LTC4041
2.5A Supercapacitor Backup Power Manager

DESCRIPTION

Demonstration circuit 2642A shows the LTC4041 supercapacitor backup power manager operating with either a stack of two series supercapacitors (DC2642A-A) or a single supercapacitor (DC2642A-B). The board demonstrates the design of a 5V rail with a short-term power backup using 10F supercapacitors.

The input current limit, charge current limit, charge voltage, power fail threshold, and boost voltage are all configurable through changing resistor values on the board. Test points for all monitoring pins and LED indicators on status pins are also available to assist in the evaluation.

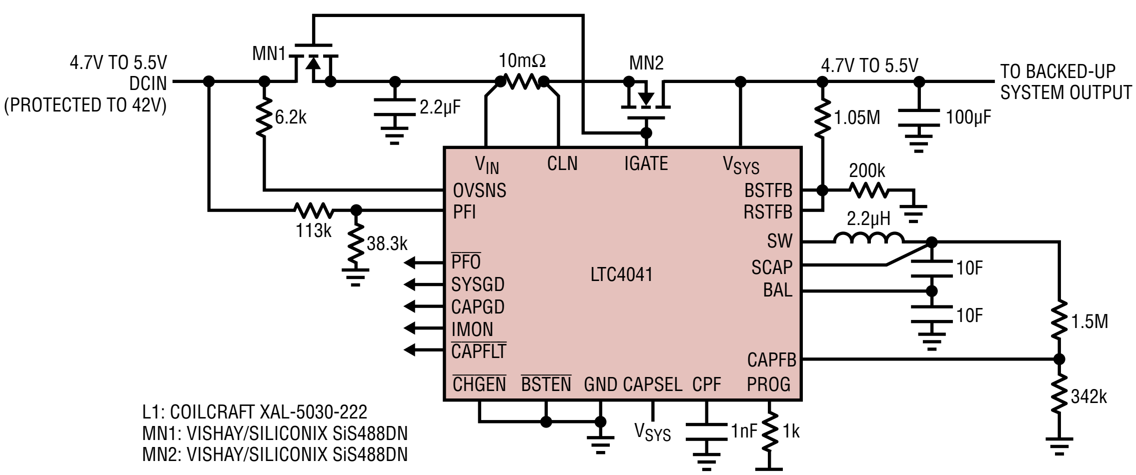
Design files for this circuit board are available at http://www.analog.com/DC2642A

PERFORMANCE SUMMARY

Specifications are at T_A = 25°C

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DCIN	Input Voltage Range	V_{PF} = 4.7V	4.7		5.5	V
$DCIN_{OV}$	DCIN Overvoltage Limit				42	V
V_{BOOST}	Backup Boost Voltage	R5 = 1.05MΩ, R2 = 200kΩ		5	5.5	V
V_{SYS}	System Voltage	V_{IN} > V_{PF} (with Hysteresis) V_{IN} < V_{PF} (with Hysteresis)		V_{IN} V_{BOOST}		V
V_{PF}	Power Fail Threshold Voltage	R1 = 113kΩ, R2 = 383kΩ		4.7		V
I_{IN}	Input Current Limit	RS1 = 10mΩ		2.5		A
I_{SCAP}	Charge Current Limit	R_{PROG} = 1kΩ		2	2.5	A

TYPICAL APPLICATION



QUICK START PROCEDURE

Refer to Figure 1 for the proper measurement equipment setup and jumper settings. Please follow the procedure below to familiarize yourself with the DC2642A.

