

# LT8228 High Voltage, High Efficiency Bidirectional Synchronous Buck or Boost Converter with Input and Output Circuit Breakers

## DESCRIPTION

Demonstration circuit 2351A is a high voltage, high efficiency synchronous buck or boost DC/DC converter. It is designed to have 36V to 56V on one side and 8V to 14V on the other side. It can supply a 35A maximum output current in buck mode and delivers 7A of current in boost mode. The demo board features the LT8228EFE controller. This part can seamlessly transition from bucking to boosting. With built-in circuit breaker function and other protection features, the **LT8228** is ideal for high reliability systems requiring N+1 redundancy or other protections

in industrial, automotive, medical, military, and avionics applications.

The DC2351A is designed to be paralleled with other DC2351A boards to increase the total output current. With adequate heatsinking or airflow, the output current can be increased.

**Design files for this circuit board are available.**

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## PERFORMANCE SUMMARY

Specifications are at  $T_A = 25^\circ\text{C}$

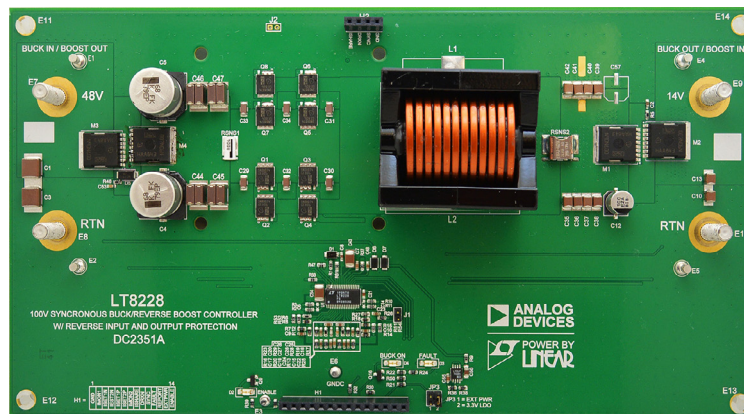
### Buck Mode

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$V_1$	Supply Range		36		56	V
$V_2$	Output Voltage		11.8	12	12.2	V
Output Current					35	A
$f_{sw}$	Operating Frequency			150		kHz
	Efficiency	48V to 12V at 37A		96		%

### Boost Mode

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$V_2$	Supply Range		8		14	V
$V_1$	Output Voltage		47	48	49	V
Output Current					7	A
$f_{sw}$	Operating Frequency			150		kHz
	Efficiency	12V to 48V at 9A		94		%

## BOARD PHOTO



## QUICK START PROCEDURE

It is highly recommended that the user first evaluates the board in buck mode only, then in boost mode only before moving to bidirectional evaluation. In bidirectional operation, make sure that the any power supply connected to V1 or V2 is reverse current protected or capable of sinking current. A battery or bank of super caps may also be required to compensate for a slow turn on time the power supply may have. Further, for ease of evaluation, it is recommended to start with a minimum load of 1A in buck mode. Refer to the following procedure:

1. Tie DRxN pin to INTV<sub>CC</sub>. Header H1 pins 9 and 13.
2. With power off, connect the input power supply to V1 (48V) and GND (input return).
3. Connect the 8.0V to 14V output load between V2 and GND.
4. Connect the DVMs to the input and the output.
5. Turn on the V1 power supply and then check for the proper V2 voltage. V2 should be between 8.0V to 14V, depending on the type of load.
6. Once the proper output voltages are established, adjust the loads within the operating range and observe the output voltage regulation, ripple voltage and other parameters.
7. Once you have completed evaluating buck mode of operation, reverse the connections by connecting a source to V2 (12V) and a load to V1. Tie DRxN pin to GND. Header pins 9 and 14.
8. Once satisfied, the user can now evaluate in bidirectional mode of operation by either directly driving the DRxN pin or floating DRxN and letting the LT8228 self-determine the operating mode.

