ANALOG DEVICES

AN-1186
APPLICATION NOTE

One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A. • Tel: 781.329.4700 • Fax: 781.461.3113 • www.analog.com

Radiated Immunity Performance of the AD7192 in Weigh Scale Applications

by Mary McCarthy and Li Ke

INTRODUCTION

The AD7192 is an ultralow noise, low drift, 24-bit sigma-delta converter which includes a PGA. The AD7192 is used in high-end weigh scale systems. The radiated immunity of the weigh scale system is tested as part of the qualification for release.

This application note describes how to achieve the best radiated immunity performance from the AD7192, taking into account the effects of board layout and component placement when designing a printed circuit board (PCB). The radiated immunity testing is performed as per standard IEC 61000-4-3 and the complete system (ADC, PCB, and load cell) is tested.

RADIATED IMMUNITY

The radiated immunity test is performed as described in the standard IEC 61000-4-3. The field strength is 10 V/m and the RF frequency is swept from 80 MHz to 1 GHz. According to the specification, a device is classified as follows:

- Class A: Normal performance within limits specified by the manufacturer, requestor, or purchaser.
- Class B: Temporary loss of function or degradation of performance, which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention.
- Class C: Temporary loss of function or degradation of performance, the correction of which requires operator intervention.
- Class D: Loss of function or degradation of performance, which is not recoverable, owing to damage to hardware or software, or to loss of data.

The ADC converts continuously during the frequency sweep. The error as referred to throughout this application note is the maximum deviation between the ADC conversions when an RF frequency is present versus when there is no RF frequency present.

For a weigh scale system to be Class A, the allowable error e in the presence of the RF interference is

$$\frac{\pm Maximum\ output\ voltage\ from\ load\ cell}{(2 \times number\ of\ counts)} =$$

$$\frac{\pm Full - scale\ output}{2n}$$

where n is the number of counts for the weigh scale system.

TABLE OF CONTENTS

REVISION HISTORY

4/13—Revision 0: Initial Version

RADIATED IMMUNITY TEST ANALYSIS

SETUP

Figure 1 is a block diagram of the circuit used for the radiated immunity testing. The AD7192 is configured as follows:

Sinc[4] filter

Chop off

Output data rate = 10 Hz

Gain = 128

The AD7192 operates from a 3.3 V power supply. This supply is also used to excite the load cell. The load cell is 6-wire with a sensitivity of 2 mV/V. For more details on weigh scale design using the AD7192, refer to Circuits from the Lab® reference circuit (CN-0119).

ERROR

As discussed in the Radiated Immunity section, the allowable error *e* for a Class A system is

$$\frac{\pm Full - scale\ output}{2n}$$

where *n* is the number of counts. The error is equivalent to ±0.5 counts.

In this application note, the goal is to design a weigh scale system that has 3000 display counts and is classified as Class A when the load cell is excited with 3.3 V. With a sensitivity of 2 mV/V and an excitation voltage of 3.3 V, the maximum signal from the load cell is 6.6 mV. Often, to use the most linear portion of the load cell's span, only two-thirds of this range is used. This reduces the full-scale output voltage from the load cell to 4.4 mV.

For an accuracy of 3000 counts, one count is

1 count = 4.4 mV/3000 = 1.46 µV

±0.5 counts = ±1.46 µV /2 = ±0.73 µV

The error must be less than ±0.73 µV while the RF frequency is present. The load cell used in the application accepts a full weight of 2 kg so the error needs to be less than ±2 kg/(2 × 3000) = ±0.33 grams—this ensures that the digital display is not affected by the RF interference.

