LTC2941/LTC2942: Battery Gas Gauge with I²C Interface and 14-Bit ADC

DESCRIPTION

Demonstration circuit 1496C-A (Figure 1) features the LTC®2941. Demonstration circuit 1496C-B features the LTC2942. Demonstration circuit 1496C-C features the LTC2941-1. Demonstration circuit 1496C-D features the LTC2942-1. The C, D options have parts that use an internal sense resistor while the A, B options rely on an external precision sense resistor. All four devices measure battery charge state in handheld PC and portable product applications. The operating range is perfectly suited for single cell Li-Ion batteries. A precision analog coulomb counter integrates current through a sense resistor between the battery's positive terminal and the load or charger. The LTC2942 adds battery voltage and on-chip temperature measurement with an internal 14-bit No Latency ΔΣ™ ADC. The three measured quantities (charge, voltage and temperature) are stored in internal registers accessible via the onboard SMBus/I²C interface.

The LTC2941/LTC2941-1 has programmable high and low thresholds for accumulated charge. The LTC2942/LTC2942-1 has programmable high and low thresholds for all three measured quantities. If a programmed threshold is exceeded, the device reports an alert using either the SMBus alert protocol or by setting a flag in the internal status register.

The LTC2941 and LTC2942 require only a single low value sense resistor to set the measured current range. The LTC2941-1 and the LTC2942-1 have their own 50mΩ internal resistor. The default value assembled on the DC1496 is 100mΩ for a maximum current measurement of 500mA. Both parts have a software-configurable charge complete/alert pin. When the pin is set for charge complete, a jumper connects the pushbutton which simulates a logic high input to indicate a full battery. When the pin is configured for alert, the same jumper is used to connect a red LED that indicates an alert is present.

The DC1496C is a part of the QuikEval™ system for quick evaluation with a host controller through a PC.

Design files for this circuit board are available at http://www.linear.com/demo/DC1496C.

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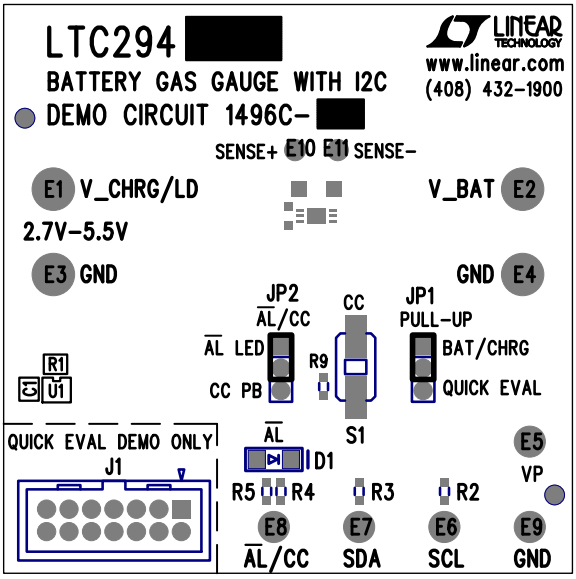

Figure 1. DC1496C

QUICK START PROCEDURE

Demonstration circuit 1496C is easy to set up to evaluate the performance of the LTC2941/LTC2942/LTC2941-1/ LTC2942-1. Refer to Figure 2 for proper measurement equipment setup and follow the procedure below.

1. Connect a 1-cell Li-Ion battery across V_BAT and GND.
2. Connect a load across V_CHRG/LD and GND for battery discharge measurement. Up to 500mA supplied from the battery can be measured with the board default 100mΩ sense resistor or 50mΩ internal resistor. Use $SENSE^+$ and $SENSE^-$ test points to read voltage across the sense resistor.
3. Connect a 2.7V to 5.5V battery charger supply across V_CHRG/LD and GND. Up to 500mA supplied to the battery can be measured with the board default 100mΩ sense resistor. Use $SENSE^+$ and $SENSE^-$ test points to read voltage across the sense resistor.
4. Connect a DC590 to 14-pin connector J1 for evaluation with QuikEval, or connect a host controller I^2C bus to the SDA, SCL and GND test turrets.
5. Set JP1 to QuikEval if a DC590 is present. Otherwise set JP1 to Bat/Chrg for bus pull-up to the battery, or float JP1 and supply a bus pull-up voltage to VP.
6. Read and write to the LTC2941/LTC2942 through I^2C.
7. Through I^2C, configure the $\overline{AL}$/CC pin. Set JP2 accordingly.
8 If $\overline{AL}$/CC is set for charge complete, use pushbutton switch S1 to simulate a logic high from a controller to indicate a fully charged battery.