## QUICK START PROCEDURE

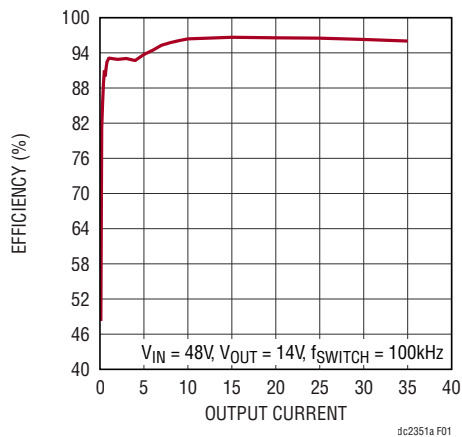


Figure 1. Buck Mode Efficiency

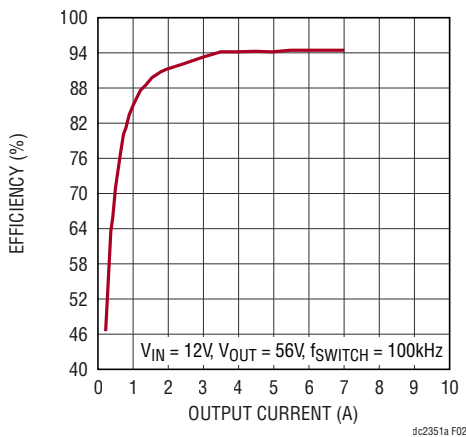


Figure 2. Boost Mode Efficiency

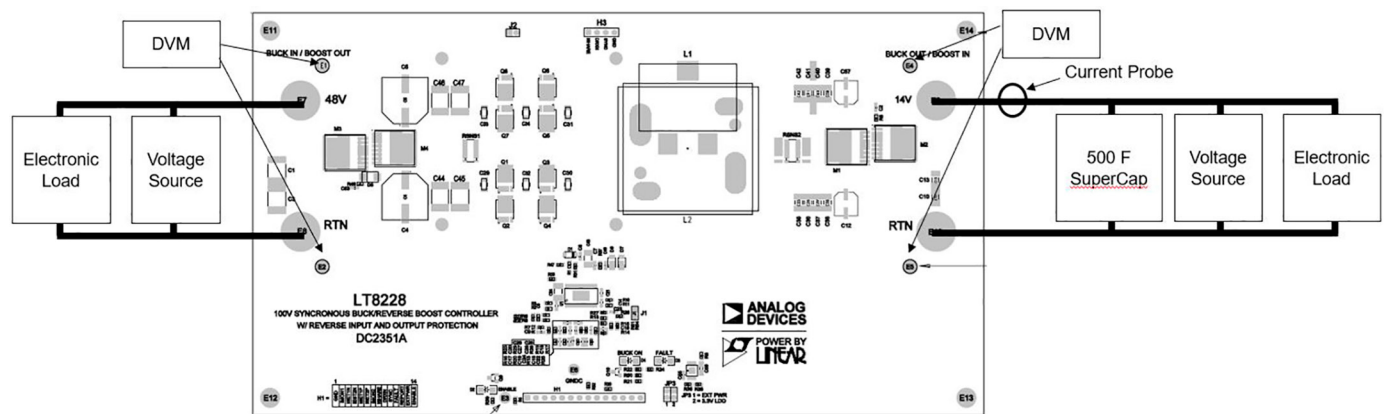


Figure 3. Test Set Up of DC2351A

QUICK START PROCEDURE

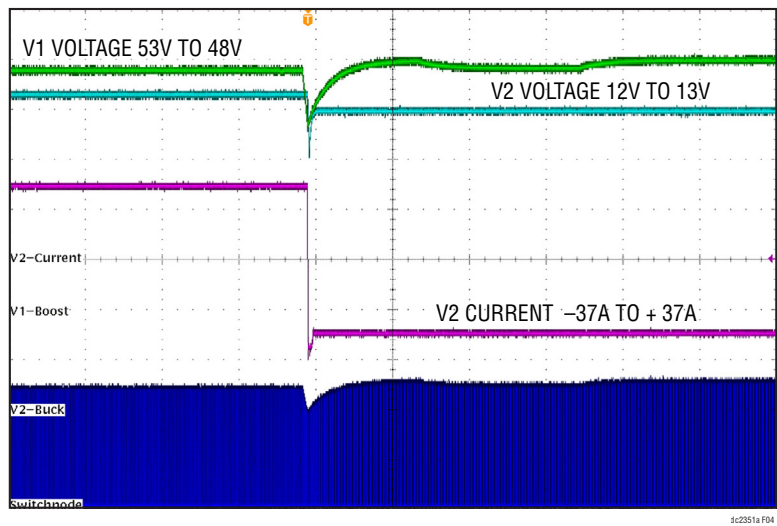


Figure 4. Transition from Boost to Buck (Current = 25A/Div)