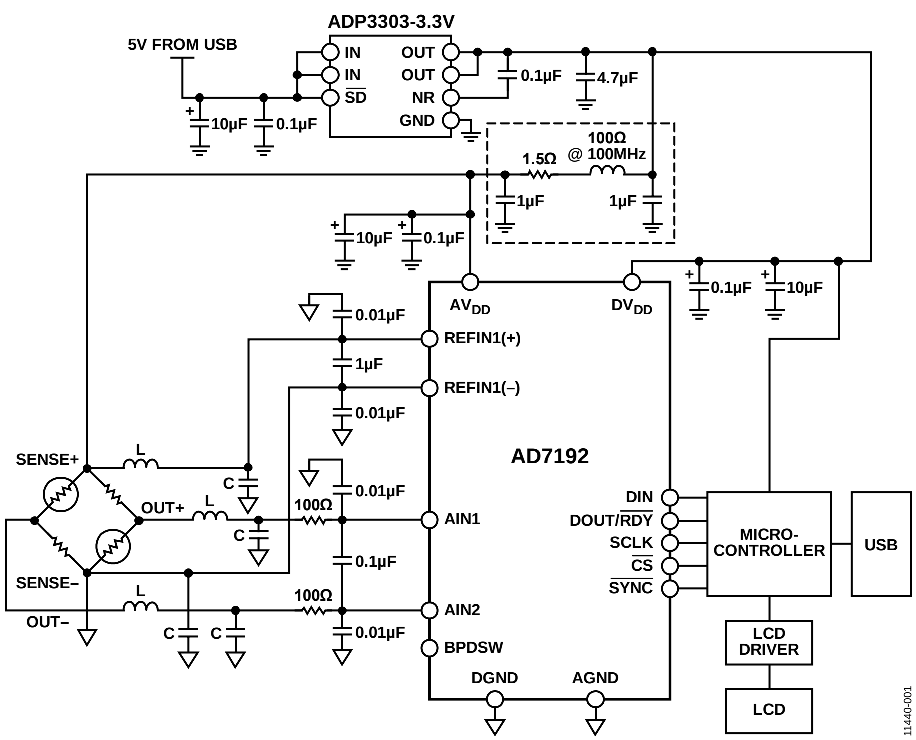


Figure 1. AD7192 Setup for Testing

PRINTED CIRCUIT BOARD

The standard AD7192 evaluation board is designed to give optimum analog-to-digital conversion performance. However, it is not optimized for EMC. For example, the standard AD7192 evaluation board includes links (vertical pins) to allow different power supply options and links are present for the noise test connection; these links act as antenna. In addition, filtering on the analog and digital inputs is not optimized in terms of location and component size (0603 components are used). However, using this board as a starting point, an investigation was performed to highlight any adverse effects due to EMC. See the Results section for details. The grounding, component location, and addition of extra filtering were all reviewed. The ADC performance was maintained at all stages.

In summary, the key findings were

- The link options (vertical pins) should not be included on the board. These act as antenna. Therefore, replace link options with a solder link option.
- The printed circuit board should be 4-layer, with the analog inputs and reference inputs buried in the inner layers. A single ground plane should be used. Flood the top and bottom sides of the board with ground. Also, flood the inner layers with ground. Multiple vias should be included to minimize any potential differences across the board. There is no hard rule on the density of vias required. On the AD7192 board, a ring of vias was included around the ADC and the filtering on the analog and reference inputs. In general, any islands on the board should have vias also, the number of vias being in excess of one. Any tracks on the top and bottom sides should be as short as possible since tracks will also act as antenna.
- Filtering is recommended on the analog and reference inputs. Figure 1 shows the R and C values that are normally recommended on the analog and reference inputs. This filtering provides attenuation at the AD7192's sampling frequency (307.2 kHz) and multiples of the sampling frequency. The AD7192 itself does not provide any attenuation at these frequencies. The capacitors need to be as close as possible to the AD7192's analog inputs and reference inputs so that the track length from the component to the ADC is minimized. Using components that are physically smaller allows the user to place the components closer to the pins. The layout should ensure that track lengths from the pins to the components are well matched.
- In addition to these filters, adding additional filtering in the R and L locations shown in Figure 1 improved the immunity further. This filtering is located at the connector to the load cell. Various combinations for the L (L2, L3, L4, and L5) and C (C1, C9, C12, and C13) values were evaluated to achieve the best results. The Bill of Materials section lists the final components selected.
- The power supplies are decoupled with a 10 μF capacitor in parallel with a 0.1 μF capacitor. Again, the components should be as close as possible to the power pins of the AD7192. The analog power supply is used as the excitation voltage to the load cell which, in turn, is used as the reference to the ADC. Therefore, the power supply tracks are also buried in an inner layer.