1. Connect test equipment as shown in Figure 1. Ensure JP1 and JP2 are both in the ON position.
2. Enable PS1 and observe as the voltage on VM2 begins to rise. The voltage on VM1 should be approximately 5V. The CAPGD LED will turn on to indicate that the supercapacitor voltage is not yet in regulation.
3. Observe that the voltage on VM2 regulates at a default 4.5V on DC2642A-A or 2.4V on DC2642A-B. At this point, the CAPGD LED will turn off.
4. Enable LD1, then disable PS1 and observe that the voltage on VM1 remains regulated at 5V. The voltage on VM2 will begin to fall.
5. Observe that the $\overline{\text{PFO}}$ and CAPGD LEDs turn on to indicate that the DCIN voltage has fallen below the 4.7V power fail threshold and the supercapacitor voltage has fallen out of regulation.
6. Eventually, the supercapacitor voltage will fall enough that the VM1 voltage will fall out of regulation. As VM1 falls past ~4.625V, the SYSGD LED will turn on briefly before VM1 falls out of regulation.

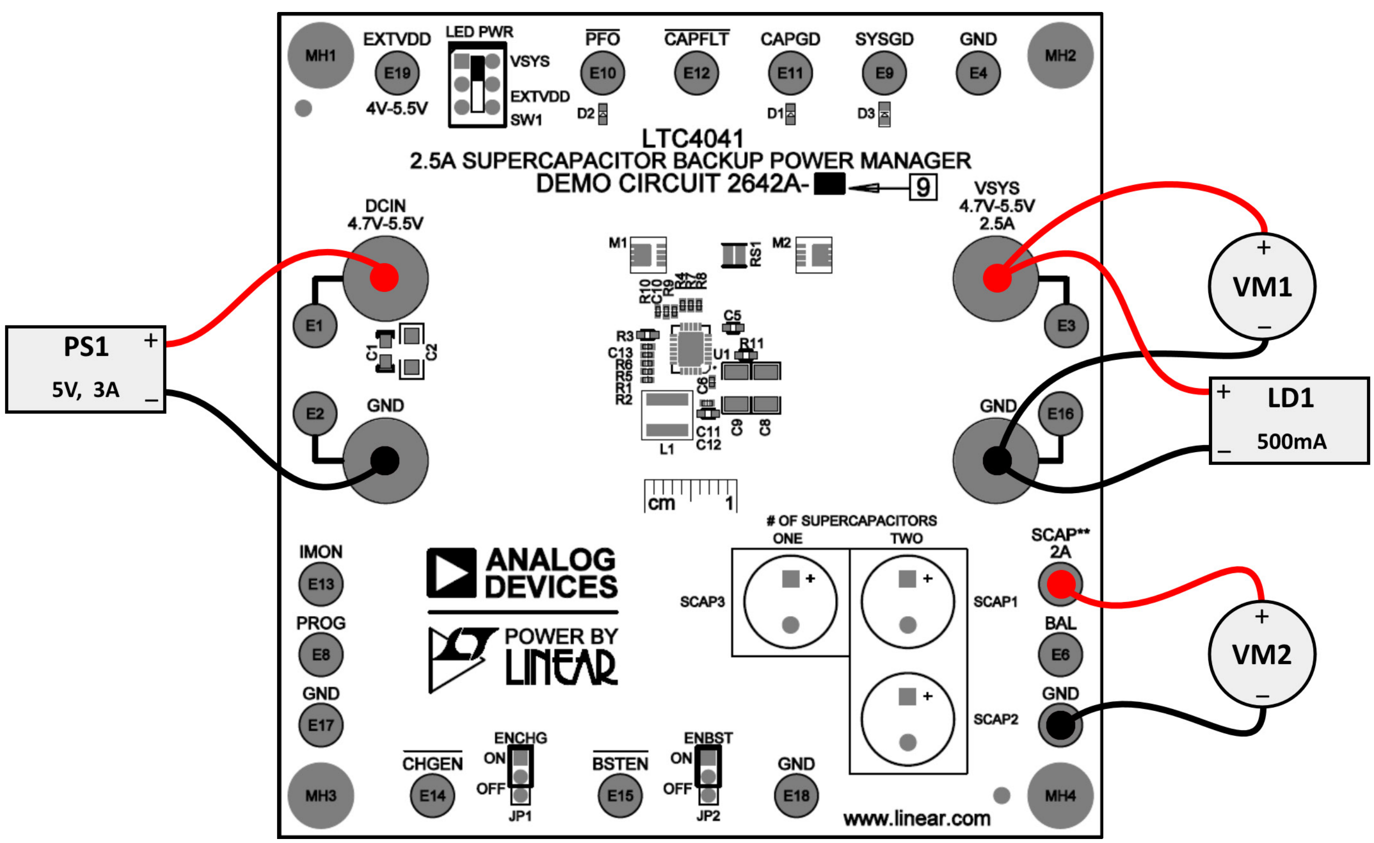


Figure 1. Quick Start Procedure Setup for DC2642A

DEMO BOARD OPERATION

DCIN Voltage Drops

Because the LTC4041's power fail function monitors the input voltage to determine its operation mode, it is important to use low-impedance connections to the demo board. Poor quality or lengthy wiring to DCIN can result in a substantial voltage drop across the wires as the DC2642A passes power to the load or charges the supercapacitor(s), leading to undesired triggering of the power fail threshold, 4.7V default.

Short, high-conductivity wires with a good connection are desirable and will mitigate this issue. As a workaround, the power fail threshold can be lowered or a higher voltage can be output from the power source to account for these drops, but this should not exceed the 5.5V rating of the DC2642A.

Number of Supercapacitors

The LTC4041 can support either one or two supercapacitors. For safety reasons, DC2642A is broken into two variants: DC2642A-A has two supercapacitors and balancing enabled, while DC2642A-B has one supercapacitor and has no need for balancing.

The LTC4041 uses the CAPSEL pin to determine whether one or two supercapacitors are present and whether balancing should be enabled. The charger also features supercapacitor over-voltage protection, and the voltage limits are based on the number of supercapacitors present as indicated by CAPSEL.

