LT6110 Cable/Wire Drop Compensator

DESCRIPTION

The DC2033A demo board features the LT®6110 cable/wire drop compensator IC. The LT6110 is a precision high side current sense that monitors load current via a sense resistor and converts the sense voltage to a sinking or sourcing current. Using the LT6110 sourcing or sinking current to control a regulator's output voltage can compensate for the voltage loss due to a cable/wire drop. The LT6110 includes an internal sense resistor or can be used with an external sense resistor.

The DC2033A is jumper-configurable for the LT6110 to use the internal sense resistor, an external 25mΩ sense resistor, or a 5.4mΩ PCB trace sense resistor. The DC2033A default configuration is for the LT6110 to use the internal sense resistor.

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

TYPICAL WIRE DROP COMPENSATION CONNECTIONS

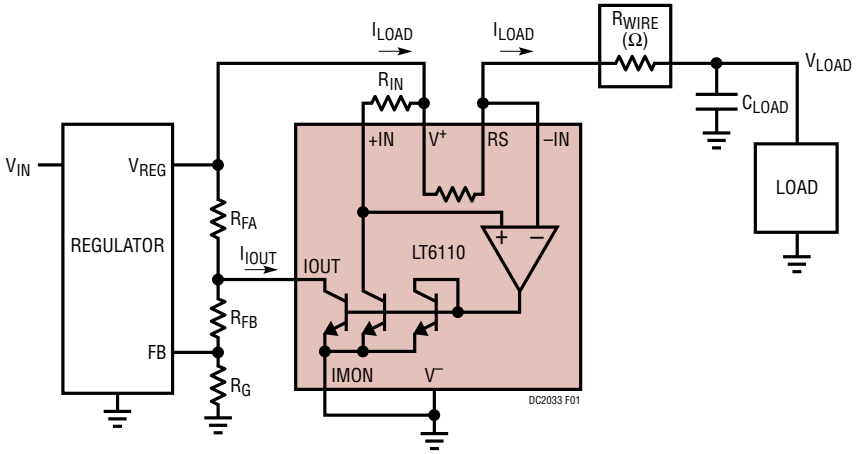

Figure 1. One Cable/Wire Compensation (One Wire to a Load Sharing the Regulator's Ground)

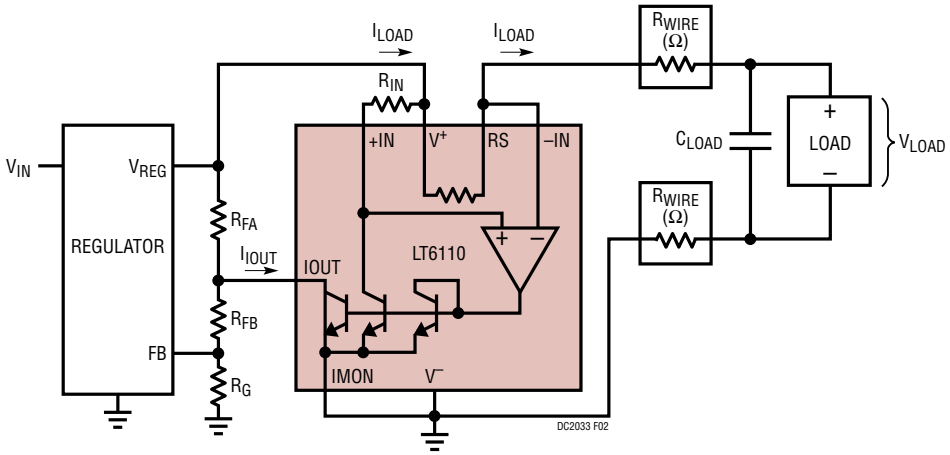

Figure 2. Two Cable/Wire Compensation (One Wire to a Load and One Ground Return Wire)

PERFORMANCE SUMMARY

Specifications are at T_A = 25°C

PARAMETER		MIN	TYP	MAX	UNITS
Supply Range (V^+ to V^-)		2		50	V
Amplifier Input Offset Voltage, V_{OS}			100	300	µV
IOUT Current Error (Does Not Include V_{OS} or R_{IN} Errors)	I_{+IN} = 10µA I_{+IN} = 100µA I_{+IN} = 1mA		0.6 0.4 1.5	1.6 1 2.5	% % %
IMON Current Error (3 • I_{+IN})	I_{+IN} = 100µA		1.5	3	%
IOUT Voltage Range		0.4		V^+	V
IOUT Current Error Change for IOUT Voltage 0.4V to 3.5V				0.2	%/V
IMON Current Error Change for IMON Voltage 0V to 3.1V				0.2	%/V
IOUT Signal Bandwidth	I_{+IN} = 100µA		180		kHz
Supply Current			16	30	µA

QUICK START SETUP

The Quick Start Setup of Figure 3, shows the basic connections required for getting familiar with a DC2033A. An ammeter is used to measure the load current to a 5Ω load or an active load. To confirm the operation of the LT6110, connect a wire jumper from VOUT1 to regulator. This jumper connects the power supply 5V to the ROUT 100Ω pull-up resistor. The voltmeter across ROUT is for monitoring the I_{IOUT} current. A DC2033A is assembled with a 402Ω R_{IN1} resistor to provide quick testing convenience.