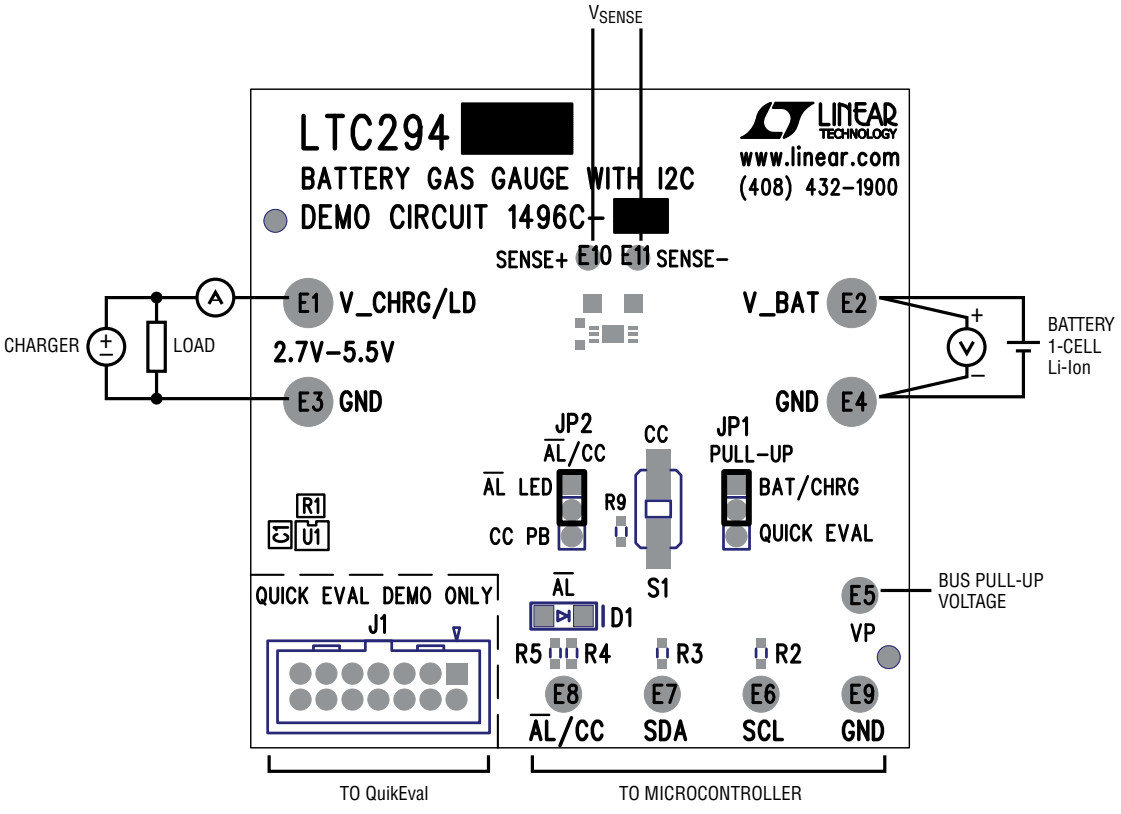

Figure 2. DC1496C Basic Setup

QuikEval INTERFACE

The DC1496C can be connected to a DC590 and used with the QuikEval software. The DC590 connects to a PC through USB. QuikEval automatically detects the demo board and brings up the LTC2941/LTC2942 evaluation software interface (Figure 3).

Compact and Detailed Form

When the interface is brought up, a compact form is first shown with a display for the accumulated charge register (ACR), voltage ADC and temperature ADC. To expand the form for a more detailed display of the LTC2941/LTC2942/LTC2941-1/LTC2942-1 registers and board configurations, click on Detail. To go back to the compact form, click on Hide.

Start/Refresh

Click on Start to begin a polling routine that refreshes the interface every 1 second. Click on Stop to halt the polling. For a single update, click on Refresh. Each refresh scans through the internal I^2C registers and updates the respective displays.

LTC2941 and LTC2942 Display

On a refresh or poll, the software reads Status bit A[7] to determine communication with an LTC2941, LTC2942, LTC2941-1 or LTC2942-1. When an LTC2941 is detected, the voltage and temperature ADC and threshold displays are not shown. Control bits B[7:6] configure VBAT Alert for the LTC2941 and ADC Mode for the LTC2942.