As a result, it is imperative that CAPSEL is configured to correctly reflect the number of series supercapacitors in the system. Resistor jumpers (R19 & R20) on the back of the DC2642A allow the CAPSEL state to be configured according to Table 1.

Table 1. Configuring Supercapacitor Count

Supercapacitor Configuration	Populated Footprint(s)	Populated CAPSEL Resistor
Dual (Series)	SCAP1 & SCAP2	R19
Single	SCAP3	R20

Evaluating Power Consumption

When evaluating the power consumption of the LTC4041 using the demo board, it is recommended that SW1 is placed in the $EXTV_{DD}$ position to disable the LEDs or power them externally.

Discharging Supercapacitors

Throughout the course of evaluation, it may become necessary to discharge the supercapacitors. If possible, it is recommended that an electronic load is used to discharge slowly and safely.

Directly shorting the supercapacitors will not damage them, but can result in sparks and damage to the conductor causing the short.

Removing Supercapacitors

The onboard supercapacitors can be moved into single-supercapacitor or dual-supercapacitor (series) configuration, or can be replaced with a user's own supercapacitor models. It is recommended that supercapacitors are discharged sufficiently before being removed.

$\overline{\text{CHGEN}}$ and $\overline{\text{BSTEN}}$ Diodes: D4

D4 is used to diode-OR the voltages on V_{SYS} and SCAP to create a logic-high voltage for the $\overline{\text{CHGEN}}$ and $\overline{\text{BSTEN}}$ pins that will be available in situations where V_{SYS} is not present. This is necessary to disable the boost function ($\overline{\text{BSTEN}}$ tied high), and it is also necessary to enter shutdown mode ($\overline{\text{CHGEN}}$ and $\overline{\text{BSTEN}}$ tied high). In applications where $\overline{\text{CHGEN}}$ and $\overline{\text{BSTEN}}$ are always tied to ground, the diode-OR is not needed.

DEMO BOARD OPERATION

Optional Components: R7 & R8

By default, the RSTFB input is fed the same voltage as the BSTFB input. The 0.74V threshold of the RSTFB pin is 92.5% of the 0.8V BSTFB servo voltage. As a result, tying both pins to the same voltage divider causes the SYSGD pin to pull low when the V_{SYS} voltage drops below 92.5% of the programmed backup boost voltage.