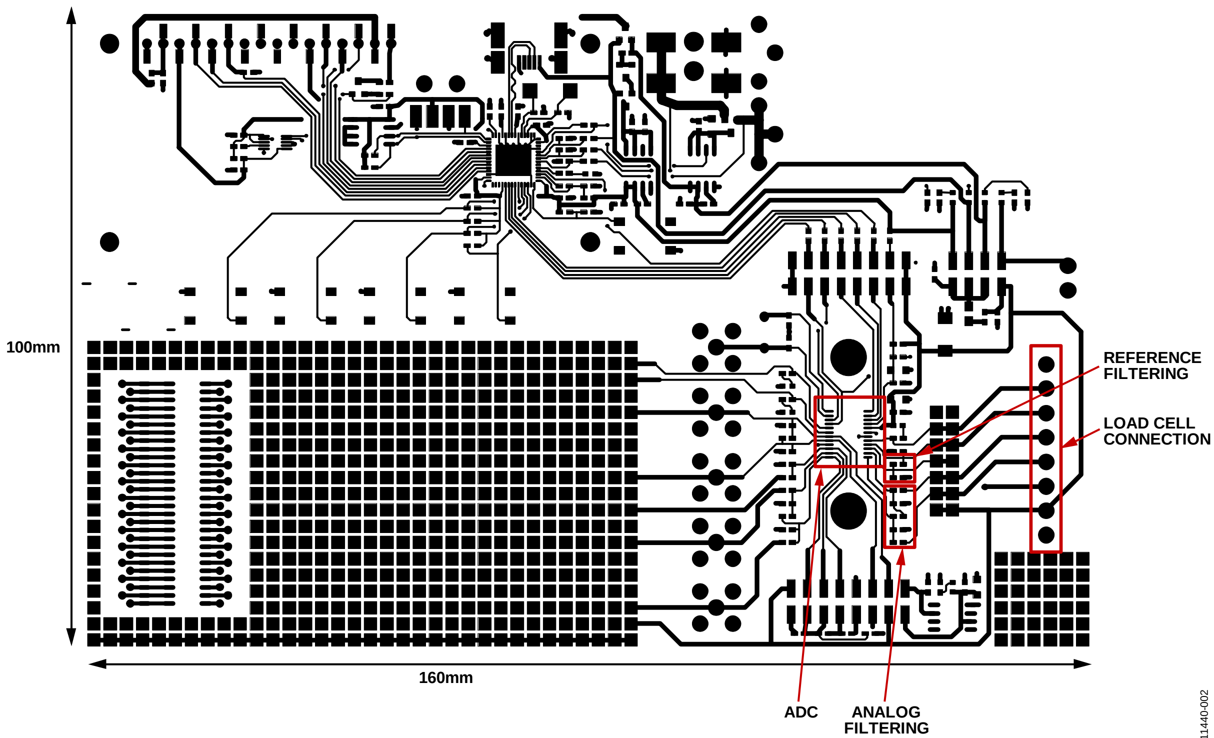


Figure 2. Top Side of Standard AD7192 Evaluation Board

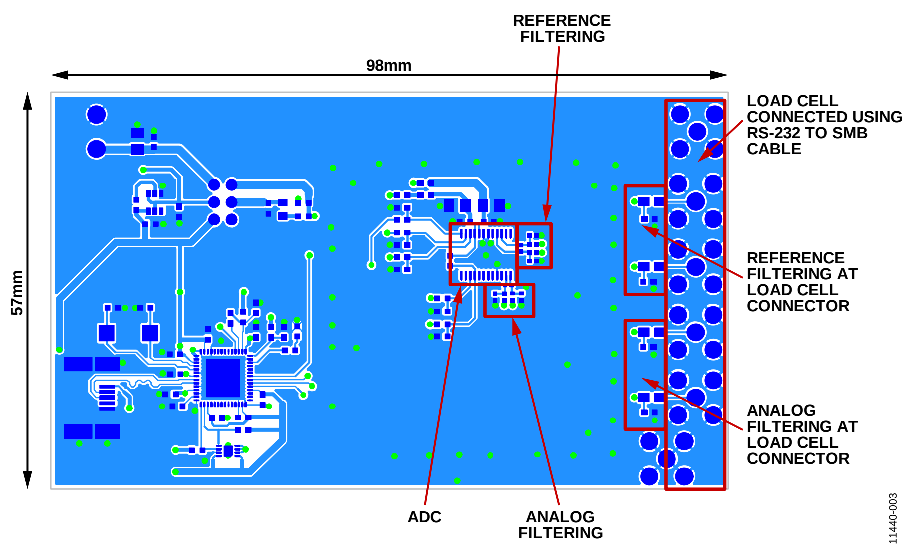


Figure 3. Top Side of AD7192 EMC Board

RESULTS

Following the investigation, a printed circuit board optimized for radiated immunity was developed (see Figure 3). The artwork and schematics for the board are included in the Evaluation Board Schematics and Artwork section of this application note. Using this board and the components listed in the Bill of Materials, the maximum error measured during radiated immunity testing was less than *e*. Figure 4 shows the conversions read from the AD7192 while the RF frequency is swept from 80 MHz to 1 GHz. A constant weight is placed on the load cell during the testing.

The error measured is 0.45 µV, which is higher than *e*. This is equivalent to 0.2 grams.

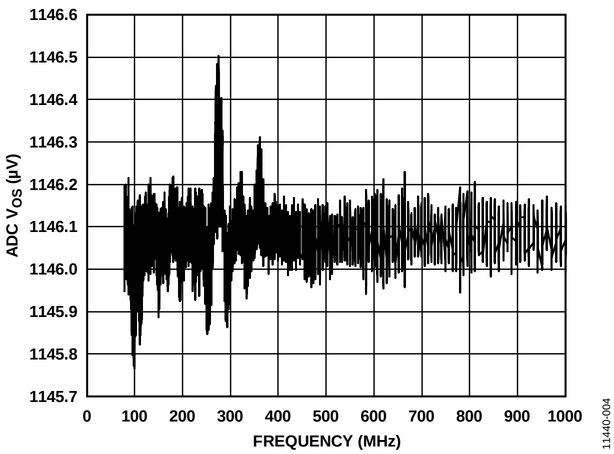


Figure 4. Error vs. Frequency of AD7192 EMC Board

For comparative reasons, Figure 5 shows the conversions read from the standard AD7192 evaluation board when tested for radiated immunity. The board has an error of 356 µV when the RF interferer is present which is equivalent to 161 grams.