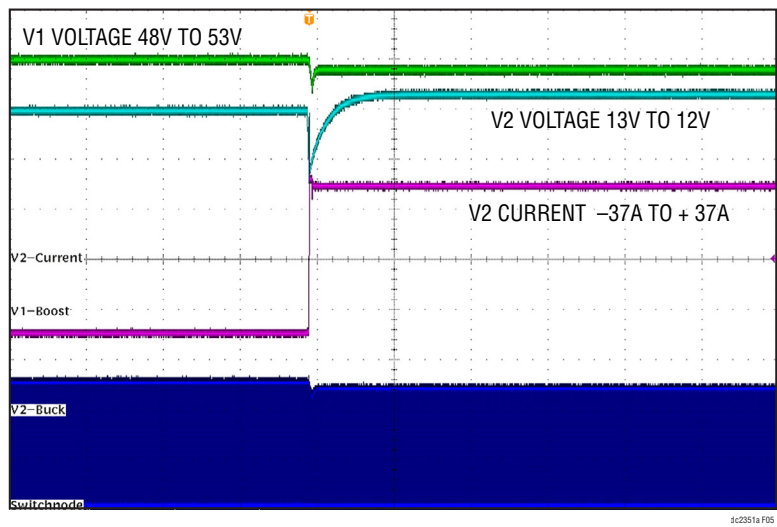


Figure 5. Transition from Buck to Boost (Current = 25A/Div)

# QUICK START PROCEDURE

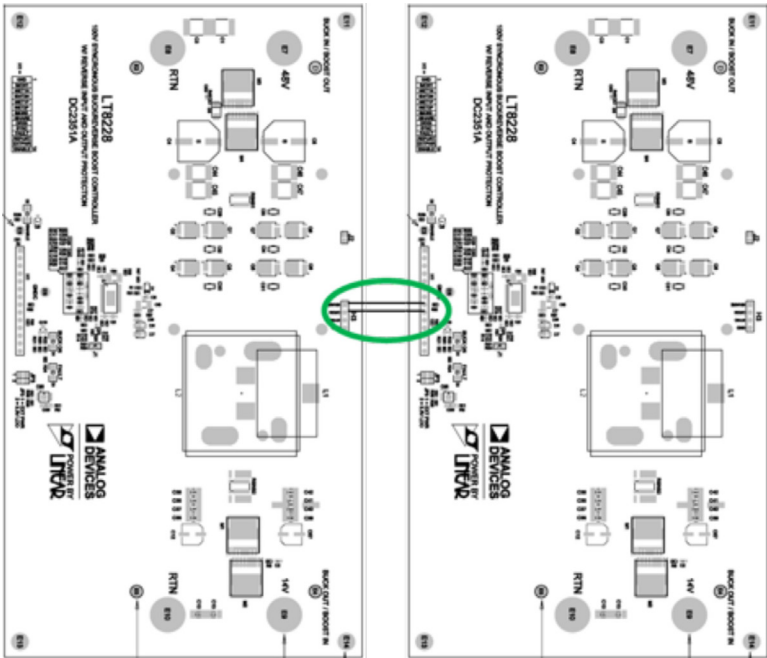


Figure 6. Configuring 2 Boards for 2-Phase Parallel Operation

Connect iShare and DRxN pins together. Feed external clock to synchronize boards to the sync input pin on the header. Load and source connections the same as Figure 3.

