LTM4712 $36V_{IN}$, 12A Buck-Boost µModule Regulator

DESCRIPTION

Demonstration circuit 3189A features the LTM®4712, a high efficiency, buck-boost µModule® regulator with a 5V to 36V input voltage range and 1V to 36V output voltage range. The output is capable of 12A in buck and buck-boost modes, and 6A under $12V_{IN}$ and $24V_{OUT}$. Derating is necessary for certain V_{IN}, V_{OUT}, frequency and thermal conditions. For more information, see the LTM4712 data sheet.

The DC3189A demo board features a constant-current mode (CCM) to deliver a precise, regulated current while the load may vary.

The DC3189A demo board is optimized using a default frequency of 400kHz. The current mode architecture used in the LTM4712 is peak-current mode control. The LTM4712 operates in continuous current mode by default but can be placed in pulse-skipping mode to optimize efficiency at light loads.

The LTM4712 is offered in a 16mm × 16mm × 8.34mm ball grid array (BGA) package suitable for automated assembly by standard surface mount equipment. The LTM4712 module package features an inductor on top of the molded substrate for improved heat sinking capability.

The LTM4712 data sheet gives a complete description of the device, including operation and application information. Refer to the data sheet in conjunction with this demo manual prior to working on or modifying DC3189A.

Design files for this circuit board are available.

BOARD PHOTO

Part marking is either ink mark or laser mark

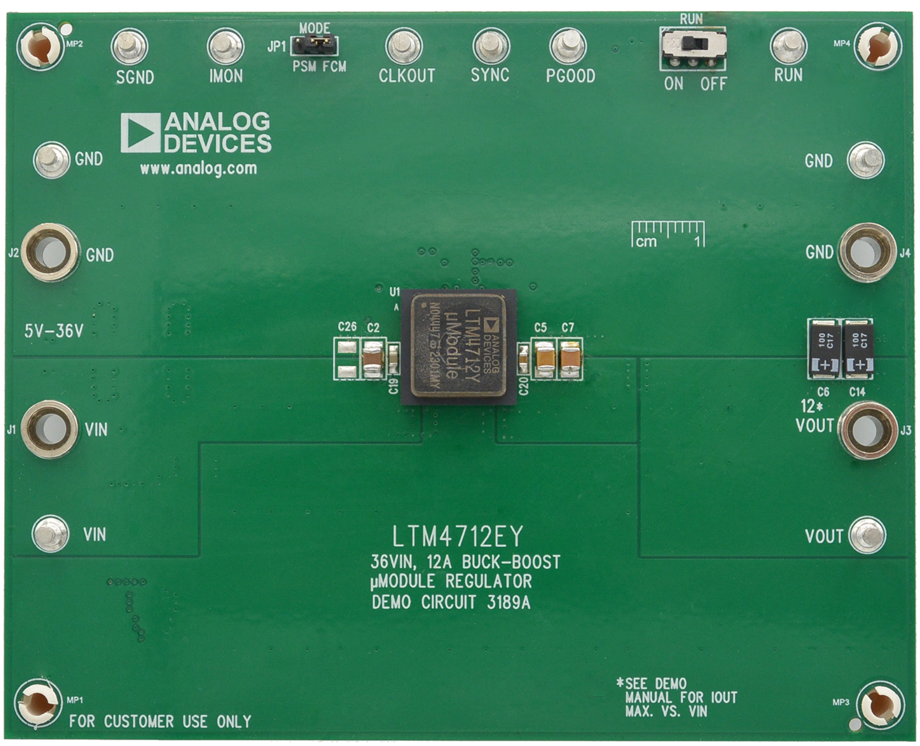


Figure 1. DC3189A Demo Board

PERFORMANCE SUMMARY Specifications are at T_A = 25°C

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{IN}	Input Voltage Range		5		36	V
V_{OUT}	Output Voltage	R_{FB} = 9.09kΩ		12		V
f_{SW}	Switching Frequency	R_{FREQ} = 140kΩ		400		kHz
I_{OUT}	Maximum Output Current	V_{IN} = 10V to 36V, f_{SW} = 400kHz			12	A
I_{OUT}	Maximum Output Current	V_{IN} = 5V to 10V, f_{SW} = 400kHz			6	A
η	Efficiency (Figure 5)	V_{IN} = 12V, I_{OUT} = 12A, f_{SW} = 400kHz		96.25		%
	Peak Efficiency	V_{IN} = 24V, I_{OUT} = 7.2A, f_{SW} = 400kHz		97.1		%