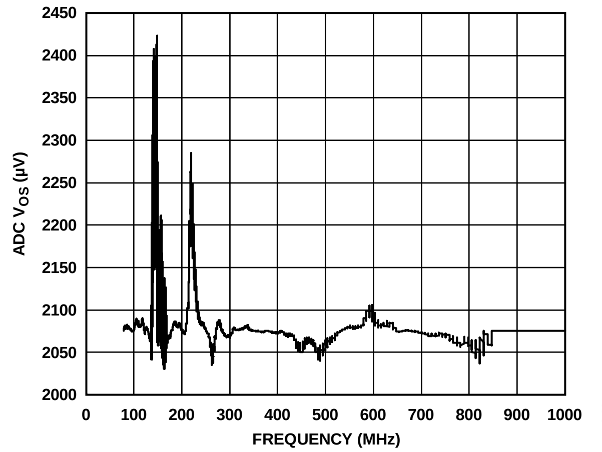


Figure 5. Radiated Immunity of AD7192 Evaluation Board

This comparison highlights the importance of layout, component selection, and component placement to achieve optimum performance in terms of radiated immunity.

To further improve the device's immunity to radiation, a copper shield can be placed over the AD7192 and the auxiliary components.

CONCLUSION

Key factors in optimizing the performance of a weigh scale system for radiated immunity are the board layout and the component placement and selection. When the layout practices discussed in this application note are used, the weigh scale system is Class A as per IEC 61000-4-3. Therefore, a weigh scale with an accuracy of 3000 counts continues to function correctly in the presence of radiated immunity, that is, the weigh scale will not react to the interferer.