If a different threshold is desired, R4 can be removed to detach the dividers from each other, and R7 & R8 can be installed with values to set a custom SYSGD indication threshold.

Backup Time

The amount of time that the supercapacitor can back up the system is influenced by many factors. The most prevalent are the supercapacitor voltage, the system boost voltage, and the system load current.

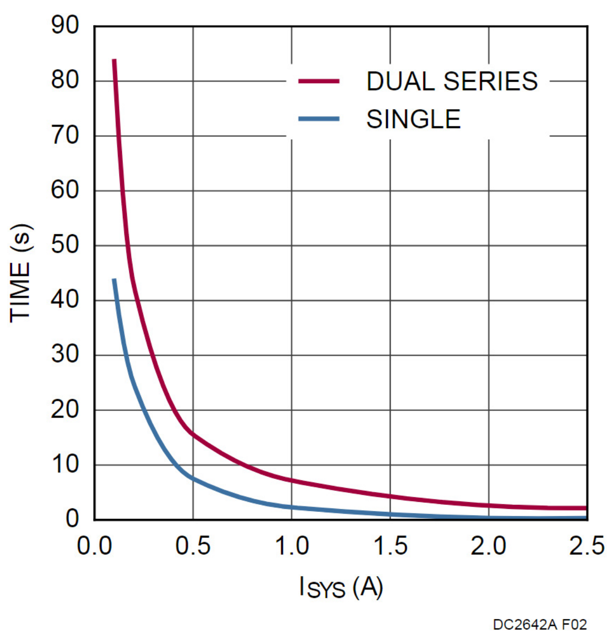


Figure 2. Measured Backup Time for Single/Dual 10F Supercapacitors (Boost to 5V)

However, other factors such as supercapacitor leakage and ESR can also play a significant role under some circumstances. An equation for estimating backup time is given in the LTC4041 data sheet, but it is still necessary to test operation with given values and components.

The backup time decreases as the load current increases, as expected. However, the decline in backup time is accelerated due to several of the aforementioned factors.

When using a single supercapacitor, the lower voltage limit of the supercapacitor and the fixed boost converter switch current of the LTC4041 will result in a shorter backup time when compared to two supercapacitors stacked in series.

Switch Current Limit

At higher load currents with lower supercapacitor voltages, the LTC4041 will need to limit the supercapacitor's discharge current as to not exceed the current limit of its internal boost switch. This protects the IC, but V_{SYS} will begin to collapse when the switch current limit is reached due to power-limiting.

Equivalent Series Resistance (ESR)

All supercapacitors have ESR which dissipates power and causes a voltage drop when they are being discharged. At lower supercapacitor voltages, the switch limit will be reached sooner, causing a faster collapse of V_{SYS}. For this reason, it is beneficial to select supercapacitors with low ESR. The 10F supercapacitors used on the DC2642A have a typical ESR of 20mΩ.

DEMO BOARD OPERATION

In Figure 3, it can be observed that the dropout voltage for dual supercapacitors (in series) is greater than the dropout voltage for a single supercapacitor. This is because the ESR is greater for series-connected capacitors.

Figure 3 shows the voltage of the supercapacitor(s) at different V_{SYS} loads after V_{SYS} has dropped out, charging has terminated, and the supercapacitor voltage has relaxed. Charging terminates at the same voltage for both supercapacitors as seen by the LTC4041; however, the voltage drop across the ESR causes the supercapacitor voltages to appear lower when being discharged. As the current draw from the supercapacitors stops, the voltage across the ESR approaches 0V, and the supercapacitors relax to a voltage unaffected by ESR. A higher voltage after the supercapacitor relaxes indicates that more energy was unused when discharging.