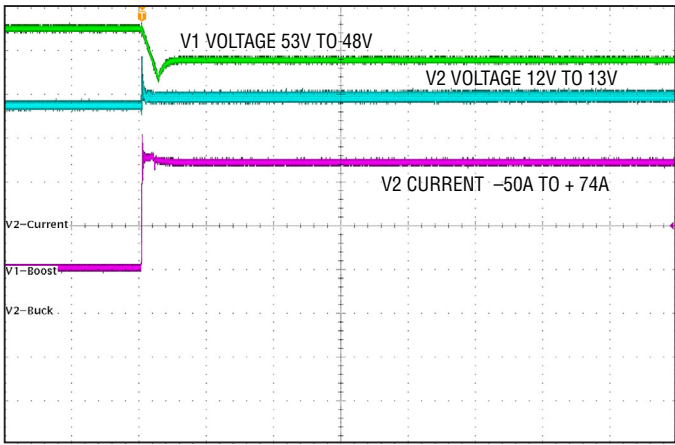


Figure 7. Transition from Boost to Buck (Current = 50A/Div)

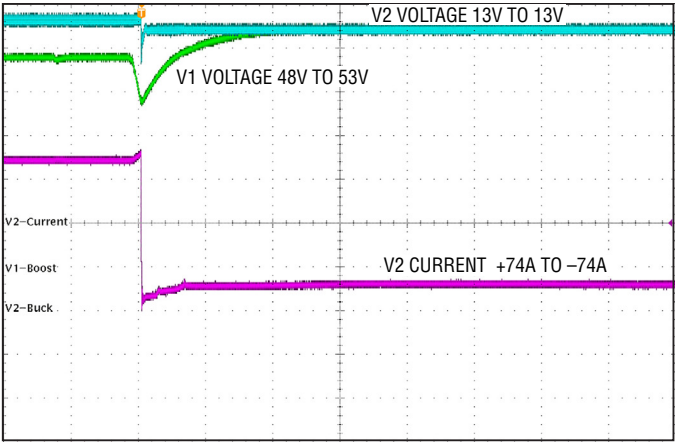


Figure 8. Transition from Boost to Buck (Current = 50A/Div)

## QUICK START PROCEDURE

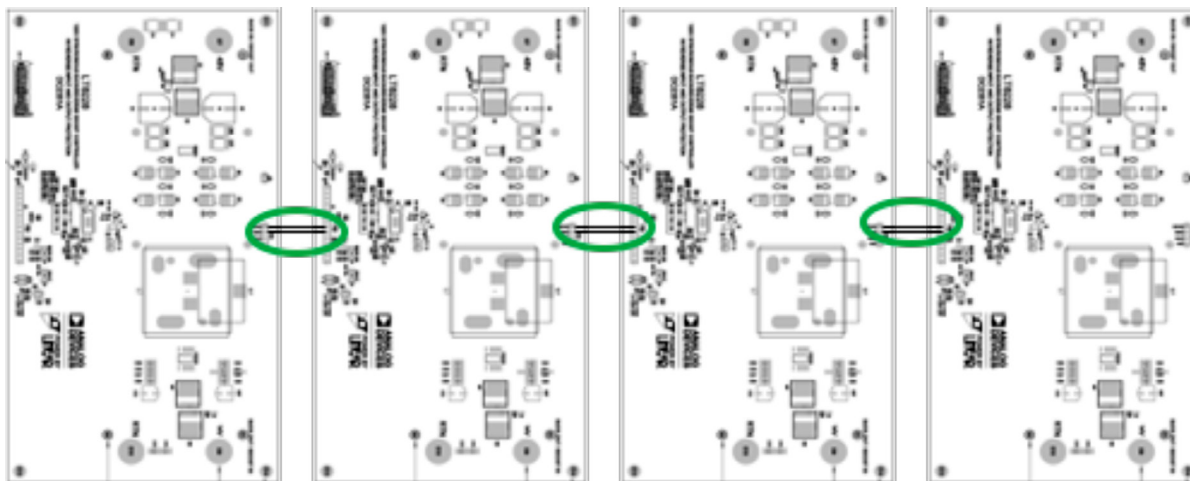


Figure 9. Configuring 4 Boards for 4-Phase Operation

Connect iShare and DRxN pins together. Feed external clock to synchronize boards to the sync input pin on the header. Load and source connections the same as Figure 3.