ACR Display

The data in the ACR (registers C and D) is displayed in one of three selected formats: Counter in coulombs, Counter in mA • hour, battery gas gauge in mA • hour, and battery gas gauge in charge percentage of battery. The two gas gauge displays correspond to the battery gas gauge full battery configuration set in the detailed form.

Voltage and Temperature ADC (LTC2942, LTC2942-1)

Data from the Voltage ADC (registers I and J) and the Temperature ADC (registers M and N) is displayed here in Volts and Celsius.

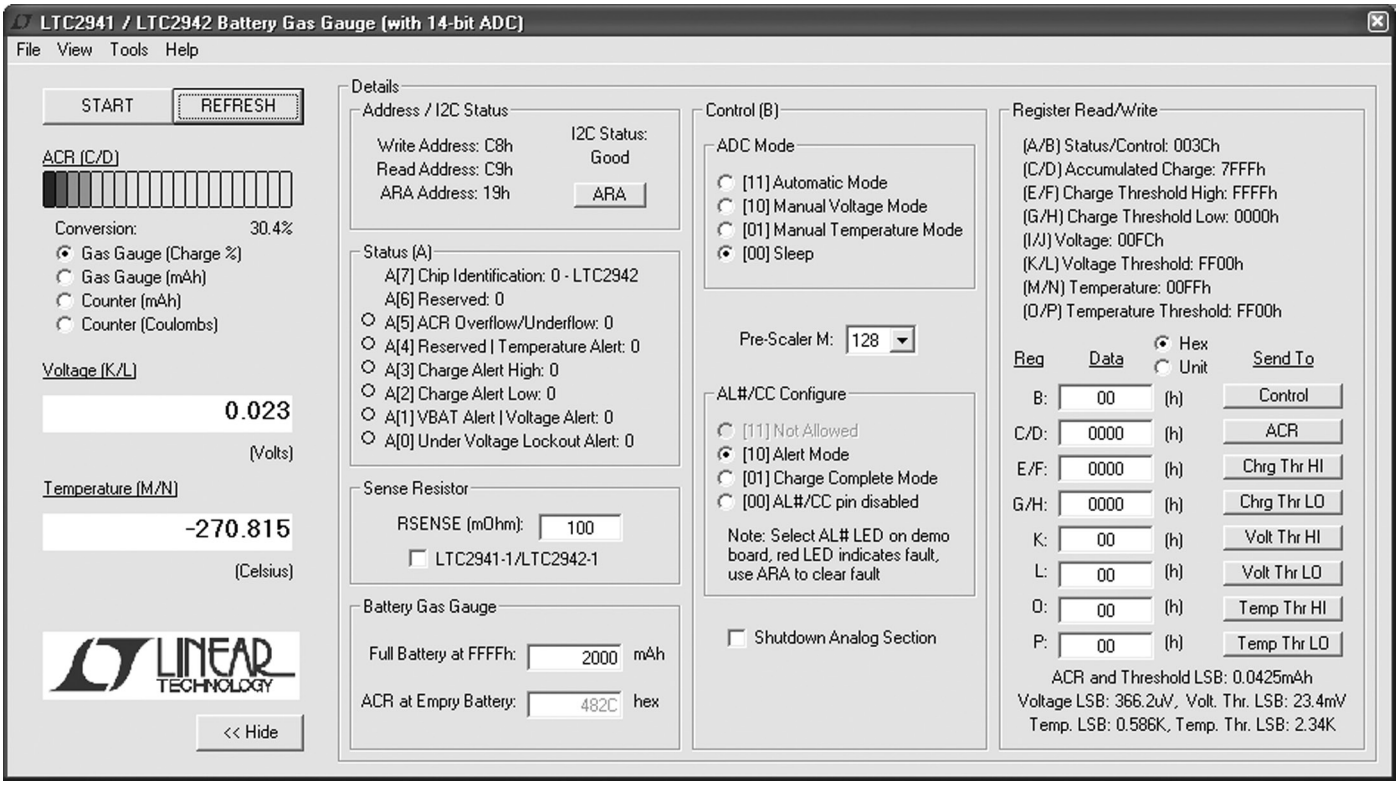

Figure 3. LTC2941/LTC2942 QuikEval Interface

QuikEval INTERFACE

Address/I²C Status

The write address for the LTC2941/LTC2942/LTC2941-1/LTC2942-1 is C8h and the read address is C9h. The alert response address (ARA) is 19h. If an error occurs while reading from the LTC2941/LTC2942/LTC2941-1/LTC2942-1, the I²C status will read as an error. Otherwise, the status is good. If the LTC2941/LTC2942/LTC2941-1/LTC2942-1 $\overline{AL}$/CC pin is set for alert mode and an alert has been latched, the device will pull down this pin. Click on ARA to send out an ARA on to the bus lines and the device will respond with its address. The Alert pin will then be cleared if the alert is no longer present.