EVALUATION BOARD SCHEMATICS AND ARTWORK

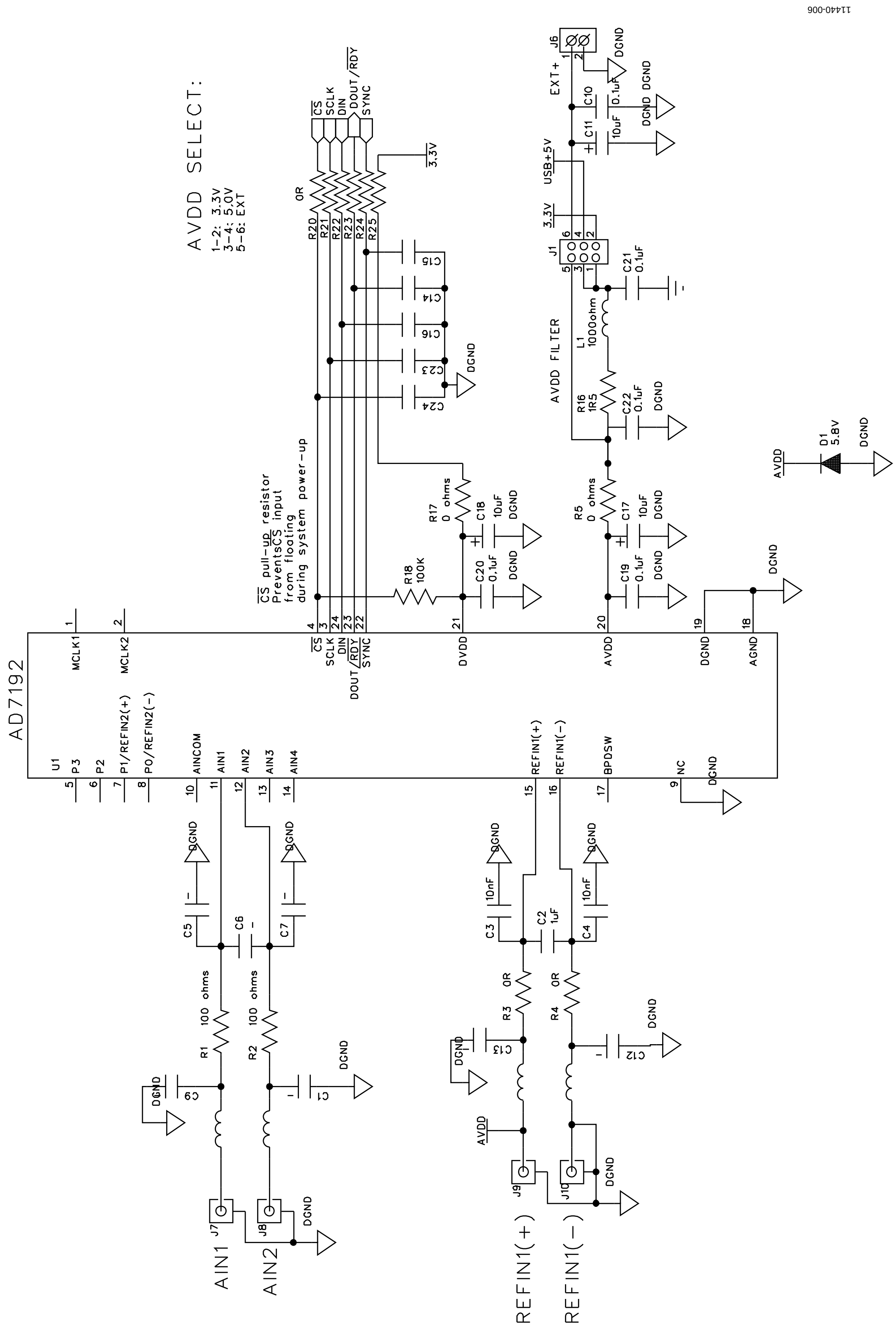


Figure 6. Schematics for EMC Board, Page 1

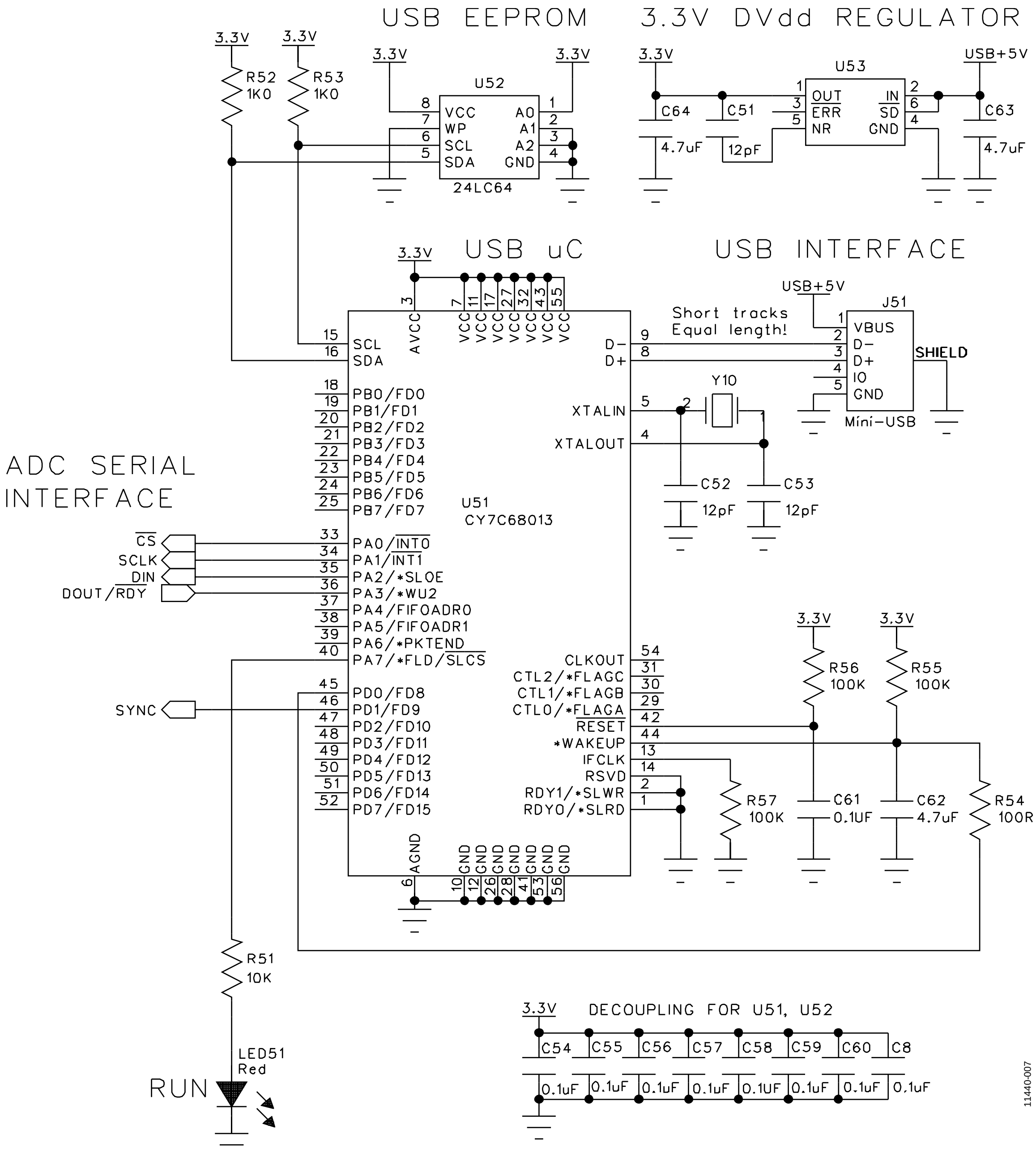
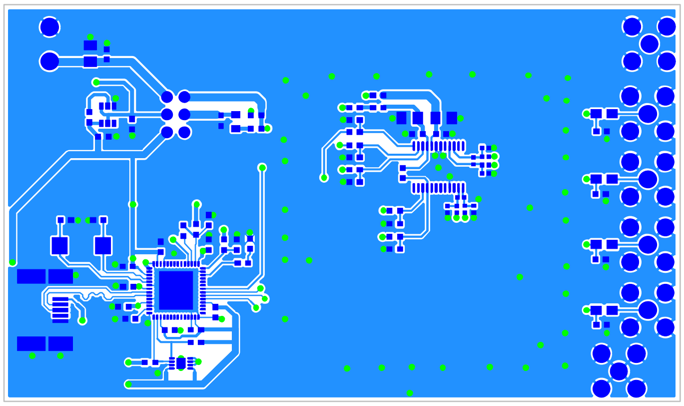
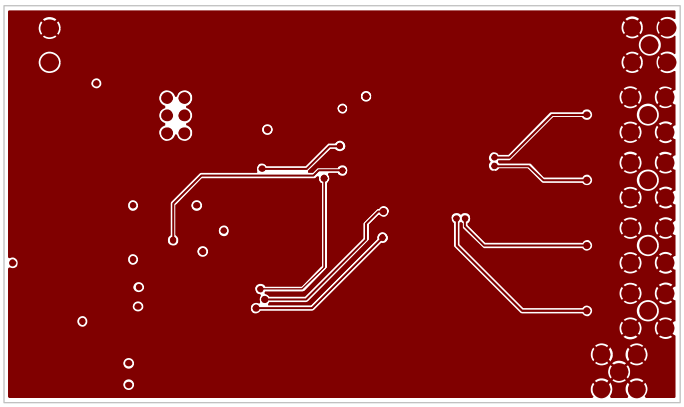