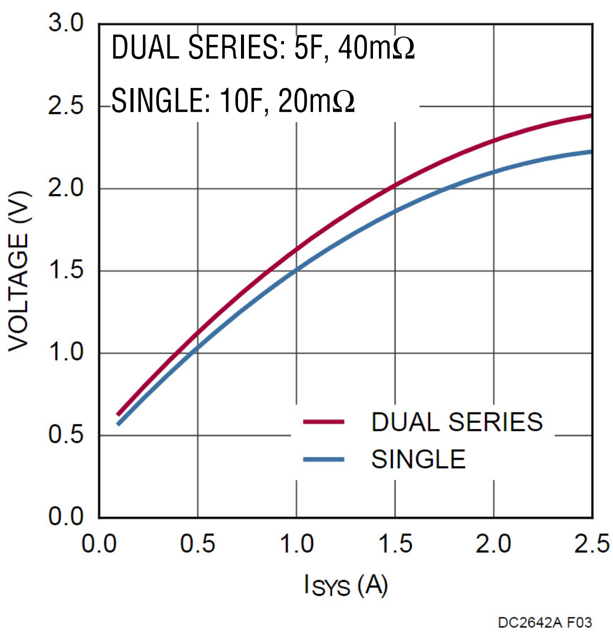


Figure 3. SCAP Voltage at V_{SYS} Dropout for Single/Dual 10F Supercapacitors (Boost to 5V)

Figure 4 shows the measured losses due to ESR for a single 10F supercapacitor configuration. The total ESR losses are a combination of the resistive loss from the ESR and the energy unused as a result of early termination due to the ESR.

The amount of energy loss is particularly high for the single-supercapacitor case at higher load currents. This is due to the low starting voltage which gives little headroom to avoid the switch current limit.

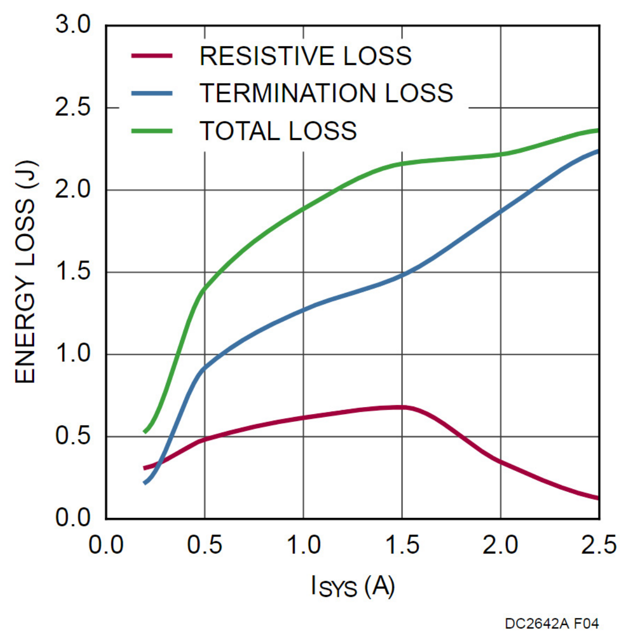


Figure 4. Energy Loss Due to ESR at Various VSYS Loads (Single 10F, Boost to 5V)

Supercapacitor Leakage

Internal leakage in a supercapacitor is comprised of diffusion current and steady-state leakage current. Diffusion current decreases as the supercapacitor is held at a voltage. Manufacturers typically spec leakage at a certain time after the supercapacitor has been charged.

DEMO BOARD OPERATION

The 10F supercapacitors on the DC2642A have a specified leakage current of 0.023mA after 72 hours of being held at the rated charge voltage. Near the start of charging, though, the leakage current is significantly higher.

Supercapacitor leakage is primarily a concern for backing up loads for a longer time. To test operation with worst-case leakage current, charge a supercapacitor and trigger a power-fail immediately after the supercapacitor reaches its full charge voltage.

Figure 5 shows the self-discharge of the supercapacitor triggering a recharge cycle. Note that the recharge cycles become less frequent as the supercapacitor remains near full charge.