Status

The individual status bits A[0:7] and their states are shown here. A red indicator next to bits A[0:5] indicates the respective alert is currently present and will latch the Alert pin if configured for alert. Bit A[7] shows if an LTC2941, LTC2942, LTC2941-1 or LTC2942-1 is detected.

Sense Resistor

Enter here the sense resistor value used in the application. The default for the DC1496C is a 100mΩ sense resistor. Check LTC2941-1/LTC2942-1 if one of these devices is used in place of the default IC. This sets the sense resistor value to 50mΩ, the value of the internal sense resistor in these devices. The sense resistor can only be changed when not polling. The software only accepts sense resistors between 0.1mΩ to 5Ω.

Battery Gas Gauge

The battery capacity in the application is entered here. The ACR full scale (FFFFh) is set to this value and affects the two Gas Gauge ACR display options. Instead of counting up from 0 as in the Coulomb Counters, the Gas Gauge is used to count down from a full battery. The battery capacity can only be entered when not polling. The data in the ACR when a battery should be empty is calculated based off of R_{SENSE}, and pre-scaler M, and displayed in hexadecimal below the ACR full scale.

Control

Configurations done in the Control section write to the Control register (register B). For the LTC2941, the Control bits B[7:6] enables a battery monitor to one of three set voltage thresholds (2.8V, 2.9V, or 3V) or disables this battery voltage alert. The ADC mode with the LTC2942 is default to Sleep where both Voltage and Temperature ADCs (LTC2942) are disabled. Setting ADC Mode to Automatic Mode enables full-time the Voltage and Temperature ADC. Selecting Manual Voltage or Temperature mode enables the respective ADC once and returns the ADC to Sleep mode.

Select a pre-scaler M value to scale the ACR according to battery capacity and maximum current. Changing the pre-scaler will halt the poll. A calculator tool is provided in the tool bar under Tools to assist in calculating a pre-scaler value and sense resistor (Figure 4).

The AL#/CC pin can be configured for Alert mode, Charge Complete mode, or disabled. Select the corresponding settings on the DC1496C jumper J2.

The Shutdown Analog Section is checked to disable the Analog portion of the LTC2941/42/41-1/42-1 and set the device in a low current state.

Register Read/Write

Data in the internal registers of the LTC2941/LTC2942/LTC2941-1/LTC2942-1 is displayed here in hexadecimal or appropriate units. Data can also be entered and written to the write registers. Enter data to be written in hexadecimal, or select Unit and enter data in decimal form. Data in decimal scale is auto corrected if the maximum or minimum full scale is exceeded. Select the ACR display in Counter (Coulombs) to be able to write to the ACR and charge thresholds in Coulombs, or select Counter (mAh) to be able to write to the ACR and charge thresholds in mA • hour. Voltage and Temperature High thresholds are rounded down in the calculations to the nearest lower count, while the low thresholds are rounded up to nearest

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higher count. Switching back and forth between Hex and Unit can be used as a conversion tool.

The LSB value for the 16-bit ACR and charge thresholds is displayed on the bottom. This value is adjusted with the sense resistor and pre-scaler M. The units are in mAh or mC depending on the selected ACR display. Shown for the LTC2942/LTC2942-1 is the LSB for the 14-bit voltage ADC, 10-bit temperature ADC, and 8-bit high and low thresholds for voltage and temperature.

Calculator Tool

A calculator tool is available in the tool bar options under Tools. In this calculator (Figure 4), enter the maximum current passed through the sense and the maximum battery capacity. Click on Calculate to calculate a recommended sense resistor and pre-scaler (M) value. The display shows the battery capacity in comparison to ACR full scale and provides an LSB value in mAh. Also shown is the recommended equation to use to determine an appropriate sense resistor as a function of the maximum battery charge and maximum current.