Figure 7. Schematics for EMC Board, Page 2



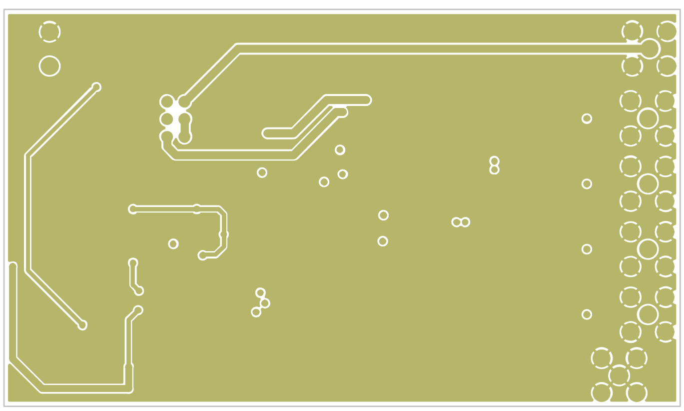
11440-008

Figure 8. Layer 1 (AD7192 EMC Board)



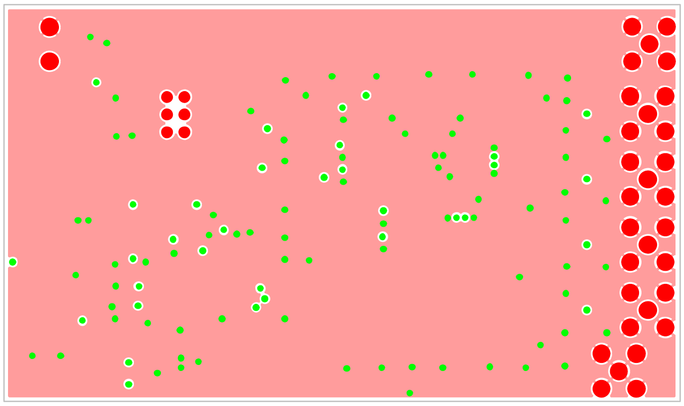
11440-009

Figure 9. Layer 2 (AD7192 EMC Board)



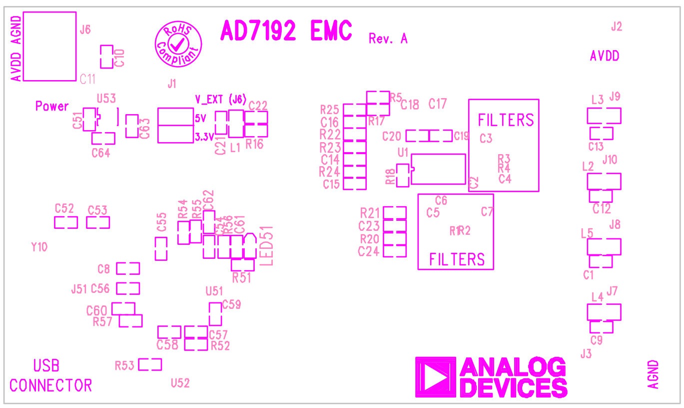
11440-010

Figure 10. Layer 3 (AD7192 EMC Board)