The R_{IN1} resistor and the V_{SENSE} voltage set the LT6110 output current (I_{IOUT}). To begin, adjust the power supply for 1A load current. With 1A load current flowing through the internal 20mΩ R_{SENSE} resistor and 100µV V_{OS}, the I_{IOUT} current is 50µA, (1A • 20mΩ + 100µV)/402Ω. The voltmeter should read 5mV (50µA • 100Ω) ± the R_{SENSE}, V_{OS}, R_{IN1}, R_{OUT} and I_{IOUT} errors. Figure 4 shows the Quick Setup schematic and I_{IOUT} equations.

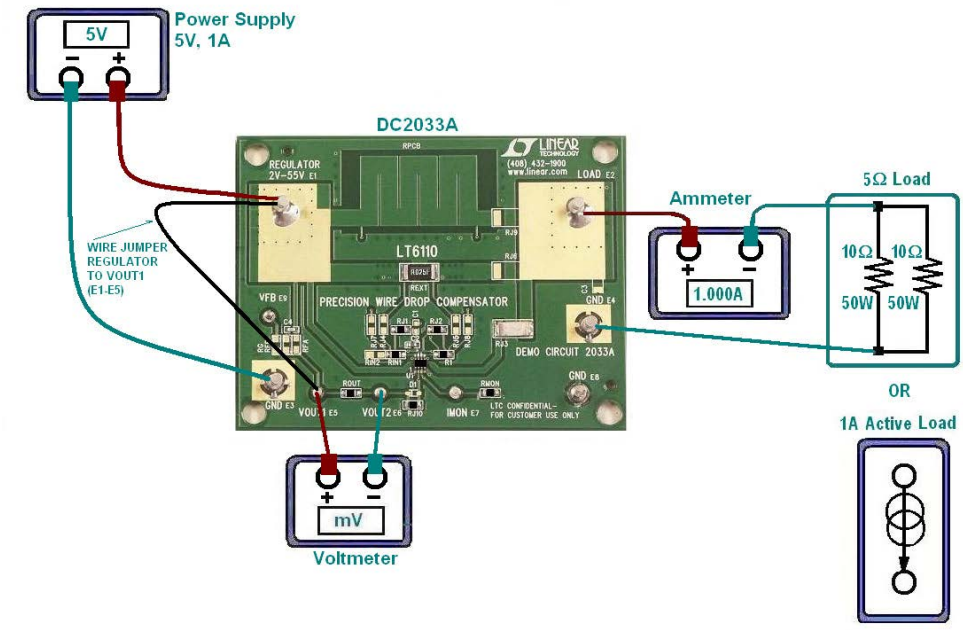

Figure 3. Quick Start Setup

QUICK START SETUP

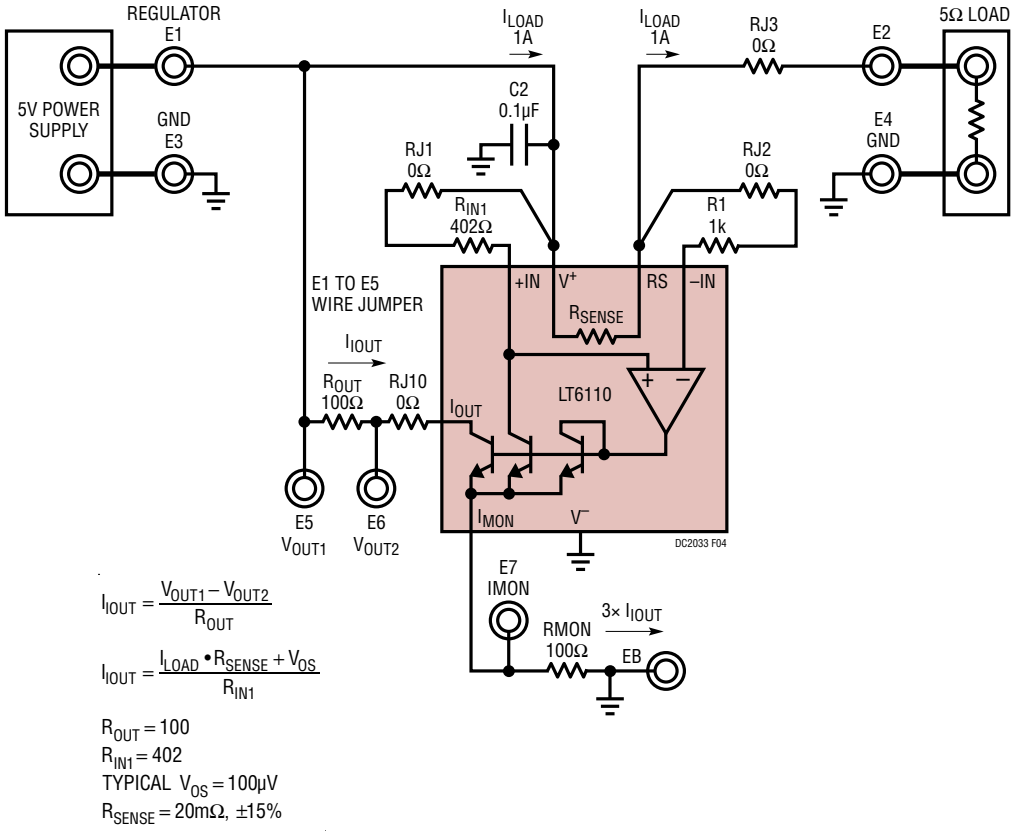

Figure 4. DC2033A Quick Setup Circuit and Equations

Setting Up the DC2033A for Wire Compensation Testing

The DC2033A default circuit uses the LT6110 internal 20mΩ sense resistor (R_{SENSE}) and is configured with 0Ω RJ1, RJ2 and RJ3 are installed with 0Ω jumpers. The RJ1 and RJ2 are standard 0Ω jumpers and connect the LT6110 amplifier across the internal R_{SENSE}. The RJ1 and RJ2 resistance is not a concern as the current flowing through them is very small (the resistance variation of standard 0Ω resistors is 20mΩ to 100mΩ). However, a standard 0Ω jumper must not be used in the path of the load current because the jumper's I • R drop adds an error term to a wire drop compensation design (for example the I • R drop of a 50mΩ jumper for 2A is 100mV). The RJ3 jumper is ultra-0Ω, with less than 1mΩ and rated for 30A at 70°C. The RJ3 jumper can be removed and re-installed as RJ6 or RJ9, to configure the DC2033A with an LT6110 and an external R_{SENSE} (for an alternative to an ultra-0Ω jumper install two 0.25 inch length of 18AWG solid copper wires in parallel for up to 20A I_{LOAD}).

The R_{IN1} resistor and the V_{SENSE} voltage set the LT6110 output current (I_{IOUT}) for regulator output voltage control. The I_{IOUT} current connects to the regulator feedback resistors and boosts the regulator's output voltage (V_{REG}). The V_{REG} voltage increases directly with the load current and cancels the wire's I • R drop (V_{DROP}) to the remote load.