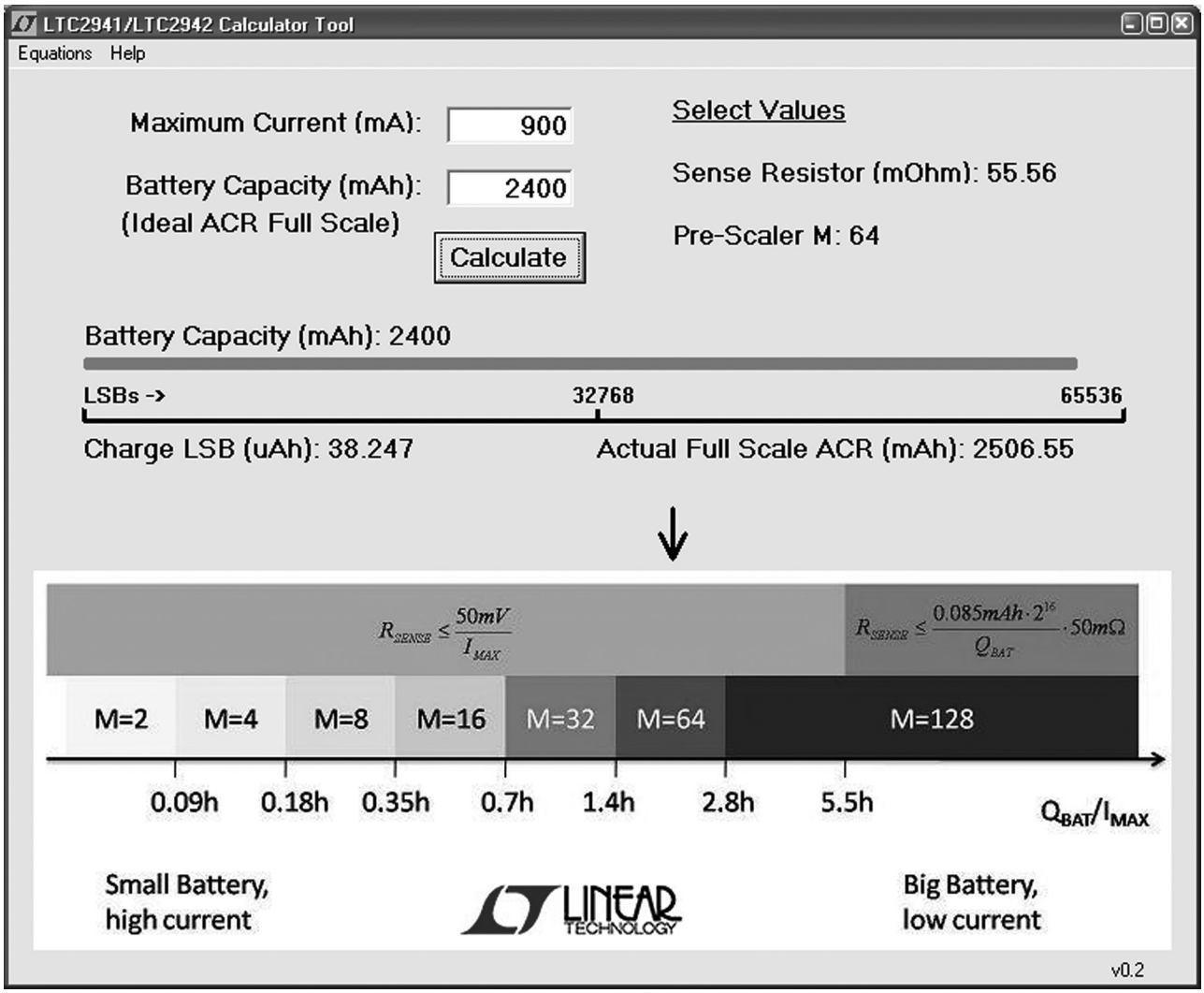