QUICK START PROCEDURE

The DC3189A is an easy way to evaluate the performance of the LTM4712. See Figure 2 for the proper measurement equipment setup, and use the following procedure:

1. With power off, connect the input power supply to VIN (J1) and to GND (J2).
2. Connect the output load to VOUT (J3) and to GND (J4).
3. Connect DMM between test points VIN (E7) and GND (E8) to measure input voltage. Connect another DMM between test points VOUT (E12) and GND (E13) to measure DC output voltage.
4. Prior to powering on, ensure RUN switch is in the "ON" position. Turn on power at the input.
5. Set the voltage of the DC power supply between 5V to 36V.

   NOTE: Make sure the input voltage does not exceed 36V. Check that output voltage measures 12V ±0.5% (or 11.94V to 12.06V).
6. Once the proper output voltage is established, adjust the load within the operating range and measure the output voltage regulation, ripple voltage, efficiency, and other parameters.

Demo Board Features

To measure the input/output voltage ripples properly, do not use the long ground lead on the oscilloscope probe. See Figure 3 for the proper probing technique of input/output voltage ripples. Short, stiff leads need to be soldered to the (+) and (–) terminals of an input or output capacitor. The probe's ground ring needs to touch the (–) lead and the probe tip needs to touch the (+) lead.

Current Monitoring

DC3189A demo board features output current monitoring (I_{MON}). By measuring the voltage between ISP and ISN, a voltage directly proportional to the measured current can be observed and used to accurately determine the amount of current leaving LTM4712 as shown in Figure 4. To accurately monitor the output current, a 2mΩ sense resistor separates the output bulk capacitors and output ceramic capacitors on the V_{OUT} line. The ISP and ISN pins are used to measure the voltage drop across the sense resistor, and the respective current values are given by $I_{OUT} = [(V_{IMON} – 0.2V)/20]/2mΩ$.

Constant-Current Mode

The LTM4712 can be enabled to produce a constant-current output after simple component selection. The µModule maintains constant output current according to (I_{SET}) voltage limit and R_{SENSE} value. $I_{OUT} = V_{SENSE\_MAX}/R_{SENSE}$. V_{SENSE} is determined by I_{SET} voltage as shown in Figure 4. Refer to the LTM4712 data sheet for more detailed information.

NOTE: V_{OUT} needs to be set higher than $I_{OUT} • R_{LOAD}$ to maintain constant-current regulation. For example, V_{OUT} is set to 12V (9.09kΩ on R_{FB}) and R_{SENSE} voltage limit is set to 10mV (26.3kΩ on I_{SET}). When a resistive load of 12Ω is placed on the output, I_{OUT} follows $12V_{OUT}/12Ω$ = 1A. As the value of R_{LOAD} decreases, I_{OUT} increases according to this equation. When I_{OUT} reaches 5A,

QUICK START PROCEDURE

R_{SENSE} voltage threshold is reached (10mV = 5A • 2mΩ). If R_{LOAD} decreases further, instead of allowing I_{OUT} to increase, COMP voltage is pulled lower and V_{OUT} changes to support a constant-current value of 5A. Therefore, if R_{LOAD} decreases to 2Ω, V_{OUT} decreases to $10V_{OUT}$ to maintain 5A load (10V/2Ω).