A DC2033A has 0805 size pads for installing a switching regulator's feedback resistors (R_{FA}, R_{FB} and R_G). A low quiescent current switching regulator has 10µA or less current flowing through the feedback divider and requires

QUICK START SETUP

three feedback resistors for an LT6110 connection, as in Figure 1. In addition, a DC2033A includes pads for a feedback loop compensation capacitor, C4.

A Quick Design Guide.

Variable Definitions:

I_{LOAD} is the maximum load current and I_{IOUT} is the LT6110 output current, (design target is 100µA).

R_{SENSE} is the LT6110 internal or external current sense resistor and R_{WIRE} is the copper wire resistance.

(R_{WIRE} includes the resistance of the load current carrying PCB traces and wire connectors minus the R_{SENSE} resistance).

V_{FB} is the regulator's feedback reference voltage.

I_Q is the no-load quiescent current flowing through the resistor feedback divider, ($I_Q = V_{FB}/R_G$), (refer to the regulator's demo manual).

V_{REG} is the no-load current regulator output voltage.

Quick Design Equations:

$$R_{IN1} = \frac{V_{SENSE}}{I_{IOUT}} \quad V_{SENSE} = I_{LOAD} \bullet R_{SENSE}$$

$$R_{FA} = \frac{V_{DROP}}{I_{IOUT}} \quad V_{DROP} = I_{LOAD} \bullet (R_{SENSE} + R_{WIRE})$$

$$R_{FB} = \frac{V_{REG} - V_{FB}}{I_Q} \quad R_G = \frac{V_{FB}}{I_Q}$$

Quick Design Check:

$$V_{REG} = (R_{FA} + R_{FB} + R_G) \bullet I_Q$$

NOTE: For DC2033A REGULATOR input voltages higher than 36V, remove the RJ10 jumper sorting the 27V Zener, D1. Refer to the LT6110 data sheet for additional application circuits and information.

APPLICATIONS

DC2033A Application Options

The DC2033A is designed to be used with a regulator board and copper wire. On board jumper pads and turrets configure an LT6110 circuit using 0Ω jumpers and provide for wired connections to a regulator board. Figures 6, 7 and 8 show typical DC2033 application circuit options.