11440-011

Figure 11. Layer 4 (AD7192 EMC Board)



11440-012

Figure 12. Silkscreen Top (AD7192 EMC Board)

BILL OF MATERIALS

Table 1. AD7192-EMC BOM

Name	Value	Tolerance	PCB Decal	Part Description	Manufacturer	Part Number	Stock Code
ADC							
U1	AD7192		TSSOP24	AD7192, sigma-delta ADC	Analog Devices	AD7192BRUZ	
ADC Reference Inputs (Filtering)							
C2	1 µF	10%	C0402	Capacitor ceramic, 6.3 V, X5R	Kemet	2238 246 13663	FEC 1310153
C3	10 nF	10%	C0402	Capacitor ceramic, 50 V, X7R	Murata		FEC 1828887
C4	10 nF	10%	C0402	Capacitor ceramic, 50 V, X7R	Murata		FEC 1828887
R3	0 Ω	1%	R0402	Resistor	Phycomp		FEC 9232516
R4	0 Ω	1%	R0402	Resistor	Phycomp		FEC 9232516
ADC Analog Inputs (Filtering)							
C5	0.01 µF		C0402	Capacitor ceramic	AVX		FEC 1650807
C6	0.1 µF		C0402	Capacitor ceramic	AVX		FEC 1833861
C7	0.01 µF		C0402	Capacitor ceramic	AVX		FEC 1650807
R1	100 kΩ	1%	R0402	Resistor	Phycomp		FEC 1697307
R2	100 kΩ	1%	R0402	Resistor	Phycomp		FEC 1697307
Load Cell Connector							
J2	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
J3	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
J7	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
J8	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
J9	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
J10	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
Load Cell Connector Reference Lines (Filtering)							
C12	1 nF	10%	C0603	Ceramic capacitor, X7R, 50 V	Murata	GRM188R71H102KA01	FEC 8819955
C13	1 nF	10%	C0603	Ceramic capacitor, X7R, 50 V	Murata	GRM188R71H102KA01	FEC 8819955
L2	300 kΩ		805	A type ferrite	TE Connectivity/ Siga Inductors	BMB2A0300AN1	FEC 1193418RL
L3	300 kΩ		805	A type ferrite	TE Connectivity/ Sigma Inductors	BMB2A0300AN1	FEC 1193418RL
Load Cell Connector Analog Inputs Lines (Filtering)							
C1	1 nF	10%	C0603	Ceramic capacitor, X7R, 50 V	Murata	GRM188R71H102KA01	FEC 8819955
C9	1 nF	10%	C0603	Ceramic capacitor, X7R, 50 V	Murata	GRM188R71H102KA01	FEC 8819955
L4	300 kΩ		805	A type ferrite	TE Connectivity /Sigma Inductors	BMB2A0300AN1	FEC 1193418RL
L5	300 kΩ		805	A type ferrite	TE Connectivity /Sigma Inductors	BMB2A0300AN1	FEC 1193418RL