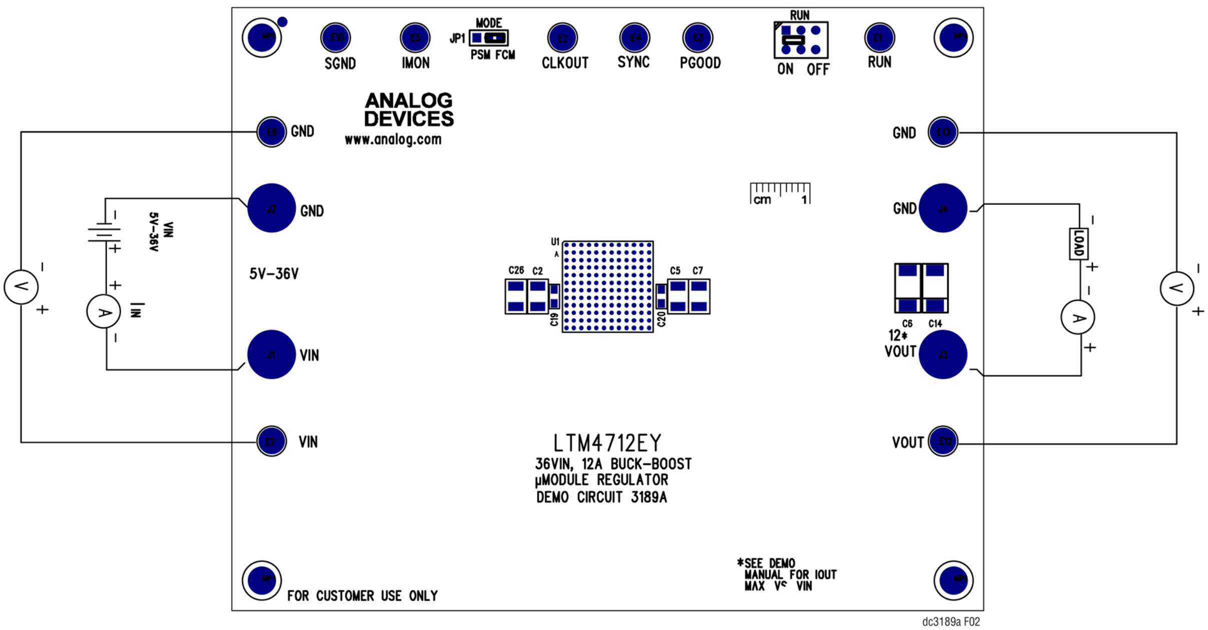


Figure 2. DC3189A Demo Board Test Setup

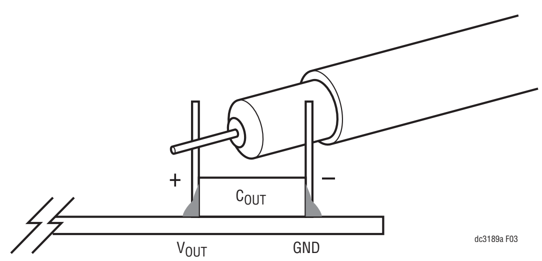


Figure 3. Scope Probe Placement for Measuring Input or Output Ripple Voltage

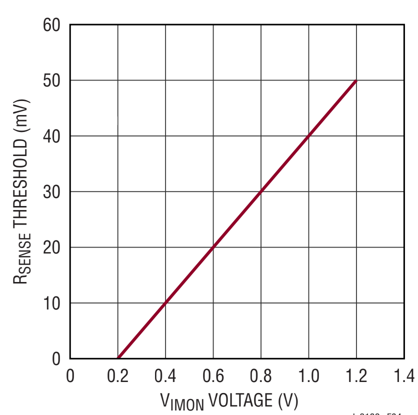


Figure 4. R_{SENSE} Voltage Threshold vs V_{IMON}

QUICK START PROCEDURE

Modifying Output Voltage

The DC3189A demo board can supply various output voltage configurations from 1V to 36V. See Table 1 for the recommended component changes when changing the supply output voltage and the recommended part numbers.