Table 2. DC2033A Current Sense Resistor, R_{SENSE} and Jumper Options

R_{SENSE}	RESISTANCE (25°C)	JUMPERS STANDARD 0Ω	JUMPERS ULTRA-0Ω	$I_{LOADMAX}$
Internal	20mΩ at I_{LOAD} = 1A, (16.5mΩ to 22.5mΩ	RJ1, RJ2	RJ3	3A at 125°C
LT6110 R_{SENSE}	22mΩ at I_{LOAD} = 3A, (18.5mΩ to 24.5mΩ			
External R_{EXT}	25mΩ at I_{LOAD} = 1A, ±1%	RJ4, RJ5	RJ6	6A at 70°C 5A at 90°C
External R_{PCB}	5.4mΩ at I_{LOAD} = 1A, ±15%	RJ7, RJ8	RJ9	20A at 25°C 10A at 90°C
	5.7mΩ at I_{LOAD} = 10A, ±15%			

The DC2033A with a Regulator Demo Board

A DC2033A board can be configured and connected to a regulator demo board for a complete cable/wire drop compensation system evaluation. Typically a regulator demo board includes a feedback resistor divider that sets the output voltage V_{REG}. Remove the feedback resistors from the regulator board and connect the regulator's feedback pin (FB or V_{REF}) to the DC2033A V_{FB} (E9). In addition, connect the V_{OUT} and GND of the regulator board to the REGULATOR (E1) and to the GND (E3) of the DC2033A respectively. Figure 5 shows Linear Technology's buck regulator demo board, DC1458A, connected to a DC2033A, using an external sense resistor, R_{EXT}. The DC1458A demo board includes the LT3972, 5V at 3.5A buck regulator. Figure 6 shows the complete cable/wire compensation schematic.

NOTE: The LT3972 R2 and R3 feedback resistors are removed from the DC1458A board and are on the DC2033A board (R_{FA}, R_{FB} and R_G). The no-load LT3972 voltage is