Name	Value	Tolerance	PCB Decal	Part Description	Manufacturer	Part Number	Stock Code
ADC Power Supplies							
C10	0.1 µF	10%	C0603	Capacitor ceramic, 16 V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C11	10 µF	10%	RTAJ_A	Capacitor Tantalum, 6.3 V,	AVX	TAJA106K006R	FEC 197-014
C17	10 µF	10%	RTAJ_A	Capacitor Tantalum, 6.3 V,	AVX	TAJA106K006R	FEC 197-014
C19	0.1 µF	10%	C0603	Capacitor ceramic, 16 V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C21	0.1 µF	10%	C0603	Capacitor ceramic, 16 V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C22	0.1 µF	10%	C0603	Capacitor ceramic, 16 V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C18	10 µF	10%	RTAJ_A	Capacitor Tantalum, 6.3 V,	AVX	TAJA106K006R	FEC 197-014
C20	0.1 µF	10%	C0603	Capacitor ceramic, 16 V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
R5	0 kΩ	1%	R0603	Resistor			FEC 923-3130
R16	1.5 kΩ	1%	R0603	Resistor	Phycomp	RC0603FR-071R5L	FEC 923-8140
R17	0 Ω	1%	R0603	Resistor			FEC 923-3130
L1	1000 kΩ		L0805	Ferrite bead, 1000 Z, 300 mA	Tyco	BMB2A1000LN2	FEC 119-3421
ADC SPI Lines							
C14			C0603	Capacitor ceramic, 50 V, X7R,			Not inserted
C15			C0603	Capacitor ceramic, 50 V, X7R,			Not inserted
C16			C0603	Capacitor ceramic, 50 V, X7R,			Not inserted
C23			C0603	Capacitor ceramic, 50 V, X7R,			Not inserted
C24			C0603	Capacitor ceramic, 50 V, X7R,			Not inserted
R20	0 Ω	1%	R0603	Resistor			FEC 923-3130
R21	0 Ω	1%	R0603	Resistor			FEC 923-3130
R22	0 Ω	1%	R0603	Resistor			FEC 923-3130
R23	0 Ω	1%	R0603	Resistor			FEC 923-3130
Regulator							
U53			SOT23-6	Voltage regulator, 3.3 V	Analog Devices	ADP3330ARTZ-3.3	
C51	12 pF	5%	C0603	Capacitor ceramic, 50 V, COG	Phycomp	CC0603JRNPO9B N120	FEC 721-979
C63	4.7 µF	10%	C0603	Capacitor ceramic, 6.3 V, X5R	Phycomp	CC0603KRX5R5B B475	FEC 940-2110
C64	4.7 µF	10%	C0603	Capacitor ceramic, 6.3 V, X5R	Phycomp	CC0603KRX5R5B B475	FEC 940-2110
USB Interface/Microcontroller							
U51	CY7C68013		LFCSP-56_RP	Microcontroller, EZ-USB FX2LP	Cypress	CY7C68013-56LFXC	FEC 126-9133
U52	24LC64		DFN-8	EEPROM, I2C, 64k	Microchip	24LC64-I/MC	FEC 133-1336
C8	0.1 µF	10%	C0603	Capacitor ceramic, 16V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C54	0.1 µF	10%	C0603	Capacitor ceramic, 16V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C55	0.1 µF	10%	C0603	Capacitor ceramic, 16V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C56	0.1 µF	10%	C0603	Capacitor ceramic, 16V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C57	0.1 µF	10%	C0603	Capacitor ceramic, 16V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210

Name	Value	Tolerance	PCB Decal	Part Description	Manufacturer	Part Number	Stock Code
C58	0.1 µF	10%	C0603	Capacitor ceramic, 16 V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C59	0.1 µF	10%	C0603	Capacitor ceramic, 16 V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C60	0.1 µF	10%	C0603	Capacitor ceramic, 16 V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C61	0.1 µF	10%	C0603	Capacitor ceramic, 16 V, X7R	Phycomp	CC0603KRX7R7B B104	FEC 432-210
C62	4.7 µF	10%	C0603	Capacitor ceramic, 6.3 V, X5R	Phycomp	CC0603KRX5R5B B475	FEC 940-2110
J1			JUMPER_3_N OTEXT	6-pin (3 × 2) 0.1" pitch SMD header	Tyco	1241050-3	Not inserted
J6	1 × 2-pin		CON\POWER	Screw terminal block, pitch 3.81 mm	Phoenix Contact	1727010	Not inserted (solder short used)
J51	Mini-USB		USB-MINI-B	Connector, USB Mini-B	Molex	548190572	FEC 978-6473
LED51	Red		LED-0603HSML-C191	LED, high intensity (> 90 mCd)	Avago Tech.	HSMC-C191	FEC 855-4528
R51	10 kΩ	1%	R0603	Resistor	Phycomp	RC0603FR-0710KL	FEC 923-8603
R52	1 kΩ	1%	R0603	Resistor	Phycomp	RC0603FR-071KL	FEC 923-8484
R53	1 kΩ	1%	R0603	Resistor	Phycomp	RC0603FR-071KL	FEC 923-8484
R54	100 kΩ	1%	R0603	Resistor	Phycomp	RC0603FR-07100RL	FEC 923-8360
R55	100 kΩ	1%	R0603	Resistor	Phycomp	RC0603FR-07100KL	FEC 923-8727
R56	100 kΩ	1%	R0603	Resistor	Phycomp	RC0603FR-07100KL	FEC 923-8727
R57	100 kΩ	1%	R0603	Resistor	Phycomp	RC0603FR-07100KL	FEC 923-8727
Crystal for Microcontroller							
Y10	24 MHz		XTAL-CSM-8A	Crystal, load 12 pF, SMD, 5 × 3.2 mm	AVX	CX5032GB24000 H0PESZZ	FEC 136-8770
C52	12 pF	5%	C0603	Capacitor ceramic, 50 V, COG	Phycomp	CC0603JRNPO9 BN120	FEC 721-979
C53	12 pF	5%	C0603	Capacitor ceramic, 50 V, COG	Phycomp	CC0603JRNPO9 BN120	FEC 721-979

NOTES

NOTES

NOTES