



## LTC4098EPDC: USB

# Compatible Switching Power Manager/Li-Ion Charger with Overvoltage Protection

## DESCRIPTION

Demonstration Circuit 1303A is a high efficiency USB Power/Li-Ion battery manager plus a HV regulator battery tracking controller. The LTC4098EPDC is available in a 20-pin (3mm × 4mm × 0.55mm) UTQFN surface mount package.

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

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$V_{BUS}$	Bus Input Voltage Range	Input disabled from 6V–30V	4.35		5.5	V
$V_{OUT}$	Output Voltage Range	Range is mode and load dependant	3.5		5.5	V
$V_{BAT}$	Output Float Voltage	Constant voltage mode		4.2		V
$I_{BAT}$	Output Charge Current	Constant current mode		0.5	1	A

## OPERATING PRINCIPLES

The LTC4098EPDC is a full featured USB power manager and Li-Ion battery charger, with reacharound.

The Bat-Track™ battery charger pre-regulator ensures the charger operates at the highest possible efficiency. The LTC4098EPDC is composed of 5 functional blocks, all working together: USB Power Manager, Pre-regulator, Battery Charger, Ideal Diode, and OverVoltage Protection.

### USB Power Manager

The USB Power Manager is used to manage the load that the LTC4098EPDC system presents to the USB interface. The load current can be programmed by changing the CLPROG resistor (R5), and by setting the operating mode to 1X, 5X or 10x, with the [d2-d0] inputs.

Please note that the charger on/off is also controlled by the [d2-d0] inputs.

The USB Power Manager also uses the “WALL” input to determine that power is being supplied directly to VOUT and shuts off the internal preregulator, minimizing the load on the USB input.

### Pre-Regulator

The pre-regulator is a high efficiency buck regulator that produces a voltage at  $V_{OUT} = BAT + 0.3V$ . The voltage at VOUT is input to the battery charger, greatly reducing dissipation in the charger.

The pre-regulator also monitors the WALL pin, and when the voltage is higher than 4.3V, it shuts off. When the voltage on the Wall pin is higher than 4.3V, the /ACPR and VC pins are also active. The /ACPR pin activates the gate of an N-channel MOSFET allowing a separate HV Buck Regulator to supply VOUT. The VC pin implements the Bat-Track function for the HV Buck Regulator, also known as reacharound, enabling the same high efficiency battery charger operation with an external HV buck regulator.

### Battery Charger

The battery charger operates in constant current mode, until the battery voltage rises to approximately the FLOAT voltage, of 4.2V, and then the charger switches to constant voltage mode.

The charge current is programmed by the PROG (R4) resistor, and has been set to 500mA, on DC1303A,

with a 2.00kΩ resistor. The battery charger implements trickle charging, for initial battery voltages less than 3.0V. It also implements a charge termination timeout of 4 hours, and a bad cell charging timeout of 30 minutes. An NTC input is used to determine if the battery temperature is suitable for charging, too hot or too cold.

The state of charge, as well as any faults, is signaled with the  $\overline{\text{CHRG}}$  pin.

### **Ideal Diode**

The Ideal Diode block is composed of an internal Ideal Diode implemented with an on die MOSFET, as well as a MOSFET gate driver that allows the use of a parallel external MOSFET.

When the voltage on VOUT drops more than 30mV below the voltage at BAT, the Ideal Diode becomes active. This will happen when there is neither a VBUS nor external HV buck to supply VOUT, or the load on VOUT exceeds the power available from those sources.

### **OverVoltage Protection**

The overvoltage protection is composed of a sense pin, OVSENSE, and an OVP MOSFET gate drive, OVGATE. If the voltage on OVSENS is less than 6V, OVGATE is driven above VBUS, by an internal charge pump, to allow the use of a low cost N-channel MOSFET.

If the voltage on OVSENS exceeds 6V, the charge pump is shut off and pulled to ground. This in turn shuts off the external OVP MOSFET.

Although the OVP is usually shown protecting the VBUS connection, it could also be used to protect the VOUT connection to an external regulator.

## **APPLICATIONS**

The parasitic inductance in some USB cables may cause the VUSB voltage to overshoot at plug in. The OVGATE signal provides a slow turn on of Q1, the OVP MOSFET. This slow turn on, in turn limits the inrush current into C2, allowing the use of a capacitor that exceeds the nominal USB specification.

R2, the OVSENS current limit resistor must be an 0603, or larger resistor. OVSENS is clamped at 6V, so for a 30V input, the dissipation in the resistor is  $24V^2/6.04k\Omega = 95mW$ . An 0603 resistor is rated at 100mW of continuous dissipation.