Table 1. Recommended Components and Configurations

C_{OUT} (CERAMIC)			C_{OUT} (BULK)		
VENDOR	**VALUE**	**PART NUMBER**	**VENDOR**	**VALUE**	**PART NUMBER**
Murata	10µF, 50V, 1210	GCM32EC71H106KA03	Panasonic	33µF, 50V	50SVPK33M
TDK	22µF, 16V, 1210	C3225X7R1C226K	Panasonic	82µF, 35V	35SVPK82M
			Panasonic	100µF, 16V	16TQC100MYF

Various Output Voltage Configurations

V_{OUT} (V)	R_{FB} R3 (kΩ)	C_{OUT} (CERAMIC)								C_{OUT} (BULK)	
		C5 (µF)	C7 (µF)	C16 (µF)	C28 (µF)	C29 (µF)	C30 (µF)	C31 (µF)	C33 (µF)	C6 (µF)	C14 (µF)
5	25	22	22	OPT	22	22	22	22	OPT	100	100
12	9.09	22	22	OPT	22	22	22	22	OPT	100	100
24	4.32	10	10	10	10	10	10	10	10	82	OPT
36	2.87	10	10	10	10	10	10	10	10	33	33

TYPICAL PERFORMANCE CHARACTERISTICS

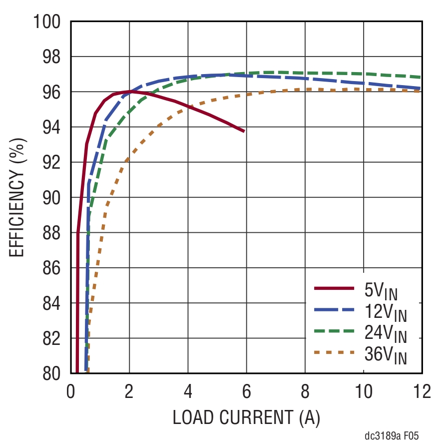


Figure 5. Efficiency vs Load Current ($12V_{OUT}$ Without EMI Filter, T_A = 25°C)

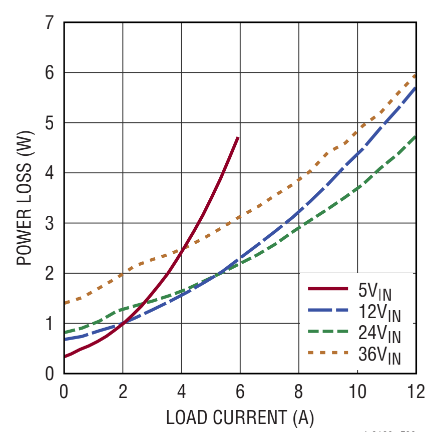
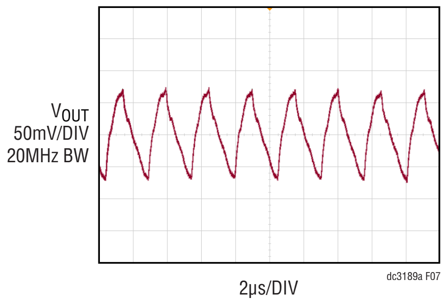


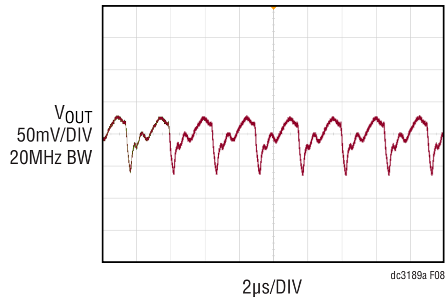
Figure 6. Power Loss vs Load Current ($12V_{OUT}$ Without EMI Filter, T_A = 25°C)

TYPICAL PERFORMANCE CHARACTERISTICS



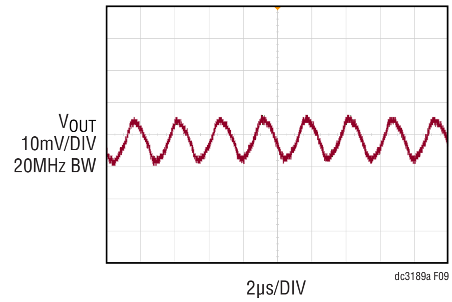
V_{IN} = 5V, V_{OUT} = 12V, I_{OUT} = 6A,
f_{SW} = 400kHz,
V_{OUT} PEAK TO PEAK = 145mV

Figure 7. Output Voltage Ripple (Boost Mode)