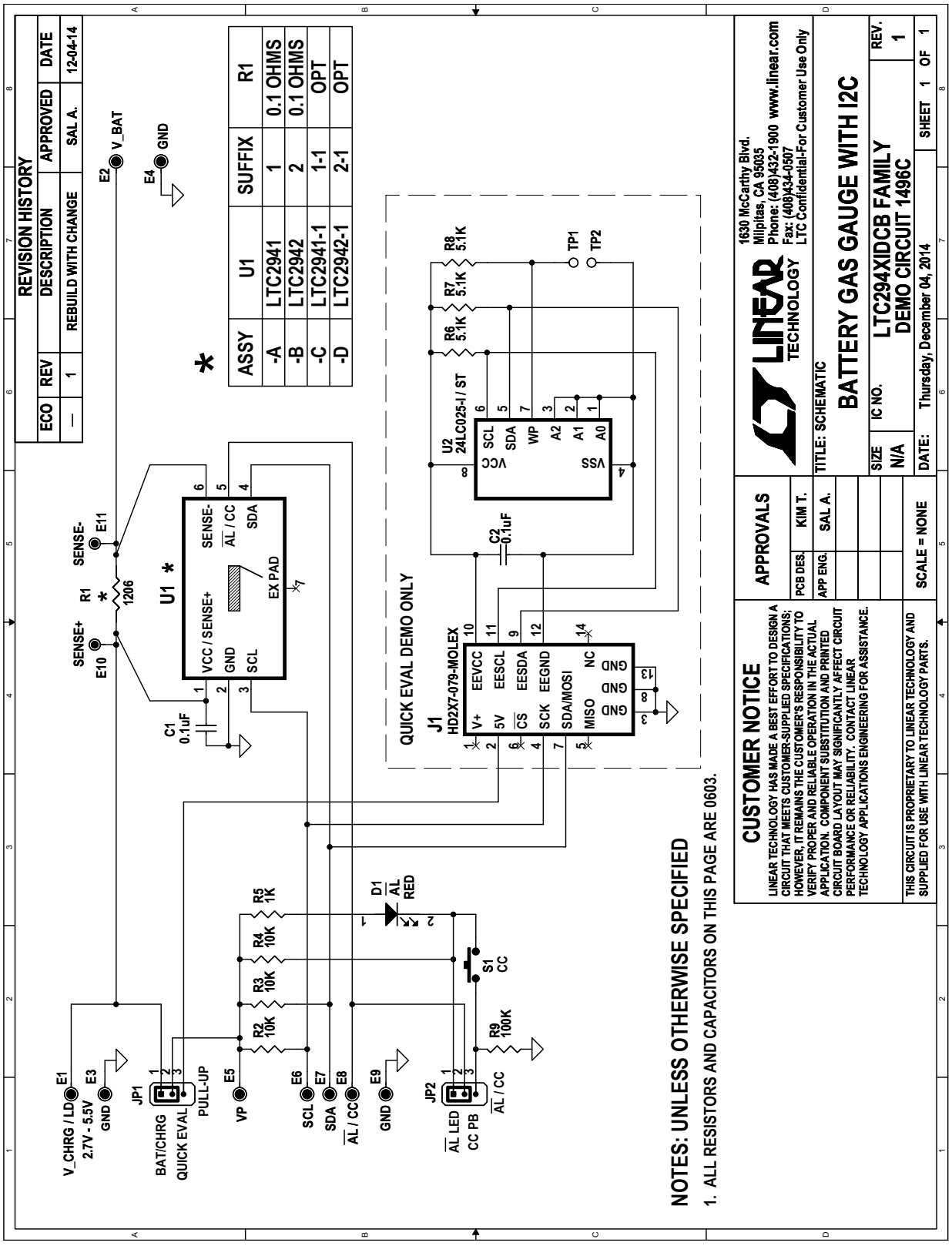