Keeping these factors in mind, the LTC4041 can be used to design a robust 5V backup system using either a single supercapacitor or two supercapacitors in series. Given the effects of the switch current limit and the ESR of the supercapacitor model, using two supercapacitors in series is generally preferable when operating at higher load currents. However, designs with lower load currents can save space and lower costs by using a single supercapacitor.

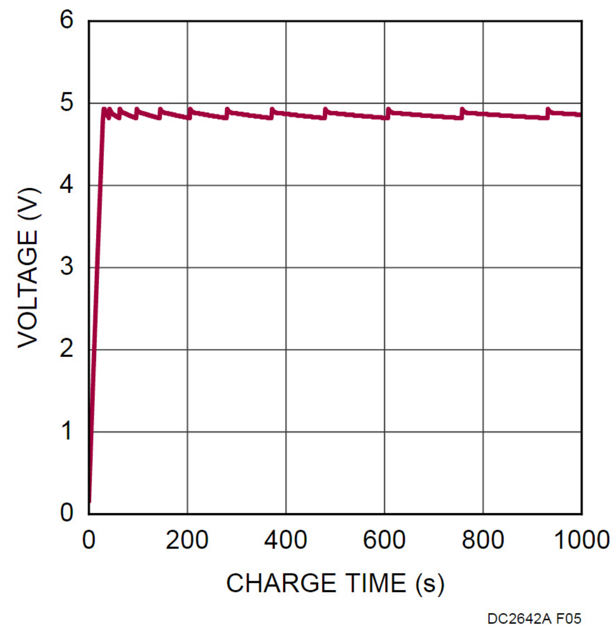


Figure 5. Supercapacitor Recharge Rate Due to Self-Discharge (Dual 10F, Unloaded)