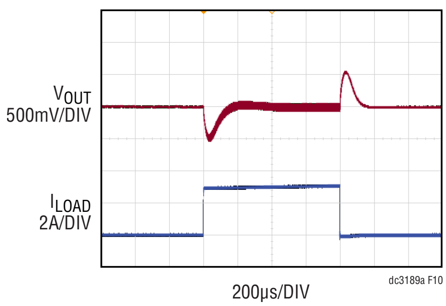
V_{IN} = 12V, V_{OUT} = 12V, I_{OUT} = 12A,
f_{SW} = 400kHz,
V_{OUT} PEAK TO PEAK = 92mV

Figure 8. Output Voltage Ripple (Buck-Boost Mode)



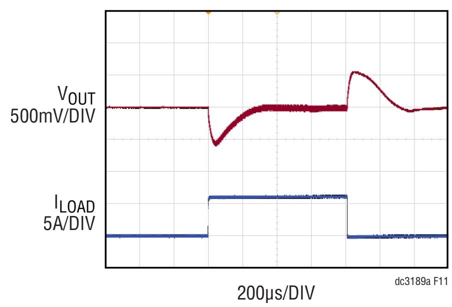
V_{IN} = 24V, V_{OUT} = 12V, I_{OUT} = 12A,
f_{SW} = 400kHz,
V_{OUT} PEAK TO PEAK = 31mV

Figure 9. Output Voltage Ripple (Buck Mode)



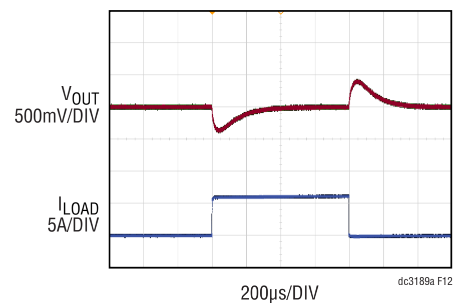
V_{IN} = 5V, V_{OUT} = 12V, I_{OUT} = 0A TO 3A,
f_{SW} = 400kHz,
V_{OUT} PEAK TO PEAK = 1.06V

Figure 10. Load Transient Response (Boost Mode)



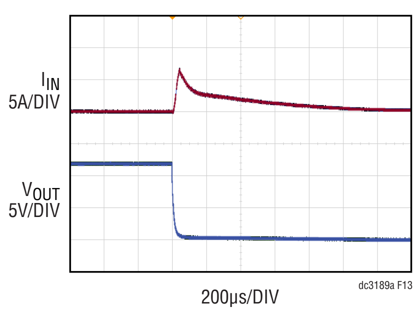
V_{IN} = 12V, V_{OUT} = 12V, I_{OUT} = 0A TO 6A,
f_{SW} = 400kHz,
V_{OUT} PEAK TO PEAK = 1.16V

Figure 11. Load Transient Response (Buck-Boost Mode)



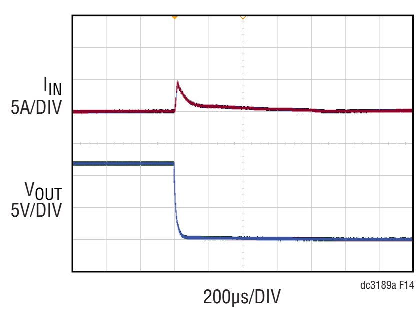
V_{IN} = 24V, V_{OUT} = 12V, I_{OUT} = 0A TO 6A,
f_{SW} = 400kHz,
V_{OUT} PEAK TO PEAK = 840mV

Figure 12. Load Transient Response (Buck Mode)



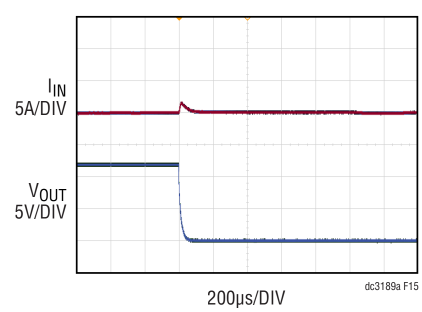
V_{IN} = 5V, V_{OUT} = 12V, I_{OUT} = 0A,
f_{SW} = 400kHz

Figure 13. Short-Circuit Response (Boost Mode)