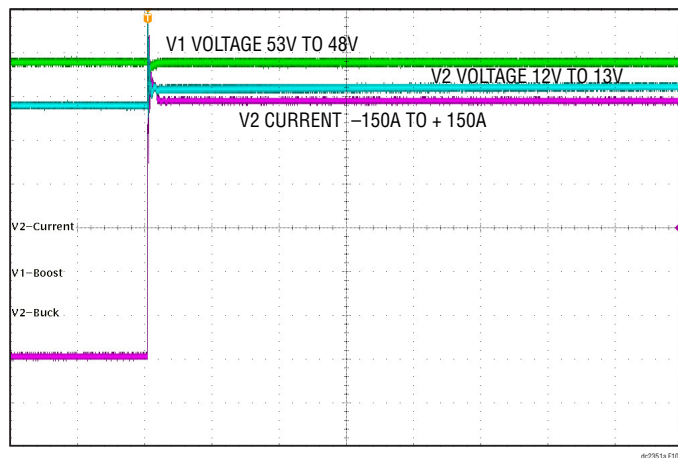


Figure 10. Transition from Boost to Buck (Current = 50A/Div)

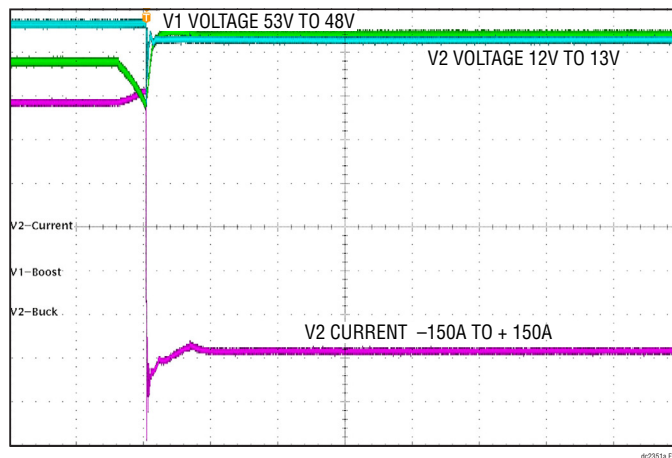


Figure 11. Transition from Boost to Buck (Current = 50 A/Div)