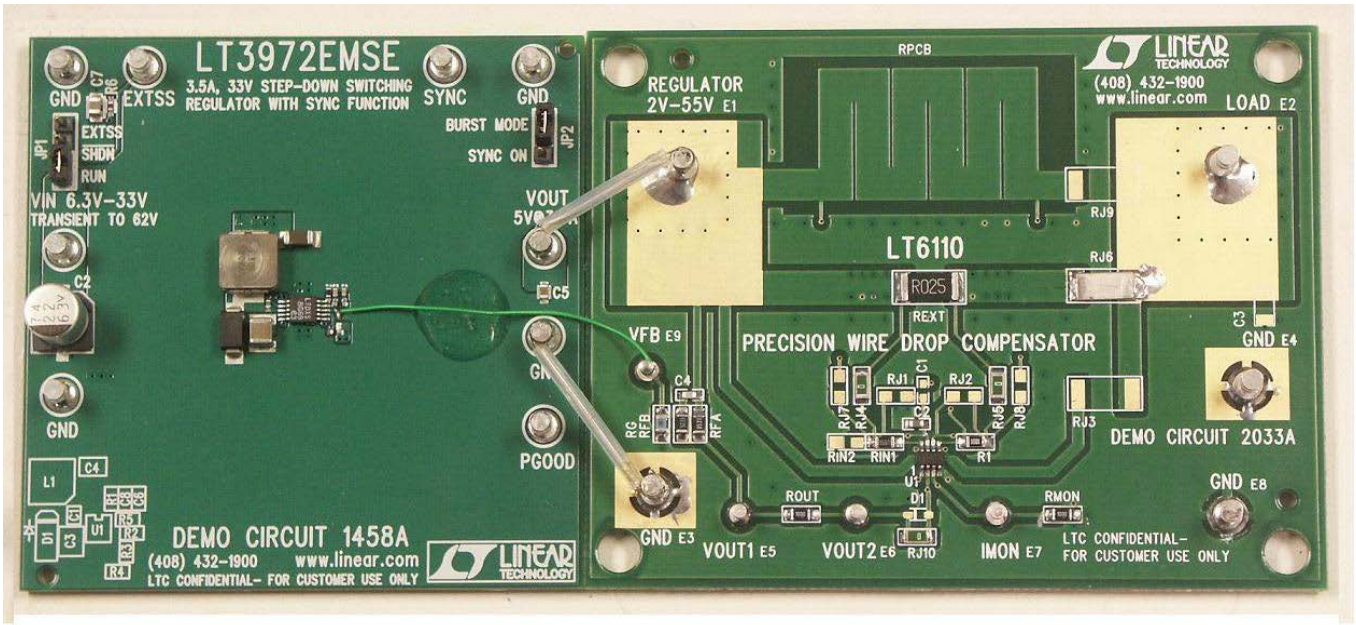

Figure 5. DC1458A and DC2033A Connections

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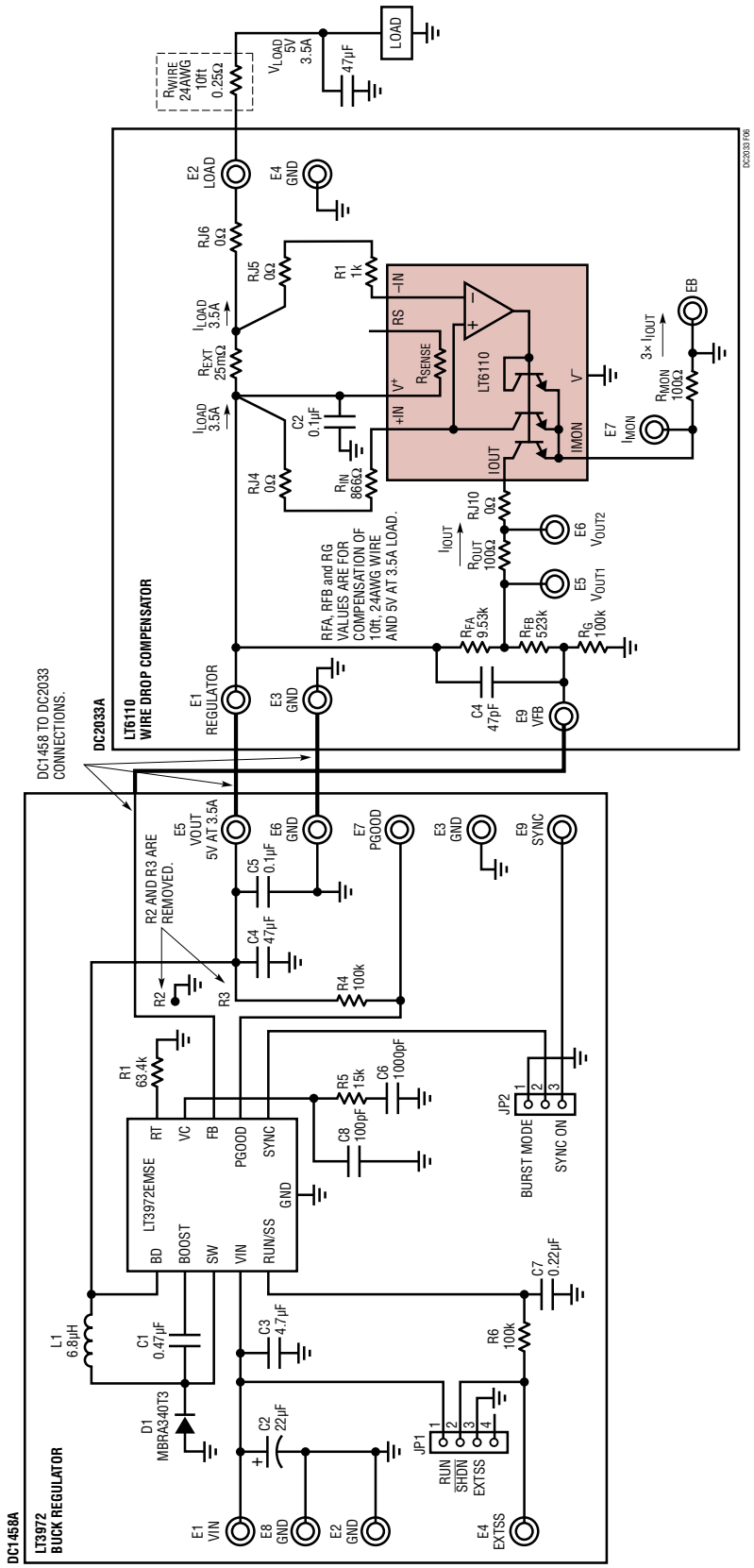

Figure 6. An LT3972 5V at 3.5A Buck Regulator with LT6110 Circuit Compensating for the Drop of a 10ft, 24AWG Cable/Wire

APPLICATIONS

5V and the feedback voltage, V_{FB} is 0.79V. The values of the feedback resistors are selected using the Quick Design Guide with an I_Q = 8µA. The specified quiescent current is 8µA. Resistors R_{FA}, R_{FB} and R_G are 9.53k, 523k and 100k respectively. V_{REG} = (9.53k + 523k + 100k) • 8µA = 5V (±1% and ±1.27% resistor and V_{FB} tolerance respectively).

The DC2033A PCB Trace R_{SENSE}

A DC2033A has a serpentine PCB trace that can be used as an LT6110 external sense resistor for high load currents (5A to 20A). Remove RJ3 ultra-0Ω jumper and install as RJ9. Remove standard 0Ω jumpers RJ1 and RJ2 and install RJ7 and RJ8. Figure 7 shows the DC2033A schematic with LT6110 and PCB R_{SENSE}.

The copper thickness of a DC2033A PCB trace is two ounces. A typical resistance for a 2oz square trace is 0.25mΩ at 25°C. The R_{PCB} serpentine trace length is six 0.15 × 0.6 inch rectangular traces connected by 0.015 × 0.15 inch traces. The current path area of each rectangular trace is equivalent to three and one-half squares. The R_{PCB} resistance is 5.4mΩ at 25°C, ±15%. R_{WIRE} is the total resistance from the regulator output to the remote load (minus the R_{SENSE} resistance).