V_{IN} = 12V, V_{OUT} = 12V, I_{OUT} = 0A,
f_{SW} = 400kHz

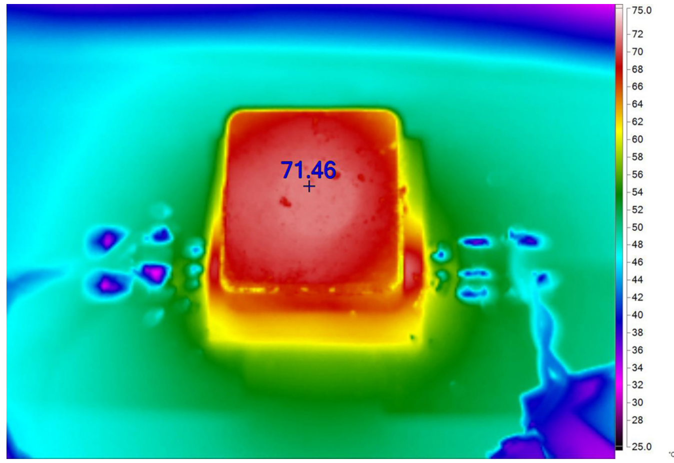
Figure 14. Short-Circuit Response (Buck-Boost Mode)



V_{IN} = 24V, V_{OUT} = 12V, I_{OUT} = 0A,
f_{SW} = 400kHz

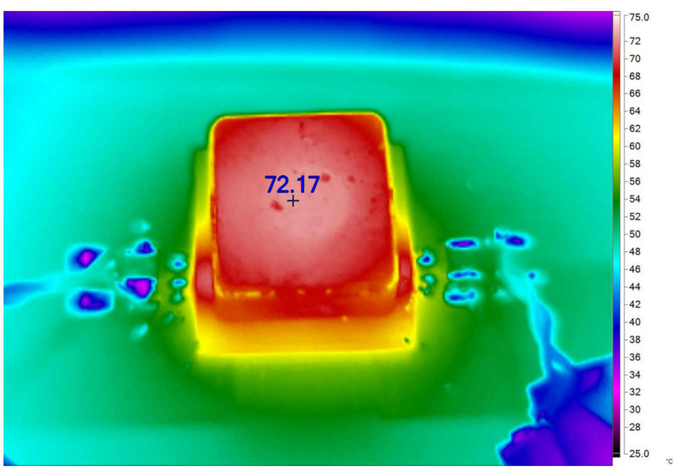
Figure 15. Short-Circuit Response (Buck Mode)

TYPICAL PERFORMANCE CHARACTERISTICS



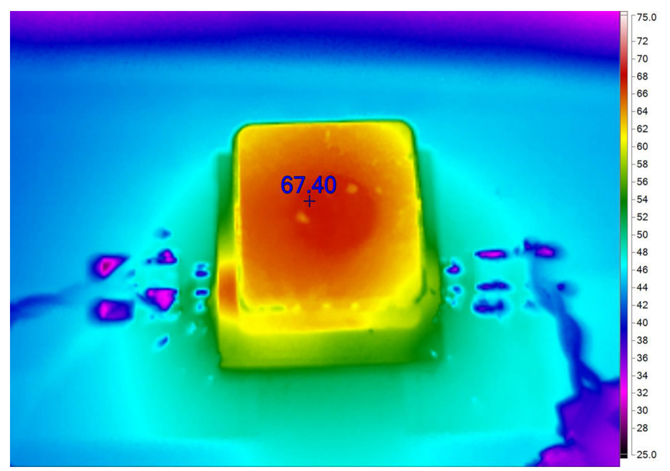
Boost Mode			
V_{IN} (V)	MAX CASE TEMP (°C)	V_{OUT} (V)	I_{OUT} (A)
5	71.5	12	6

Figure 16. Boost Mode Measured Thermal Captures Without Forced Airflow, T_A = 25°C



Buck-Boost Mode			
V_{IN} (V)	MAX CASE TEMP (°C)	V_{OUT} (V)	I_{OUT} (A)
12	72.17	12	12

Figure 17. Buck-Boost Mode Measured Thermal Captures Without Forced Airflow, T_A = 25°C