The battery charger must see a low impedance to ground, which is case when a battery is attached. In the event that a battery emulator is being used, or the impedance to ground is above 1Ω, the circuit of C4 and R9-11 is recommended. Without this circuit there will be approximately 100ma of 20-80kHz ac current in the USB input. While this will not damage the LTC4098EPDC, nor cause incorrect operation, it may produce voltage waveforms that are undesirable. If this is the case the network of C4 and R9-11 will resolve this issue.

The HV buck interface connector is intended for use with specific demonstration boards, that contain HV buck regulators tested to work with the LTC4098EPDC.

## **ASSEMBLY TEST PROCEDURE**

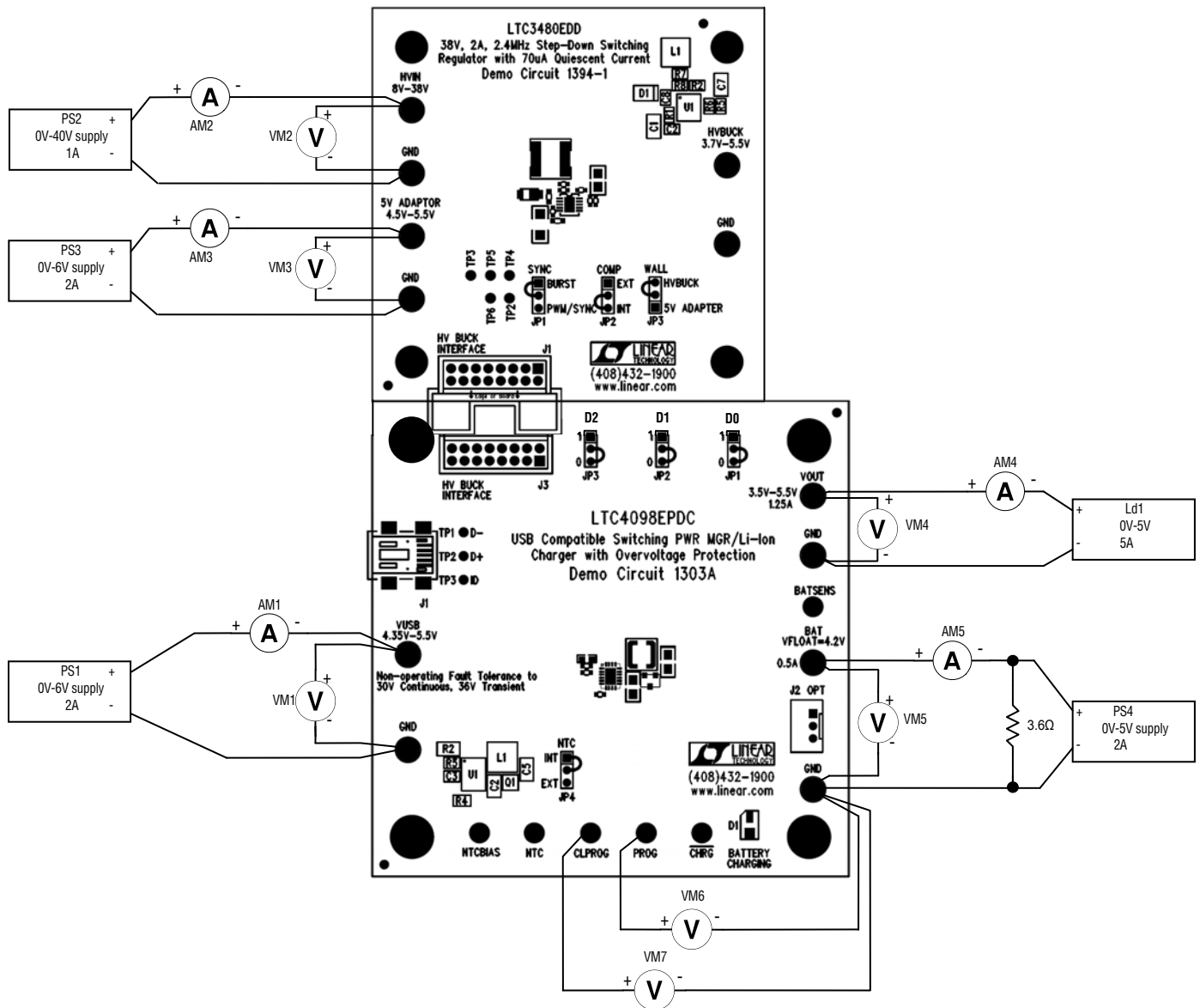
Using short twisted pair leads for any power connections, with all loads and power supplies off, refer to Figures 1 & 2 for the proper measurement and equipment setup.