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
1	2	C1, C3	CAP, 15 $\mu$ F, X7S, 100V, 20%, 2220, AEC-Q200	CGA9P3X7S2A156M250KB
2	1	C2	CAP, 1000pF, C0G, 100V, 5%, 0603, AEC-Q200	CGA3E2C0G2A102J080AA, C0603C102J1GACAUTO
3	2	C4, C5	CAP, 68 $\mu$ F, ALUM, 80V, 20%, SMD, AEC-Q200	EEV-FK1K680Q
4	1	C7	CAP, 4.7 $\mu$ F, X5R, 25V, 10%, 0603	GRM188R61E475KE15D, C1608X5R1E475K080AC
5	1	C8	CAP, 0.1 $\mu$ F, X7S, 100V, 10%, 0603, AEC-Q200	CGA3E3X7S2A104K080AB
6	10	C10, C13, C35, C36, C37, C38, C39, C40, C41, C42	CAP, 22 $\mu$ F, X7R, 25V, 20%, 1210, AEC-Q200	TMK325B7226MMHP, CGA6P3X7R1E226M250AB
7	1	C12	CAP, 100 $\mu$ F, ALUM. ELECT., 25V, 20%, 6.3 $\times$ 7.7mm SMD, D8, AEC-Q200	EEHZA1E101XP
8	7	C15, C17, C18, C19, C20, C22, C23	CAP, 0.01 $\mu$ F, X8R, 50V, 10%, 0603, AEC-Q200	GCM188R91H103KA37D, CGA3E2X8R1H103K080AA
9	1	C21	CAP, 2.2 $\mu$ F, X7R, 10V, 20%, 0603	C1608X7R1A225M080AC
10	1	C24	CAP, 0.1 $\mu$ F, X7R, 50V, 10%, 0603, AEC-Q200	CGA3E2X7R1H104K, CGA3E2X7R1H104K080AA
11	1	C25	CAP, 0.047 $\mu$ F, X7S, 100V, 10%, 0603	C1608X7S2A473K080AB
12	1	C26	CAP, 0.22 $\mu$ F, X7R, 50V, 10%, 0603, AEC-Q200	GCM188R71H224KA64D, CGA3E3X7R1H224K080AB
13	1	C27	CAP, 220pF, C0G, 50V, 5%, 0603	06035A221JAT2A, GCM1885C1H221JA16D
14	1	C28	CAP, 470pF, X7R, 10V, 10%, 0603	885012206006
15	6	C29, C30, C31, C32, C33, C34	CAP, 1 $\mu$ F, X7R, 100V, 10%, 1206, AEC-Q200	CGA5L2X7R2A105K160AA
16	2	C43, C54	CAP, 4.7 $\mu$ F, X7S, 100V, 10%, 1210, AEC-Q200	GCM32DC72A475KE02L, CGA6M3X7S2A475K200AB
17	4	C44, C45, C46, C47	CAP, 33 $\mu$ F, X7S, 100V, 20%, 2220, AEC-Q200, PRELIM	CAA572X7S2A336M
18	1	C48	CAP, 0.015 $\mu$ F, X7R, 16V, 10%, 0603, HIGH RELIABILITY	CGJ3E2X7R1C153K080AA
19	1	C53	CAP, 3300pF, X7R, 25V, 10%, 0603	06033C332KAT2A, C0603C332K3RACTU
20	1	C55	CAP, 2.2 $\mu$ F, X7S, 16V, 10%, 0603, AEC-Q200	CGA3E1X7S1C225K080AC
21	1	C56	CAP, 1 $\mu$ F, X7S, 100V, 20%, 0805	GRJ21BC72A105ME11L, C2012X7S2A105M, C2012X7S2A105M125AB
22	1	D1	DIODE, RECT., 400V, 1A, SOD123F, AEC-Q101	US1GWF-7
23	2	D2, D4	LED, GREEN, WATERCLEAR, 1206	150120GS75000
24	1	D3	LED, RED, WATERCLEAR, 1206	150120RS75000
25	1	D5	DIODE, TVS, 60V, 400W, DO-214AC	824501601
26	2	D6, D7	DIODE, SCHOTTKY, 100V, 1A, POWERDI-123, AEC-Q101	DFLS1100Q-7
27	4	E1, E2, E4, E5	TEST POINT, TURRET, 0.094" MTG. HOLE, PCB 0.062" THK	2501-2-00-80-00-00-07-0
28	2	E3, E6	TEST POINT, TURRET, 0.064" MTG. HOLE, PCB 0.062" THK	2308-2-00-80-00-00-07-0
29	4	E7, E8, E9, E10	EVAL BOARD STUD HARDWARE SET, #10-32	720-0010
30	1	H1	CONN., RECPT, 1 $\times$ 14, 0.100" (2.54mm), TH	SSW-114-01-G-S
31	1	H3	CONN., RECEPT, 1 $\times$ 4, 0.100" (2.54mm), TH	SSW-104-01-F-S
32	1	J1	CONN., HDR, MALE, 1 $\times$ 2, 2mm, VERT, STR, THT, 10 $\mu$ Au	TMM-102-02-L-S
33	1	JP3	CONN., HDR, MALE, 2 $\times$ 2, 2mm, VERT, STR, THT, 10 $\mu$ Au	TMM-102-02-L-D
34	1	L2	IND., 10 $\mu$ H, PWR, 20%, 60A, 1m $\Omega$ , 36 $\times$ 31 $\times$ 41mm	7443763540100
35	1	LB1	LABEL SPEC, DEMO BOARD SERIAL NUMBER	THT-96-717-10
36	4	M1, M2, M3, M4	XSTR., MOSFET, N-CHAN, 60V, 300A, PG-HSOF-8-1	IPT007N06NATMA1