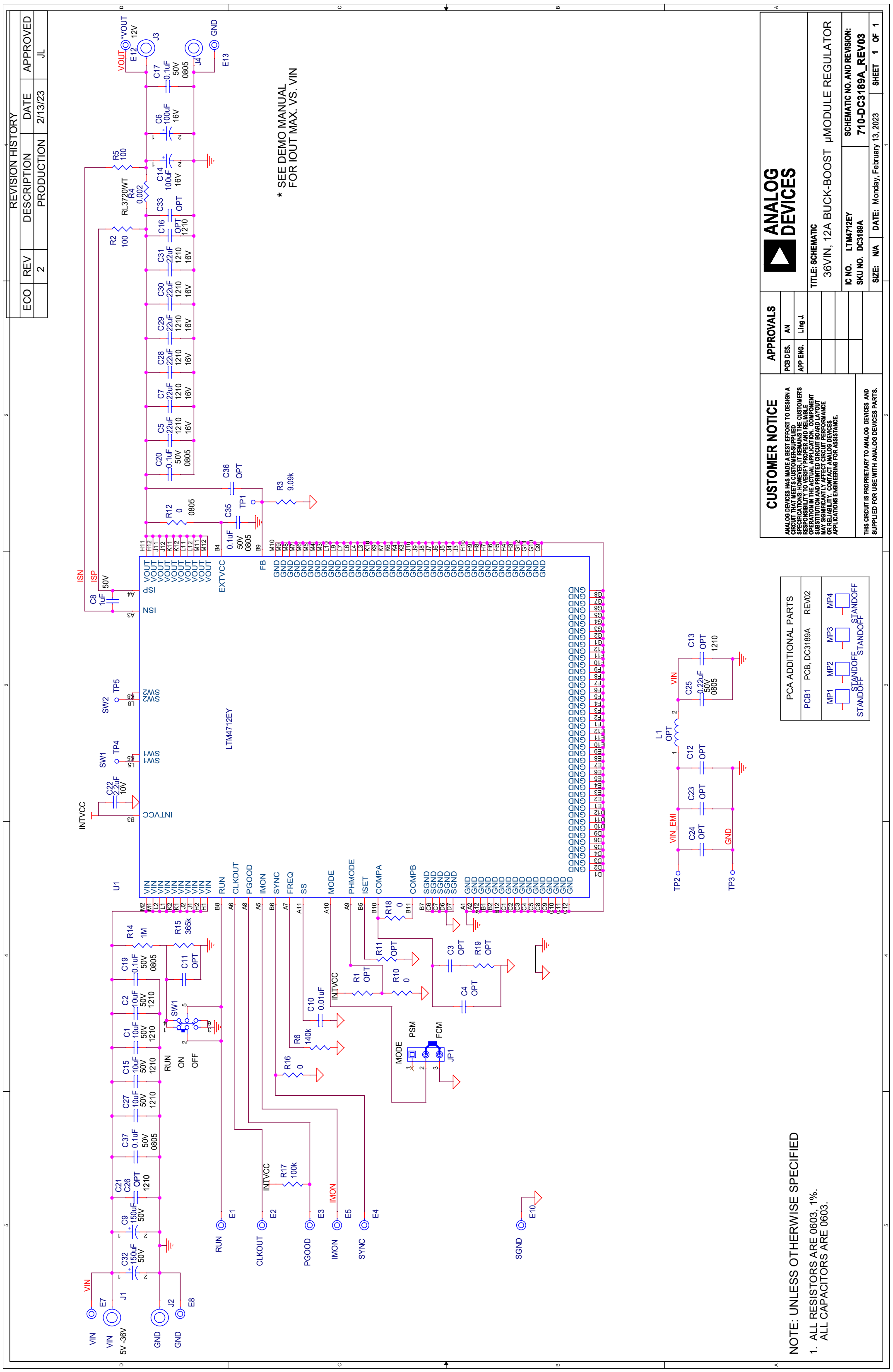
Buck Mode			
V_{IN} (V)	MAX CASE TEMP (°C)	V_{OUT} (V)	I_{OUT} (A)
24	67.4	12	12

Figure 18. Buck Mode Measured Thermal Captures Without Forced Airflow, T_A = 25°C