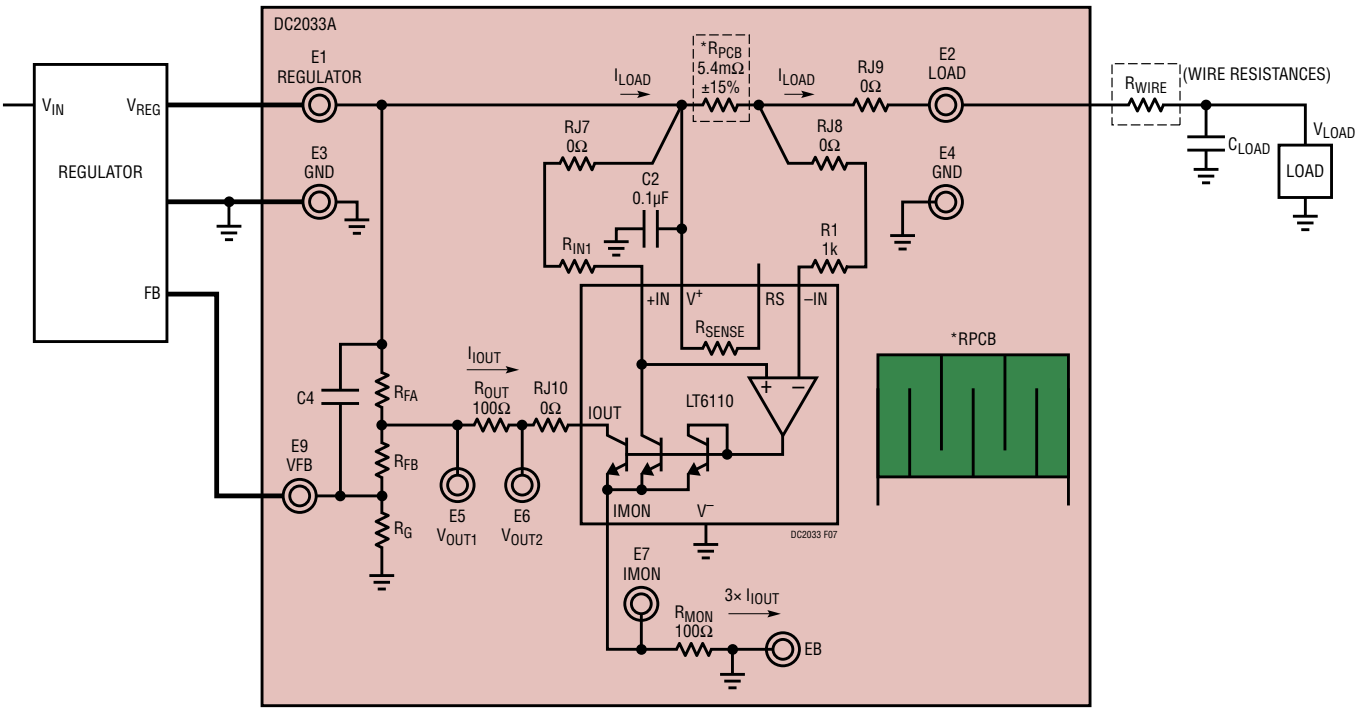

Figure 7. DC2033 Configured for R_{PCB} (PCB Trace Sense Resistor)

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The RJ9 jumper in the load current path must be ultra-0Ω, 1mΩ or less (the jumper's I • R drop adds an error term to a wire drop compensation design). The RJ3 jumper is ultra-0Ω, less than 1mΩ and can be removed and installed as RJ9 (for an alternative to an ultra-0Ω jumper install two 0.25 inch length of 18AWG solid copper wires in parallel for an RJ9 jumper).

Using the DC2033A with an LT6110 DFN Package

The bottom layer of a DC2033A is designed for an LT6110 DFN IC. To use a DC2033A for evaluating with an LT6110 DFN IC with an internal R_{SENSE} requires the following: Remove U1 (LT6110 SOT IC) and jumper RJ3 from the top of the board. Install a U2 (LT6110 DFN), RJ11 and RJ12 on the bottom of DC2033A. Figure 8 shows the schematic of a DC2033A with an LT6110 DFN package.

The DC2033A PCB layout is optimized for an LT6110 SOT23 package. A DC2033A with a LT6110 DFN (U2) and an internal R_{SENSE}, adds a 2% R_{SENSE} error due to a PCB via from the top to the bottom PCB layer. In addition to using a DC2033A with a LT6110 DFN and an internal R_{SENSE}, the DC2033A can be configured for an LT6110 DFN with an external REXT or RPCB current sense resistor (refer to the jumper table on the DC2033A schematic).

The load current path RJ6, RJ9, RJ11 and RJ12 jumpers must be ultra-0Ω, less than 1mΩ, (for an alternative to an ultra-0Ω jumper install two 0.25 inch length of 18AWG solid copper wires in parallel for an RJ6, RJ9, RJ11 or RJ12 jumper).