A companion HV Buck demo board is required for this check out procedure. The DC1394 (LT3480) board is recommended, and will be used for the following procedure. Please refer to the DC1394 Quick Start Guide for further information.

Follow the procedure below:

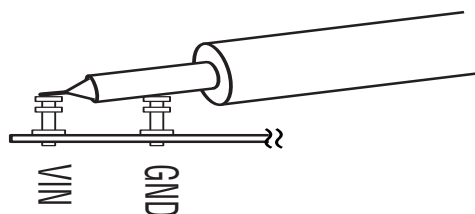
1. Select input from VUSB: Set WALL jumper (DC1394, JP3) to "5V ADAPTOR". Ensure that PS3 is off. Since PS3 is off and the voltage input is set to "5V ADAPTOR", no voltage will be sourced to VOUT from the DC1394 board. Thus the only source of energy is the USB voltage input.
2. Set PS1 to 5V, and PS4 to 3.6V. Observe VOUT (VM4)  $\cong$  3.6V, I(VUSB) (AM1)  $\cong$  100mA, (CLPROG) (VM7)  $\cong$  1V. The default operating mode is 100mA USB input current limit, and the

- battery charger on. The battery charger is programmed for 500mA of charge current by R4 (2k), so the charge is trying to source more current from the USB input than the USB input current limit. So Vout collapses down to approximately the battery voltage.
3. Set D1 (JP2) to “1”. Observe VOUT (VM4)  $\cong$  3.95V, I(VUSB) (AM1)  $\cong$  500mA, V(CLPROG) (VM7)  $\cong$  1.15V and V(PROG) (VM6)  $\cong$  1V. By setting D1 to “1”, the USB input current limit has been increased to 5X (500mA) mode. The USB input can now supply the battery with 500mA, so VOUT rises to V(BAT) + 0.35V.
  4. Set D1 (JP2) to “0” and D0 (JP1) to “1”. Observe VOUT (VM4)  $\cong$  3.95V, I(VUSB) (AM1)  $\cong$  500mA, V(CLPROG) (VM7)  $\cong$  0.6V and V(PROG) (VM6)  $\cong$  1V. The USB input current limit is now in 10X (1A) mode, so the USB input current limit current sense voltage, V(CLPROG), is at about half its threshold (1.15V) value. But the charge current sense is still  $\cong$  1V, as the charger is delivering the full programmed charge current.
  5. Set PS1 to 0V, and Ld1 to 0A. Observe VOUT (VM4)  $\cong$  3.6V and V(VOUT,BAT)  $\cong$  15mV. With voltage on USB now 0V, there is no source of energy so VOUT collapses until the ideal diode comes on, and the battery holds VOUT up.
  6. Set Ld1 to 1A. Observe VOUT (VM4)  $\cong$  3.6V and V(VOUT,BAT)  $\cong$  30mV. Set Ld1 to 0A. The Rds(on) of the external ideal diode MOSFET is approximate 30m $\Omega$ , so at 1A, the voltage drop in the ideal diode is approximately 30mV.
  7. Set PS1 to 5V. Set NTC (JP4) to “EXT”. Does the “Battery Charging” LED blink? Set NTC (JP4) to “INT”. Setting the NTC (JP4) jumper to “EXT”, uses the temperature sense NTC in the battery pack. There is no battery pack connected, so this connection is open. This is the same as if the NTC where high impedance indicating a “battery too cold” fault.
  8. Set WALL (DC1394, JP3) to “HVBUCK”, and SYNC (DC1394, JP1) to “PWM/SYNC”. Increase PS2 from 0V to 8V. Observe VOUT (VM4)  $\cong$  3.95V and V(PROG) (VM6)  $\cong$  1V. The LTC3480EDD HV buck regulator on the DC1394 board is now providing energy for the charger. The LTC4098EPDC on the DC1303A board is controlling the output voltage to provide the Bat-Track function, and minimize dissipation in the charger.
  9. Set Ld1 to 1A. Observe VOUT (VM4)  $\cong$  3.95V and V(PROG) (VM6)  $\cong$  1V. The LTC3480EDD can supply up to 2A of load current. The DC1303A board is currently drawing 1.5A, 500mA for the charger, and 1A into Ld1.
  10. Set PS2 to 38V. Observe VOUT (VM4) and V(PROG) (VM6). The LTC3480EDD can supply up to 2A of load current. The DC1303A board is currently drawing 1.5A, 500mA for the charger, and 1A into Ld1.
  11. Set Ld1 to 0A. Set WALL (DC1394, JP3) to “5V ADAPTOR” and PS3 to 5V. Observe VOUT (VM4)  $\cong$  5V and V(PROG) (VM6)  $\cong$  1V. The charger current is now being supplied by the 5V ADAPTOR, but the voltage is fixed, as the LTC4098EPDC cannot control this voltage. This means that the dissipation will be higher than when operating the LTC4098EPDC from the USB or HV buck inputs.
  12. Set D2 (JP3) to “1”. Does “BATTERY CHARGING” LED go out? This turns the battery charger off.