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	4	C1, C2, C15, C27	CAP., 10µF, X7R, 50V, 10%,1210	MURATA, GRM32ER71H106KA12L
2	6	C5, C7, C28-C31	CAP., 22µF, X7R, 16V, 10%, 1210	MURATA, GRM32ER71C226KEA8L
3	2	C6, C14	CAP., 100µF, TANT, POLY, 16V, 20%, 2917, POSCAP	PANASONIC, 16TQC100MYF
4	1	C8	CAP., 1µF, X5R, 50V, 10%, 0603	TDK, C1608X5R1H105K080AB
5	2	C9, C32	CAP., 150µF, ALUM ELECT, 50V, 20%, 10mm × 10.2mm, G, SMD, RADIAL, FK SERIES, AEC-Q200	PANASONIC, EEEFK1H151P
6	1	C10	CAP., 0.01µF, X7R, 25V, 10%, 0603	TDK, C1608X7R1H103K080AA
7	5	C17, C19, C20, C35, C37	CAP., 0.1µF, X7R, 50V, 10%, 0805	WURTH ELEKTRONIK, 885012207098
8	1	C22	CAP., 2.2µF, X7R, 10V, 10%, 0603	MURATA, GRM188R71A225KE15D
9	1	C25	CAP., 0.22µF, X7R, 50V, 10%, 0805	WURTH ELEKTRONIK, 885012207100
10	2	R2, R5	RES., 100Ω, 1%, 1/10W, 0603	VISHAY, CRCW0603100RFKEA
11	1	R3	RES., 9.09k, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06039K09FKEA
12	1	R4	RES., 0.002Ω, ±1%, 1W, 1508, LONG-SIDE TERM	SUSUMU, RL3720WT-R002-F
13	1	R6	RES., 140k, 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3EKF1403V
14	1	R14	RES., 1M, 1%, 1/10W, 0603, AEC-Q200	NIC, NRC06F1004TRF
15	1	R15	RES., 365k, 1%, 1/10W, 0603, AEC-Q200	KOA SPEER, RK73H1JTTD3653F
16	1	R17	RES., 100k, 1%, 1/10W, 0603	VISHAY, CRCW0603100KFKEA
17	1	U1	IC, 36V_{IN} 12A BUCK-BOOST µModule REGULATOR, BGA-144	ANALOG DEVICES, LTM4712EY#PBF
Additional Demo Board Circuit Components				
1	0	C3, C4, C11, C24, C36	CAP., OPTION, 0603	
2	0	C12, C13, C16, C21, C26, C33	CAP., OPTION, 1210	
3	0	C23	CAP., OPTION, 0805	
4	0	L1	IND., OPTION	
5	0	R1, R11, R19	RES., OPTION, 0603	
6	3	R10, R16, R18	RES., 0Ω,1/10W,0603,AEC-Q200	PANASONIC, ERJ3GEY0R00V
7	1	R12	RES., 0Ω, ±0.005%,0805	KEYSTONE, 5106
Hardware: For Demo Board Only				
1	10	E1-E5, E7, E8, E10, E12, E13	TEST POINT, TURRET, 0.094" MTG. HOLE, PCB 0.062" THK	MILL-MAX, 2501-2-00-80-00-00-07-0
2	4	J1-J4	CONN.,BANANA JACK, FEMALE, THT, NON-INSULATED, SWAGE, 0.218"	KEYSTONE, 575-4
3	1	JP1	CONN., HDR, MALE, 1×3, 2mm, VERT, ST, THT, NO SUBS. ALLOWED	WURTH ELEKTRONIK, 62000311121
4	4	MP1-MP4	STANDOFF, NYLON, SNAP-ON, 0.625"	KEYSTONE, 8834
5	1	SW1	SWITCH, SLIDE, DPDT, 0.3A, 6VDC, PTH	C&K, JS202011CQN
6	1	XJP1	CONN., SHUNT, FEMALE, 2-POS, 2mm	WURTH ELEKTRONIK, 60800213421

SCHEMATIC DIAGRAM



REVISION HISTORY

REV	DATE	DESCRIPTION	PAGE NUMBER
0	10/23	Initial Release.	—

ESD Caution

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.