, R3, R4, R5, R9, R10, R11, R13, R17, R22, R24, R28, R29, R30, R31, R32, R34, R39, R40, R41, R43, R47, R52, R54, R58, R59, R60, R61, R62, R64	RES SMD 0Ω JUMPER 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2GE0R00X
17	2	R12, R42	RES SMD 5.1KΩ 1% 1/16W 0402 AEC-Q200	VISHAY, CRCW04025K10FKED
18	2	R14, R44	RES SMD 0.005 1% 3W 2512 AEC-Q200 LONG SIDETERM	SUSUMU CO, LTD, KRL6432E-M-R005-F-T1
19	2	R16, R46	RES SMD 49.9Ω 1% 1/10W 0603 AEC-Q200	PANASONIC, ERJ-3EKF49R9V
20	2	R18, R48	RES SMD 56KΩ 1% 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2RKF5602X
21	2	R27, R57	RES SMD 100KΩ 1% 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2RKF1003X
22	2	R33, R63	RES SMD 0Ω JUMPER 2W 1225 AEC-Q200 WIDE-TERM	VISHAY, RCA12250000Z0EGLS
23	2	R35, R65	RES SMD 232KΩ 1% 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2RKF2323X
24	2	R36, R66	RES SMD 10KΩ 1% 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2RKF1002X
25	2	R7, R37	RES SMD 301KΩ 1% 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2RKF3013X
26	2	R8, R38	RES SMD 21.5KΩ 1% 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2RKF2152X
27	4	R6, R67, R69, R70	RES SMD 1Ω 5% 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2BQF1R0X
28	2	R68, R71	RES SMD 5.1Ω 5% 1/10W 0402 AEC-Q200	VISHAY, CRCW04024R99FKED

29	2	U1, U2	IC-ADI 70V PARALLELABLE 4-SWITCH BUCK BOOST CONTROLLER WITH INDUCTOR DCR SENSING	ANALOG DEVICES, LTC7878AUH#TRPBF
OPTIONAL CIRCUIT COMPONENTS				
1	6	C13, C17, C22, C46, C50, C55	DO NOT INSTALL (TBD_C0402) PLEASE USE SYM_3AND/OR SYM_4	TBD0402
2	2	C20, C53	CAP CER 4.7µF 35V 10% X7R 0805	TDK, C2012X7R1V475K125AC
3	2	C32, C65	CAP ALUM POLYMER 220µF 35V 20% 2.5A 0.02Ω 10000HRS AEC-Q200	PANASONIC, EEHZA1V221P
4	4	M5, M6, M13, M14	TRAN N-CHANNEL POWER MOSFET 80V 100A	INFINEON TECHNOLOGIES, BSC030N08NS5ATMA1
5	4	M7, M8, M15, M16	TRAN N-CH MOSFET 30V 433A	INFINEON TECHNOLOGIES, BSC005N03LS5ATMA1
6	2	R15, R45	RES SMD 0.005 1% 3W 2512 AEC-Q200 LONG SIDETERM	SUSUMU CO, LTD, KRL6432E-M-R005-F-T1
7	10	R19, R20, R21, R25,R26, R49, R50, R51, R55, R56	DO NOT INSTALL (TBD_R0402), PLEASE USE SYM_3AND/OR SYM_4	TBD0402
8	2	R23, R53	DO NOT INSTALL (TBD_R0603), PLEASE USE SYM_3AND/OR SYM_4	TBD0603
9	6	C13, C17, C22, C46,C50, C55	DO NOT INSTALL (TBD_C0402) PLEASE USE SYM_3AND/OR SYM_4	TBD0402
10	2	C20, C53	CAP CER 4.7µF 35V 10% X7R 0805	TDK
HARDWARE – FOR EVALUTATION CIRCUIT ONLY				
1	12		NUT, HEX STEEL, 10-32 THREAD, 9.27MM OUTDIA	KEYSTONE, 4705
2	4		STANDOFF, BRD SPT SNAP FIT 12.7MM LENGTH	KEYSTONE, 8833
3	6		CONNECTOR RING LUG TERMINAL, 10 CRIMP, NON-INSULATED	KEYSTONE, 8205
4	6		WASHER, #10 FLAT STEEL	KEYSTONE, 4703
5	4	J1, J2, J3, J4	CONN-PCB THREADED BROACHING STUD 10-32 FASTENER 0.625, USE ALT_SYMBOL FOR C450D200 PAD	CAPTIVEFASTENER, CKFH1032-10
6	12	TP1, TP4, TP5, TP6,TP7, TP8, TP22, TP25, TP30, TP31, TP32, TP33	CONN-PCB SOLDER TERMINAL TURRETS FOR CLIPLEADS	MILL-MAX, 2308-2-00-80-00-00-07-0