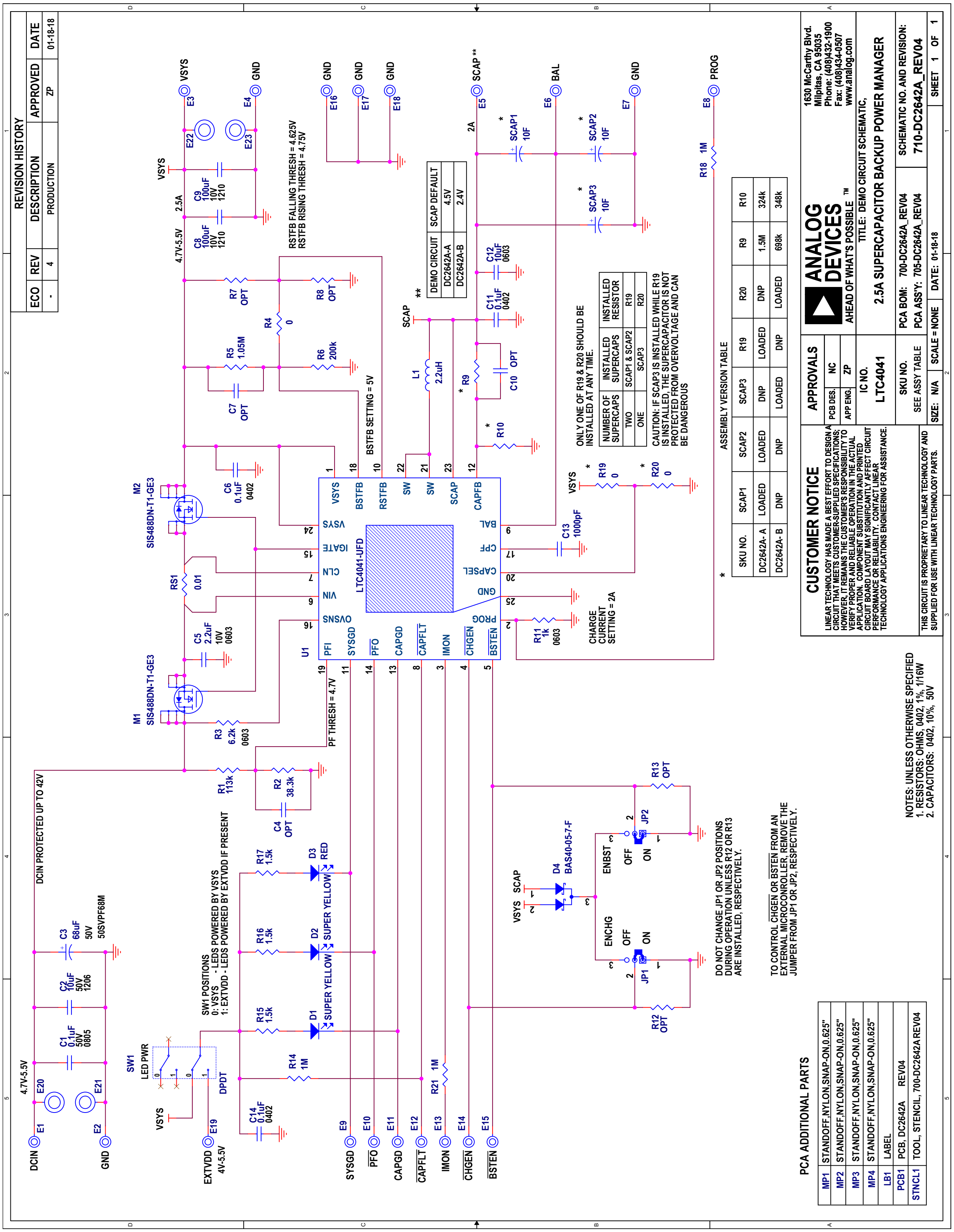
PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	1	C1	CAP., 0.1µF, X7R, 50V, 10%, 0805	AVX 08055C104KAT2A
2	1	C2	CAP., 10µF, X5R, 50V, 10%, 1206	MURATA GRM31CR61H106KA12L
3	1	C3	68µF ±20% 50V Aluminum Polymer Capacitor Radial, Can - SMD 20mΩ	Panasonic Electronic Components 50SVPF68M
4	1	C5	CAP., 2.2µF, X5R, 10V, 10%, 0603, NO SUBS. ALLOWED	MURATA GRM188R61A225KE34D
5	3	C6, C11, C14	CAP., 0.1µF, X7R, 10V, 10%, 0402	MURATA GRM155R71A104KA01D
6	2	C8, C9	CAP., 100pF, C0G, 100V, 5%, 0805	AVX 08051A101JAT2A
7	1	C12	CAP., 10µF, X5R, 10V, 20%, 0603	AVX 0603ZD106MAT2A
8	1	C13	CAP., 1000pF, X7R, 16V, 10%, 0402	AVX 0402YC102KAT2A
9	1	D4	DIODE ARRAY SCHOTTKY 40V SOT23	Diodes Incorporated BAS40-05-7-F
10	1	L1	IND., 2.2µH, PWR, 20%, 9.2A, 14.5mΩ, 5.48mm × 5.28mm, XAL5030,AEC-Q200	COILCRAFT XAL5030-222MEB
11	2	M1, M2	MOSFET N-CH 40V 40A 1212-8	Vishay Siliconix SIS488DN-T1-GE3
12	1	R1	RES., 113kΩ, 1%, 1/10W, 0402	PANASONIC ERJ2RKF1133X
13	1	R2	RES SMD, 38.3KΩ, 1%, 1/16W, 0402	Vishay Dale CRCW040238K3FKED
14	1	R3	RES SMD, 6.2KΩ, 5%, 1/4W, 0603	Rohm Semiconductor ESR03EZPJ622
15	1	R4	RES., 0Ω, 1/16W, 0402	ROHM MCR01MZPJ000
16	1	R5	RES., AEC-Q200, 1.05MΩ, 1%, 1/16W, 0402	VISHAY CRCW04021M05FKED
17	1	R6	RES., 200kΩ, 1%, 1/16W, 0402	PANASONIC ERJ2RKF2003X
18	1	R11	RES., 1kΩ, 1%, 1/10W, 0603	NIC NRC06F1001TRF
19	3	R14, R18, R21	RES., 1MΩ, 1%, 1/16W, 0402	Vishay Dale CRCW04021M00FKED
20	3	R15-R17	RES., 1.5kΩ, 1%, 1/16W, 0402	NIC NRC04F1501TRF
21	1	RS1	RES., SENSE, 0.01Ω, 1%, 1/3W, 0603	SUSUMU PRL0816-R010-F-T1
22	1	U1	IC,2.5A Supercap Backup Power Manager	LINEAR TECHNOLOGY LTC4041EUFD#TRPBF
Additional Demo Board Circuit Components				
23	0	C4, C7, C10	CAP., OPTION, 0402	
24	0	R7,R8	RES., OPTION, 0402	
25	0	R12, R13	RES., OPTION, 0603	
Hardware: For Demo Board Only				
26	2	D1, D2	LED,SUPER YELLOW, MILKY WHITE DIFF., 0603 SMD	LUMEX SML-LX0603SYW-TR
27	1	D3	LED, RED, WATER CLEAR, 0603	LITE-ON TECHNOLOGY CORP LTST-C193KRKT-5A
28	19	E1-E19	TEST POINT, TURRET, 0.094", MTG. HOLE	MILL-MAX 2501-2-00-80-00-00-07-0
29	4	E20-E23	CONN., BANANA JACK, FEMALE, THT, NON-INSULATED, SWAGE	KEYSTONE 575-4
30	2	JP1, JP2	CONN., HDR, MALE, 1 × 3, 2mm, THT, STR, NO SUBS. ALLOWED	Wurth Elektronik 62000311121
31	1	LB1	LABEL SPEC, DEMO BOARD SERIAL NUMBER	BRADY THT-96-717-10
32	4	MP1-MP4	STANDOFF, NYLON, SNAP-ON, 0.625"	KEYSTONE 8834
33	1	SW1	SWITCH SLIDE DPDT 300MA 6V	C&K JS202011CQN
34	2	XJP1, XJP2	CONN., SHUNT, FEMALE, 2 POS, 2mm	Wurth Elektronik 60800213421