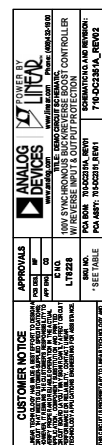
# DEMO MANUAL DC2351A

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
37	4	MP1, MP2, MP3, MP4	STANDOFF, NYLON, SNAP-ON, 0.25" (6.4mm)	8831702931000
38	1	PCB1	PCB, DC2351A	600-DC2351A
39	8	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8	XSTR., MOSFET, N-CH, 80V, 70A, PG-TDSON-8, AEC-Q101	IAUC70N08S5N074, IAUC70N08S5N074ATMA1
40	2	Q9, Q16	XSTR., MOSFET, N-CH, 60V, 220mA, SOT23-3, AEC-Q101	2N7002A-13, 2N7002A-7
41	6	R1, R9, R33, R47, R53, R54	RES., 0 $\Omega$ , 1/10W, 0603, AEC-Q200	ERJ3GEY0R00V, CRCW06030000Z0EA
42	4	R2, R3, R10, R11	RES., 1.5k, 0.1%, 1/10W, 0603, AEC-Q200	ERA-3AEB152V
43	1	R4	RES., 22.1k, 1%, 1/10W, 0603, AEC-Q200	NRC06F2212TRF, CRCW060322K1FKEA
44	2	R5, R48	RES., 10k, 1%, 1/10W, 0603, AEC-Q200	ERJ3EKF1002V, CRCW060310K0FKEA, CRCW060310K0FKEB, RK73H1JTTD1002F
45	1	R6	RES., 365k, 1%, 1/10W, 0603, AEC-Q200	RK73H1JTTD3653F, ERJ3EKF3653V, CRCW0603365KFKEA
46	2	R7, R14	RES., 60.4k, 1%, 1/10W, 0603, AEC-Q200	CRCW060360K4FKEA, ERJ3EKF6042V
47	2	R8, R18	RES., 12.1k, 1%, 1/10W, 0603, AEC-Q200	ERJ3EKF1212V, CRCW060312K1FKEA
48	1	R12	RES., 1.33k, 1%, 1/10W, 0603, AEC-Q200	ERJ3EKF1331V, CRCW06031K33FKEA
49	5	R13, R16, R19, R20, R26	RES., 24.3k, 1%, 1/10W, 0603, AEC-Q200	CRCW060324K3FKEA
50	1	R15	RES., 80.6k, 1%, 1/10W, 0603	CRCW060380K6FKEA, NRC06F8062TRF, RC0603FR-0780K6L
51	1	R17	RES., 5.62k, 1%, 1/10W, 0603	ERJ3EKF5621V, CRCW06035K62FKEA, RC0603FR-075K62L
52	1	R21	RES., 6.65k, 1%, 1/10W, 0603	NRC06F6651TRF, CRCW06036K65FKEA, RC0603FR-076K65L
53	3	R22, R24, R39	RES., 4.99k, 1%, 1/10W, 0603, AEC-Q200	ERJ3EKF4991V, CRCW06034K99FKEA, NRC06F4991TRF
54	2	R23, R25	RES., 40.2k, 1%, 1/10W, 0603, AEC-Q200	NRC06F4022TRF, CRCW060340K2FKEA, ERJ3EKF4022V
55	1	R27	RES., 68k, 1%, 1/10W, 0603	RC0603FR-0768KL
56	2	R28, R29	RES., 1k, 1%, 1/10W, 0603, AEC-Q200	CRCW06031K00FKEA, NRC06F1001TRF, ERJ3EKF1001V
57	1	R30	RES., 100k, 1%, 1/10W, 0603, AEC-Q200	CRCW0603100KFKEA, NRC06F1003TRF, ERJ3EKF1003V
58	3	R31, R32, R37	RES., 1 $\Omega$ 5%, 1/10W, 0603, AEC-Q200	ERJ3GEYJ1R0V
59	1	R36	RES., 499k, 1%, 1/10W, 0603, AEC-Q200	CRCW0603499KFKEA, NRC06F4993TRF, ERJ3EKF4993V
60	1	R38	RES., 316k, 1%, 1/10W, 0603, AEC-Q200	NRC06F3163TRF, CRCW0603316KFKEA
61	1	R50	RES., 1.21M $\Omega$ , 1%, 1/10W, 0603, AEC-Q200	CRCW06031M21FKEA
62	1	RSNS1	RES., 0.002 $\Omega$ , 2%, 2W, 2512, LONG SIDE, AEC-Q200	KRL6432T4-M-R002-G-T1
63	1	RSNS2	RES., 0.002 $\Omega$ , 1%, 4W, 4026, 4-TERM., SENSE, AEC-Q200	CSS4J-4026K-2L00F
64	1	U1	IC, BUCK/BOOST CONTROLLER, TSSOP-38	LT8228EFE#PBF
65	1	U3	IC, LDO $\mu$ PWR LINEAR REG., MSOP-8	LT3010EMS8E#PBF, LT3010EMS8E#TRPBF



## SCHEMATIC DIAGRAM



NOTE: UNLESS OTHERWISE SPECIFIED  
ALL RESISTORS AND CAPACITORS ARE 0903 PACKAGE.

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**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

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