Note: All connections from equipment should be Kelvin connected directly to the Board PINS which they are connected to on this diagram and any input, or output, leads should be twisted pair

**Figure 1. Proper Measurement Equipment Setup for DC1303A**



**Figure 2. Measuring Input or Output Ripple**

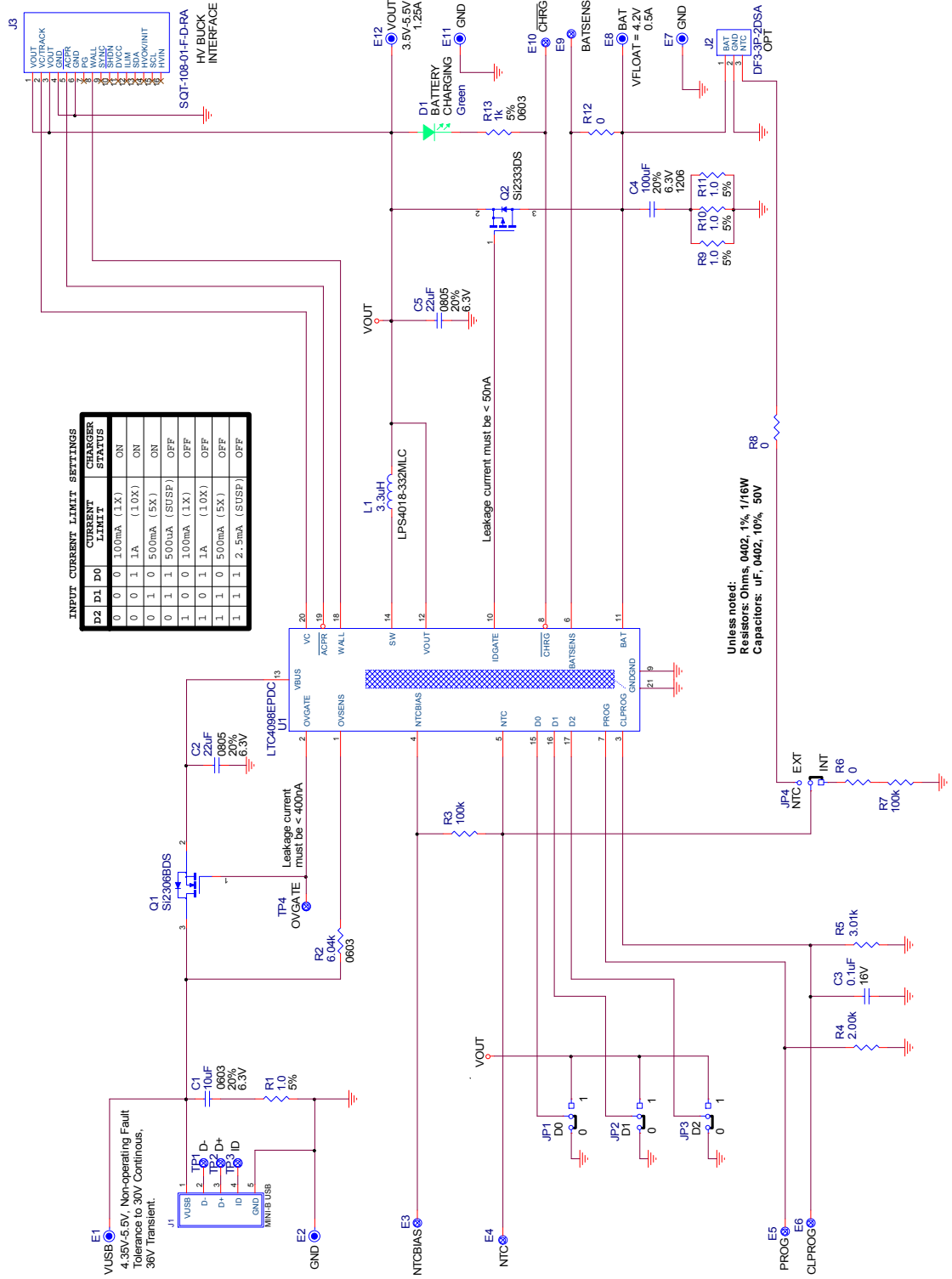


Figure 3. DC1303A Schematic

Qty	Reference	Part Description	Manufacture / Part #	
<b>REQUIRED CIRCUIT COMPONENTS:</b>				
1	2	C2,C5	CAP, CHIP, X5R, 22 $\mu$ F, $\pm$ 20%, 6.3V, 0805	TAIYO-YUDEN, JMK212BJ226MG
2	1	C3	CAP, CHIP, X7R, 0.1 $\mu$ F, $\pm$ 10%, 16V, 0402	MURATA, GRM155R71C104KA88
3	1	L1	IND, SMT, 3.3 $\mu$ H, 80m $\Omega$ , $\pm$ 20%, 2.2A, 4mmX4mm	COILCRAFT, LPS4018-332MLC
4	1	Q1	MOSFET, 30V, 65m $\Omega$ , 3.5A, SOT-23	VISHAY, Si2306BDS
5	1	R2	RES, CHIP, 6.04k $\Omega$ , $\pm$ 1%, 1/10W, 0603	VISHAY, CRCW06036K04FKED
6	1	R4	RES, CHIP, 2.00k $\Omega$ , $\pm$ 1%, 1/16W, 0402	VISHAY, CRCW04022K00FKED
7	1	R5	RES, CHIP, 3.01k $\Omega$ , $\pm$ 1%, 1/16W, 0402	VISHAY, CRCW04023K01FKED
8	1	R12	RES, CHIP, 0 $\Omega$ jumper, 1/16W, 0402	VISHAY, CRCW04020000Z0ED
9	1	U1	IC, SMT, USB Compatible Switching Power Manager/Li-Ion Charger with Overvoltage Protection	LINEAR TECH., LTC4098EPDC