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
DC2642A-A Required Circuit Components				
35	1	R9	RES., AEC-Q200, 1.5MΩ, 1%, 1/16W, 0402	Vishay Dale CRCW04021M50FKED
36	1	R10	RES., 324kΩ, 1%, 1/16W, 0402	NIC NRC04F3243TRF
37	1	R19	RES., 0Ω, 1/10W, 0603	YAGEO RC0603FR-070RL
38	0	R20	RES., OPTION, 0603	-
39	2	SCAP1, SCAP2	CAP., 10F, ULTRA, 2.7V, –10/+20%, THT, RADIAL	NESSCAP CO. LTD. ESHSR-0010C0-002R7
40	0	SCAP3	CAP., 10F, ULTRA, 2.7V, –10/+20%, THT, RADIAL	NESSCAP CO. LTD. ESHSR-0010C0-002R7
DC2642A-B Required Circuit Components				
41	1	R9	RES., 698kΩ, 1%, 1/16W, 0402	Vishay Dale CRCW0402698KFKED
42	1	R10	RES., 348kΩ, 1%, 1/16W, 0402	KOA SPEER RK73H1ETTP3483F
43	0	R19	RES., OPTION, 0603	
44	1	R20	RES., 0Ω, 1/10W, 0603	YAGEO RC0603FR-070RL
45	0	SCAP1, SCAP2	CAP., 10F, ULTRA, 2.7V, –10/+20%,T HT, RADIAL	NESSCAP CO. LTD. ESHSR-0010C0-002R7
46	1	SCAP3	CAP., 10F, ULTRA, 2.7V, –10/+20%, THT, RADIAL	NESSCAP CO. LTD. ESHSR-0010C0-002R7

SCHEMATIC DIAGRAM



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.

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