APPLICATIONS

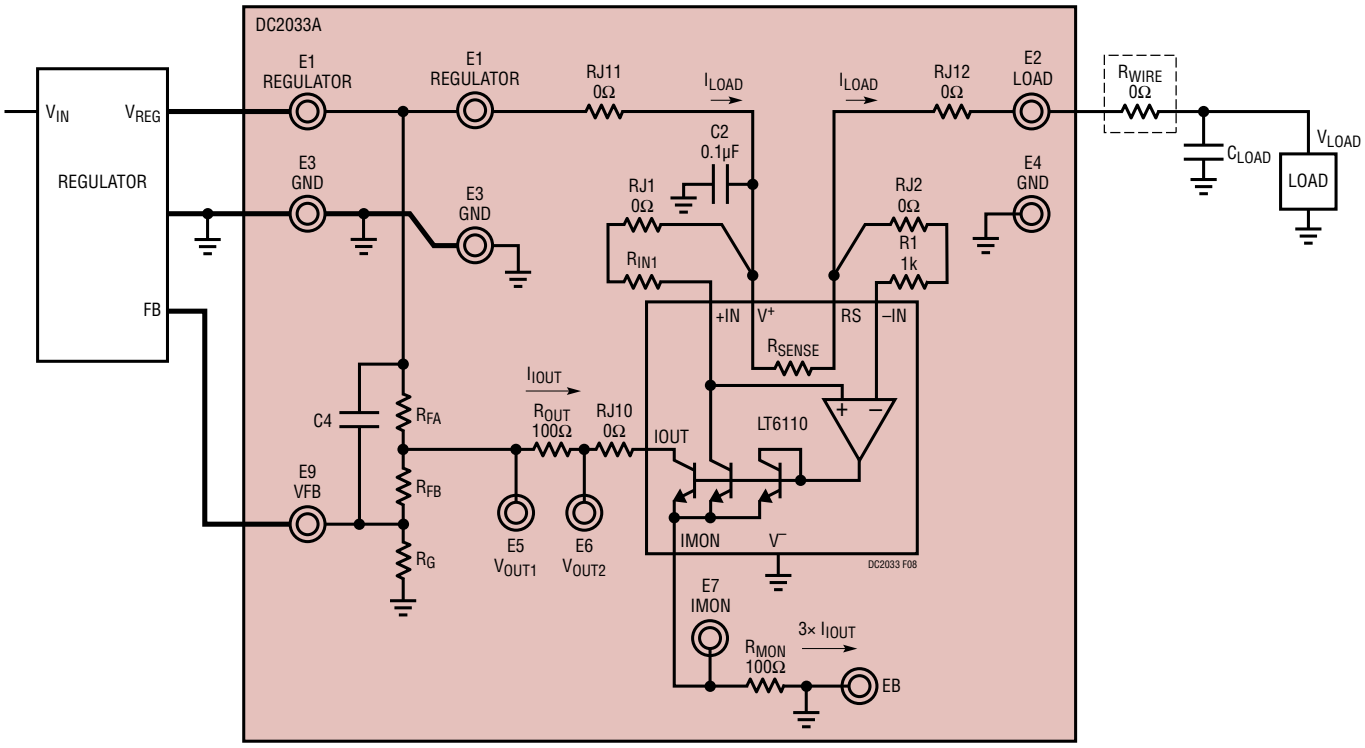
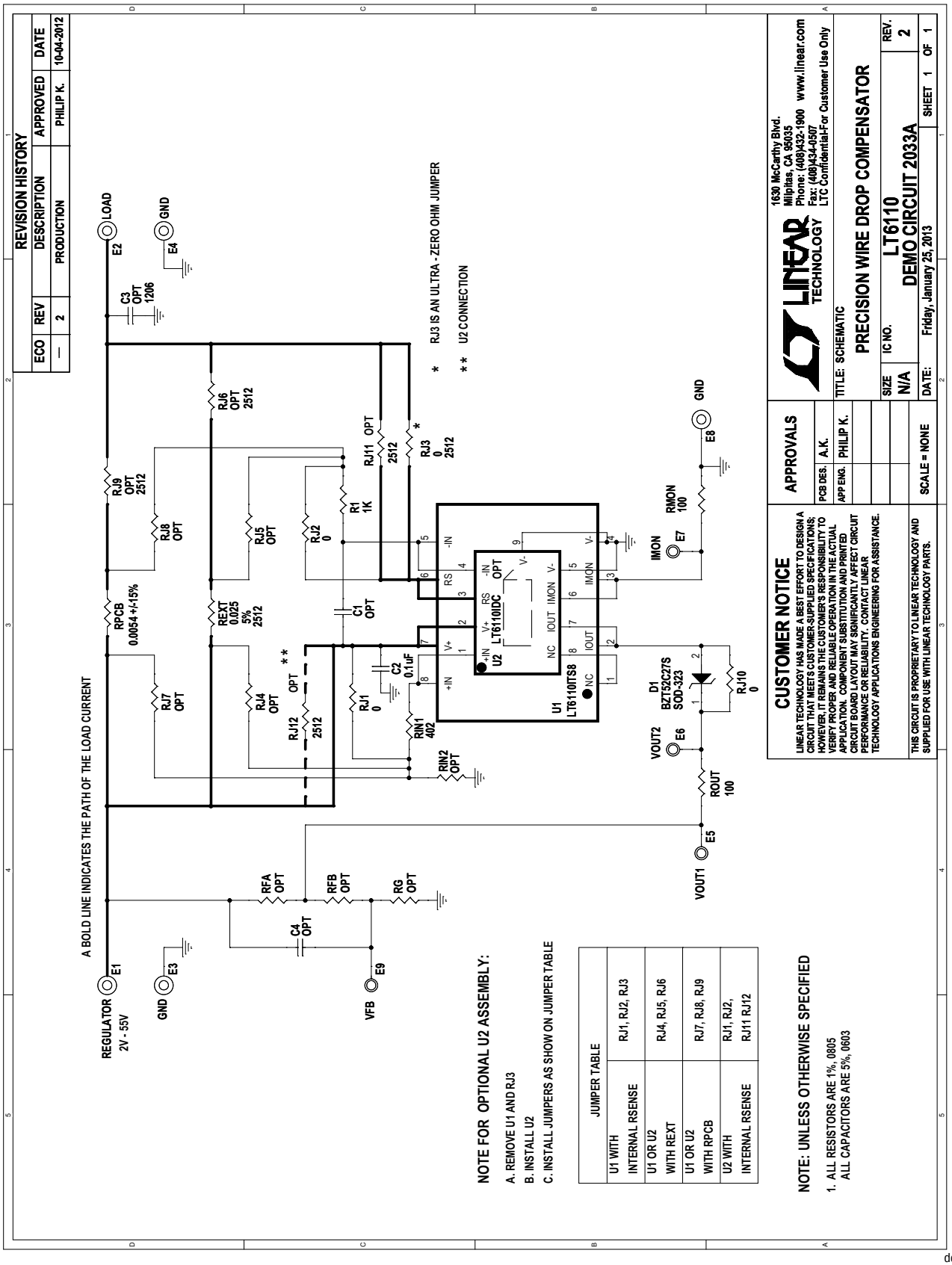