Figure 4. LTC2941/LTC2942 Pre-Scaler and Sense Resistor Calculator

PARTS LIST

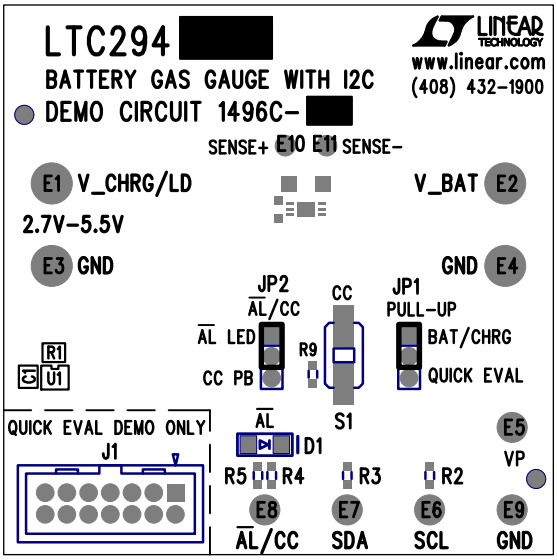
ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURE/PART NUMBER
1	2	C1, C2	CAP., CHIP X7R, 0.1µF, 25V, 0603	AVX, 06033C104KAT2A
2	4	E1-E4	TURRET, TESTPOINT 0.094"	MILL-MAX, 2501-2-00-80-00-00-07-0
3	5	E5-E9	TURRET, TESTPOINT 0.064"	MILL-MAX, 2308-2-00-80-00-00-07-0
4	2	E10, E11	TURRET, TESTPOINT 0.054"	MILL-MAX, 2309-1-00-80-00-00-07-0
5	0	TP1, TP2	SMT PADS ONLY	
6	2	JP1, JP2	HEADER, 3-PIN 1 ROW 0.079CC	SAMTEC, TMM-103-02-L-S
7	2	JP1, JP2	SHUNT, 0.079" CENTER	SAMTEC, 2SN-BK-G
8	1	J1	HEADERS, VERTICAL DUAL 2 X 7 0.079CC	MOLEX, 87831-1420
9	1	D1	LED, RED, LED-ROHM-SML-010VT	ROHM, SML-010VTT86L
10	3	R6, R7, R8	RES., CHIP, 5.10kΩ, 1%, 0603	VISHAY, CRCW06035K10FKEA
11	3	R2, R3, R4	RES., CHIP, 10kΩ, 5%, 0603	VISHAY, CRCW060310K0JNEA
12	1	R5	RES., CHIP, 1kΩ, 5%, 0603	VISHAY, CRCW06031K00JNEA
13	1	R9	RES., CHIP, 100kΩ, 5%, 0603	VISHAY, CRCW0603100KJNEA
14	1	S1	SWITCH, SMT PUSH BUTTON	PANASONIC, EVQPE105K
15	1	U2	I.C., SERIAL EEPROM TSSOP8	MICROCHIP, 24LC025-I/ST
16	1	(J1)	CABLE ASSY., 8" STRIP	MMT PRECISION CORP., CA-2440
17	2		STENCILS (TOP & BOTTOM)	STENCIL DC1496C-1
DC1496C-A				
2	0	R1	RES., CHIP, 0.1Ω, 1/8W, 1%, 1206	IRC, LRC-LR1206LF-01-R100-F
3	0	U1	I.C., BATTERY GAS GAUGE WITH I^2C	LINEAR TECH., LTC2942IDCB
DC1496C-B				
2	1	R1	RES., CHIP, 0.1Ω, 1/8W, 1%, 1206	IRC, LRC-LR1206LF-01-R100-F
3	1	U1	I.C., BATTERY GAS GAUGE WITH I^2C	LINEAR TECH., LTC2942IDCB
DC1496C-C				
2	0	R1 (OPT)	RES., 1206	
3	1	U1	I.C., BATTERY GAS GAUGE WITH I^2C	LINEAR TECH., LTC2941IDCB-1
DC1496C-D				
2	0	R1 (OPT)	RES., 1206	
3	1	U1	I.C., BATTERY GAS GAUGE WITH I^2C	LINEAR TECH., LTC2942IDCB-1