<b>ADDITIONAL DEMO BOARD CIRCUIT COMPONENTS:</b>				
1	1	C1	CAP, CHIP, X5R, 10 $\mu$ F, $\pm$ 20%, 6.3V, 0603	TDK, C1608X5R0J106M
2	1	C4	CAP, CHIP, X5R, 100 $\mu$ F, $\pm$ 20%, 6.3V, 1206	MURATA, GRM31CR60J107ME39L
3	1	D1	DIODE, LED, GREEN, 1206	PANASONIC, LN1351-C-TR
4	1	Q2	MOSFET, -12V, 35m $\Omega$ , -5.3A, SOT-23	VISHAY, Si2333DS
5	4	R1,R9,R10,R11	RES, CHIP, 1.0 $\Omega$ , $\pm$ 5%, 1/16W, 0402	VISHAY, CRCW04021R00JNED
6	2	R3,R7	RES, CHIP, 100k $\Omega$ , $\pm$ 1%, 1/16W, 0402	VISHAY, CRCW0402100KFED
7	2	R6,R8	RES, CHIP, 0 $\Omega$ jumper, 1/16W, 0402	VISHAY, CRCW04020000Z0ED
8	1	R13	RES, CHIP, 1k $\Omega$ , $\pm$ 5%, 1/10W, 0603	VISHAY, CRCW06031K00JNED
<b>HARDWARE FOR DEMO BOARD ONLY:</b>				
1	6	E1,E2,E7,E8,E11,E12	Turret, 0.09"	MILL-MAX, 2501-2
2	6	E3,E4,E5,E6,E9,E10	Turret, 0.061"	MILL-MAX, 2308-2
3	1	J1	CONN, USB MINI-B	TYCO, 1734035-2
4	0	J2-OPT	CONN, Battery	HIROSE, DF3-3P-2DSA
5	1	J3	CONN, HV interface	SAMTEC, SQT-108-01-F-D-RA
6	4	JP1,JP2,JP3,JP4	3 Pin Jumper, 2mm	SAMTEC, TMM-103-02-L-S
7	4	JP1,JP2,JP3,JP4	SHUNT, 2mm	SAMTEC, 2SN-BK-G
8	4		STAND-OFF, NYLON 0.375" tall (SNAP ON)	KEYSTONE, 8832 (SNAP ON)

Figure 4. DC1303A BOM

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