Figure 8. DC2033 Configure with an LT6110 DFN Package and Internal R_{SENSE}

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
1	0	C1, C4	CAP, X7R, 50V, 10%, 0603 OPT	
2	1	C2	CAP, X7R, 0.1µF, 50V, 10%, 0603	TDK C1608X7R1H104K
3	0	C3	CAP, X7R, 50V,1206 OPT	
4	1	D1	DIODE, ZENER 27V 200MW SOD-323	DIODES/ZETEX, BZT52C27S-7-F
5	4	E5, E6, E7, E9	TESTPOINT, TURRET, 0.063"	MILL-MAX, 2308-2-00-80-00-00-07-0
6	5	E1 TO E4, E8	TESTPOINT, TURRET, 0.093"	MILL-MAX, 2501-2-00-80-00-00-07-0
7	1	REXT	CURRENT SENSE RESISTOR 0.025Ω 1% 2512	VISHAY, WSL2512R0250FEA18
8	0	RIN2, RG, RFA, RFB	RES, CHIP, 1%, 1/8W, 0805 OPT	
9	1	RIN1	RES, CHIP, 1%, 1/8W, 402Ω, 0805	VISHAY, CRCW0805402RFKEA
10	3	RJ1, RJ2, RJ10	RES, 0Ω JUMPER, 0805	VISHAY, CRCW08050000Z0EA
11	0	RJ4, RJ5, RJ7, RJ8	RES, 0Ω JUMPER, 0805 OPT	
12	1	RJ3	RES, ULTRA-0Ω JUMPER, 2512	NACOMA/TEPRO RN5326
13	0	RJ6, RJ9, RJ11, RJ12	RES, ULTRA-0Ω JUMPER, 2512 OPT	USE TWO 0.25in,18AWG SOLID COPPER WIRES IN PARALLEL
14	2	ROUT, RMON	RES, CHIP, 1%, 1/8W, 100Ω, 0805	VISHAY, CRCW0805100RFKEA
15	0	RPCB	RES PCB TRACE, 5.4mΩ, ±15%	(PCB TRACE RESISTOR)
16	1	R1	RES, CHIP, 1%, 1/8W, 1k, 0805	VISHAY, CRCW08051K00FKEA
17	1	U1	IC, WIRE DROP COMPENSATOR, TSOT-23-8	LINEAR TECHNOLOGY, LT6110ITS8#PBF
18	0	U2	IC, WIRE DROP COMPENSATOR, 8 LEAD DFN, OPT	
19	4	MH1, MH2, MH3, MH4	STANDOFF, SNAP ON	KEYSTONE, 8831

SCHEMATIC DIAGRAM



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