SCHEMATIC DIAGRAM

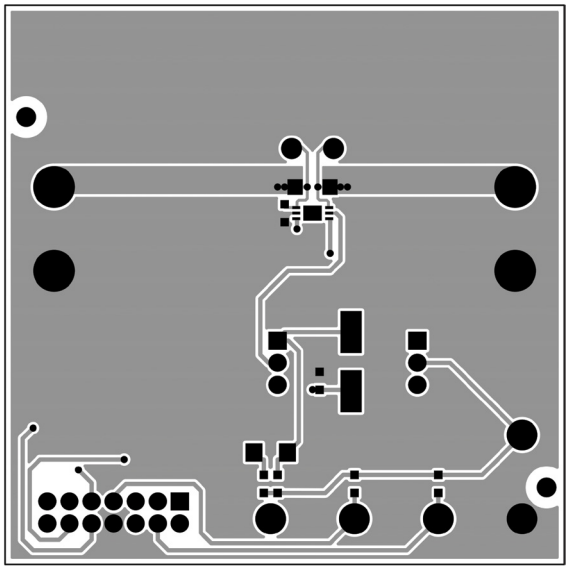


PCB LAYOUT AND FILM

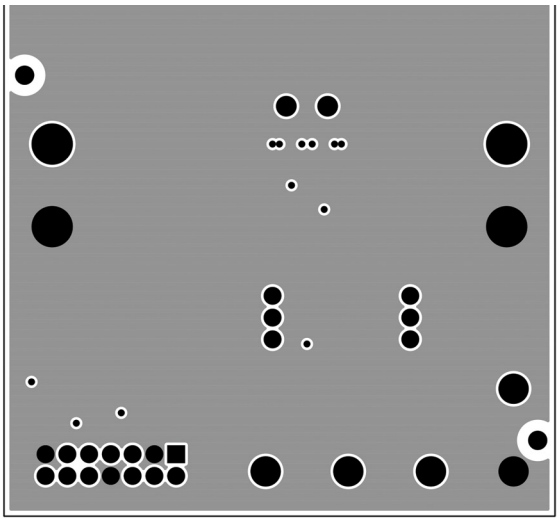
Silkscreen Top



Component Side

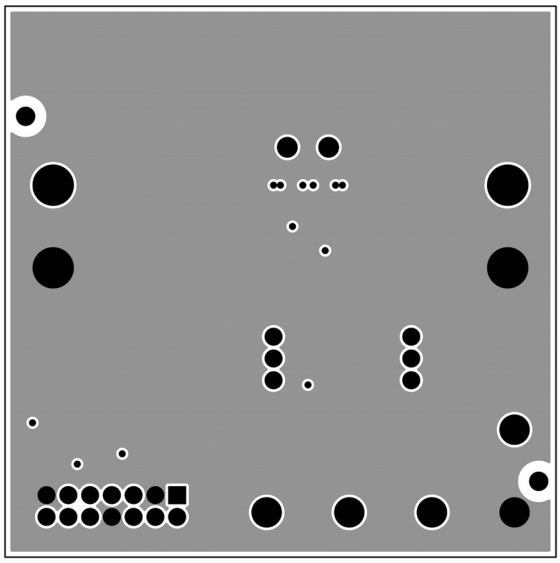


Inner Layer 2

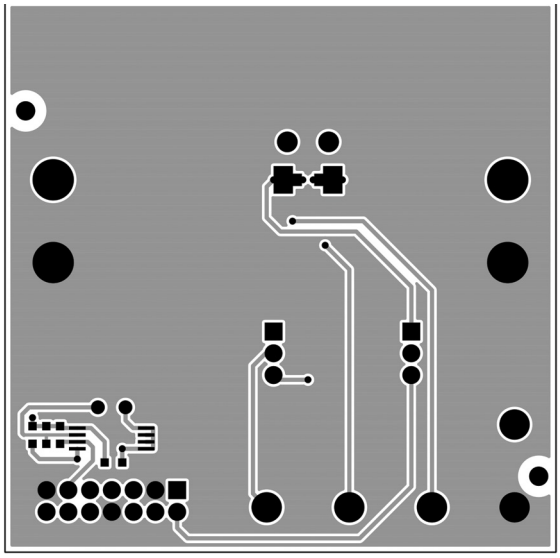


PCB LAYOUT AND FILM

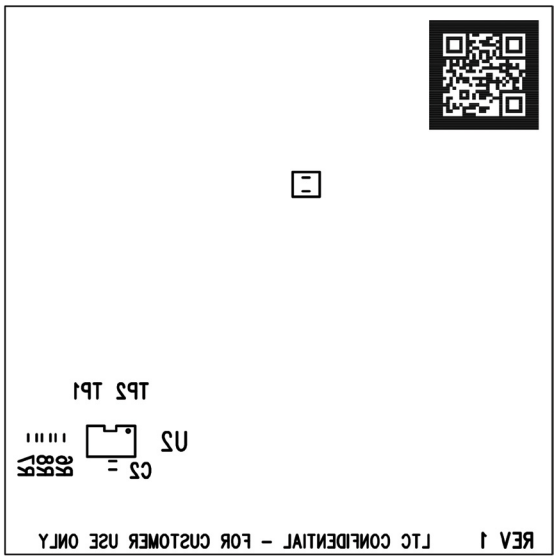
Inner Layer 3



Solder Side



SilkScreen Bottom



REVISION HISTORY

BOARD REV	DATE	DESCRIPTION	PAGE NUMBER
C	01/15	LED D1 Changed in BOM and Board	6

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