Schematic


U1
LTC7878AUH#TRPBF
NOTES: UNLESS OTHERWISE SPECIFIED
ALL RESISTORS ARE 0402
ALL CAPACITORS ARE 0402
PARALLEL PHASE
CONNECT
VIN
18V-65V
PGND
VOUT
24V 20A
L1
15UH
7443641500
M1
BSC030N08NS5ATMA1
M2
BSC030N08NS5ATMA1
M3
BSC005N03LS5ATMA1
M4
BSC005N03LS5ATMA1
BOOST2
SW2
ISNSN
ISNSP
ISNSD
SW1
BOOST1
BG2
TG2
VOUT
EXTVCC
CSP
CSN
VFB
DRVCC
INTVCC
PGOOD
NC
PHASMD
MODE/ILIM
SETCUR
FREQ
PGND
SGND
BG1
TG1
VIN
RUN
SYNC
CLKOUT
SS
ITHB
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600

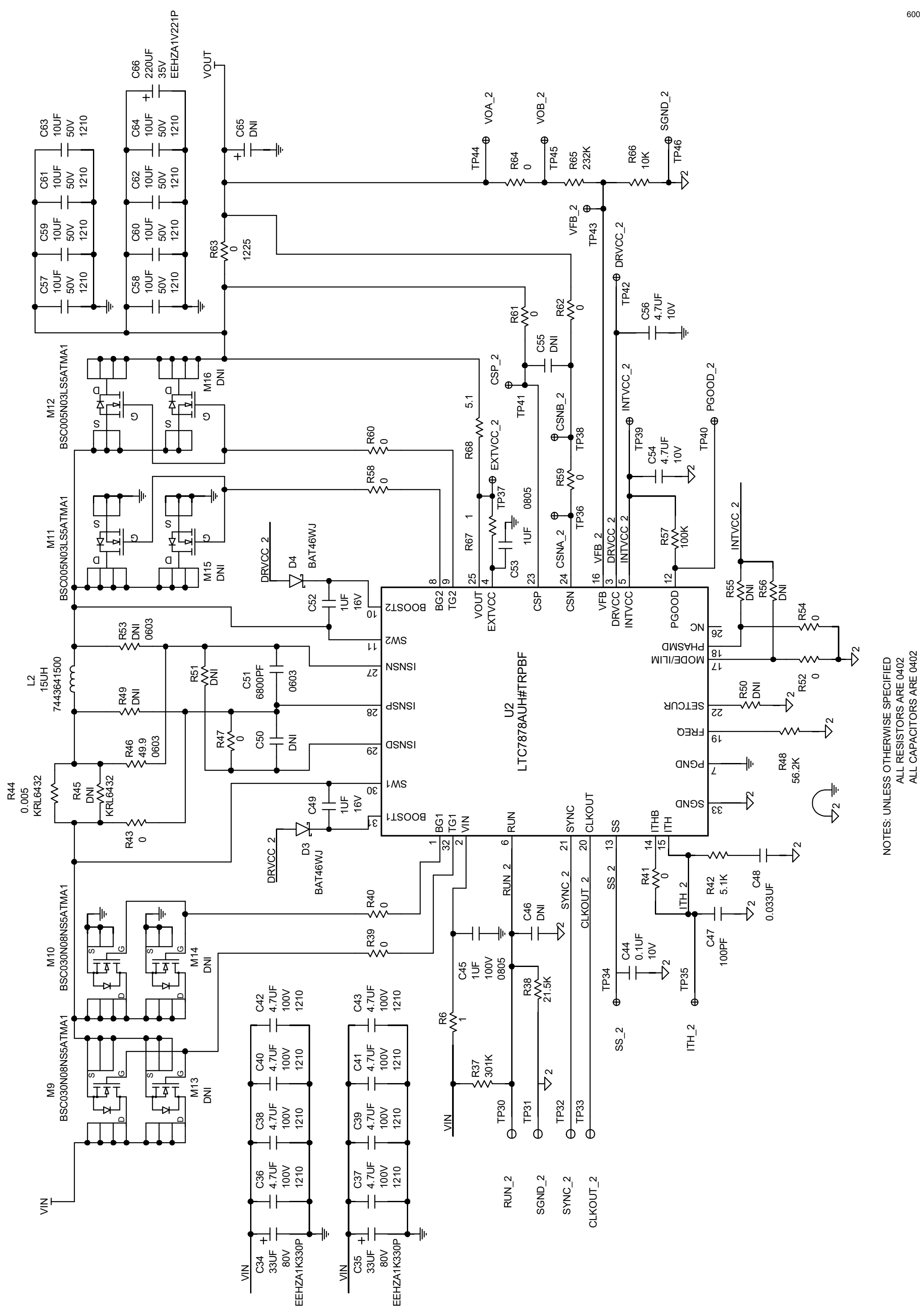

Figure 9. High Efficiency 18V to 65V Input, 24V_{OUT}/20A Output Buck-Boost Converter

Revision History

Revision Number	Revision Date	Nature of Change	Page Number
Rev 0	12/23	Initial Release	—