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Radiated Immunity Performance of the AD7780 in Weigh Scale Applications

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INTRODUCTION

The AD7780 is a low noise, low power, 24-bit sigma-delta converter which includes a PGA. The AD7780 is used in low-end to mid-end weigh scale systems. The radiated immunity of the weigh scale system is tested as part of the release process. This application note describes how to achieve the best-radiated immunity performance from the AD7780, 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 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.

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REVISION HISTORY

3/13—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 AD7780 is configured as follows:

Output data rate = 10 Hz

Gain = 128

The AD7780 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 AD7780, refer to Circuits from the Lab® reference circuit (CN-0107).

ERROR

As discussed in the Radiated Immunity section, the allowable error *e* 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 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

$\pm$0.5 counts = $\pm$1.46 µV /2 = $\pm$0.73 µV

The error must be less than $\pm$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 $\pm$2 kg/(2 × 3000) = $\pm$0.33 grams—this ensures that the digital display is not affected by the RF interference.

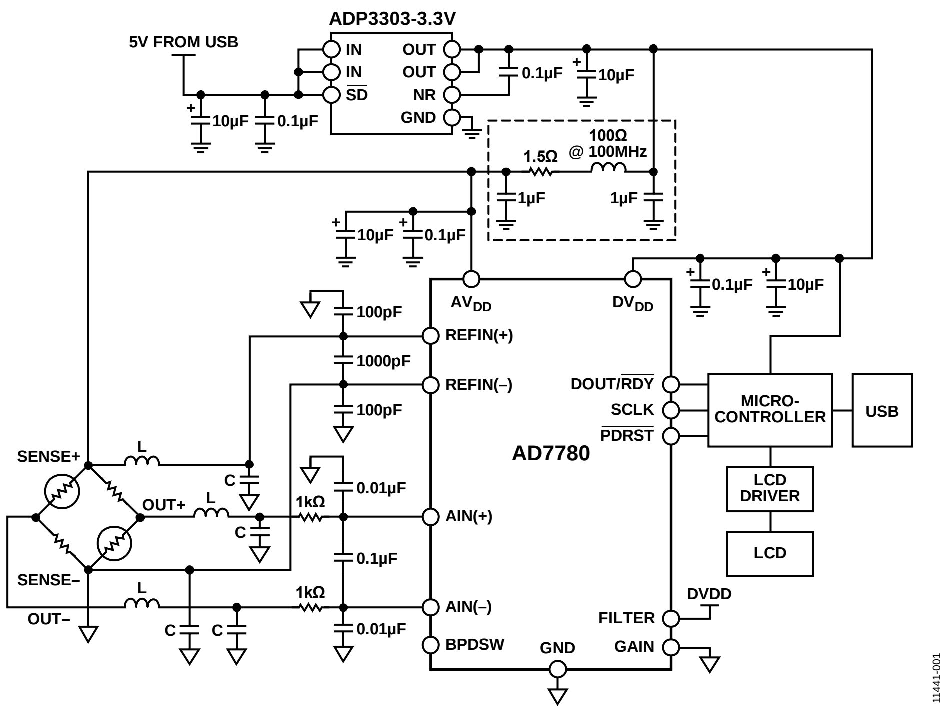

Figure 1. AD7780 Setup for Testing

PRINTED CIRCUIT BOARD

The standard AD7780 evaluation board is designed to give optimum analog to digital conversion performance. However, it is not optimized for EMC. For example, the standard AD7780 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 start point, 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 AD7780 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 1shows the R and C values that are normally recommended on the analog and reference inputs. This filtering provides attenuation at the AD7780's sampling frequency (64 kHz) and multiples of the sampling frequency. The AD7780 itself does not provide any attenuation at these frequencies. The capacitors need to be as close as possible to the AD7780'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 (C38, C39, and C40) 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 AD7780. 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.

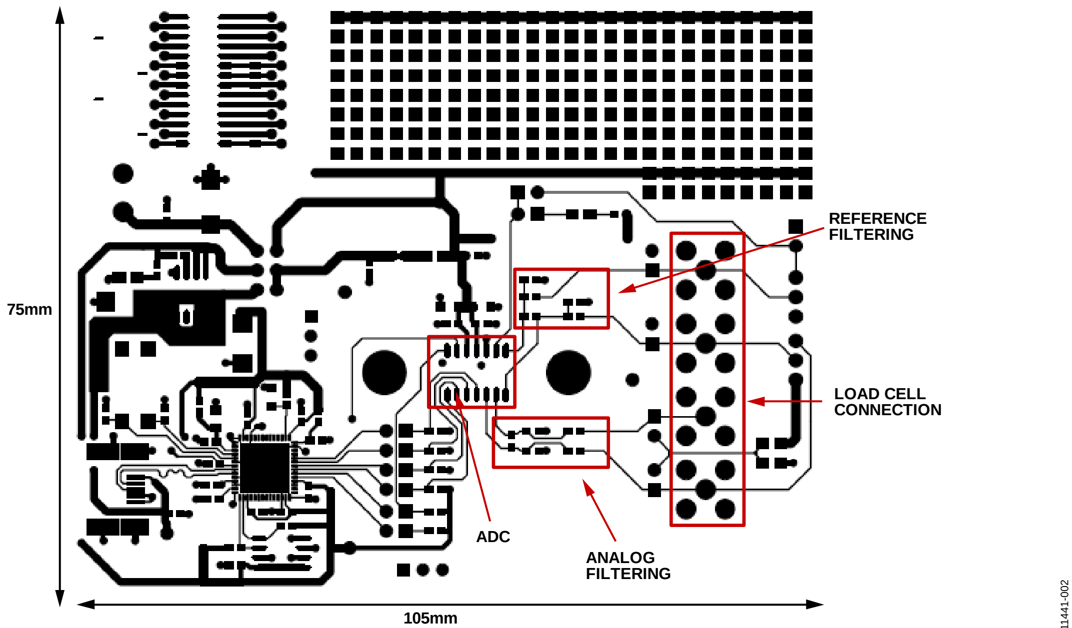

Figure 2. Top Side of Standard AD7780 Evaluation Board

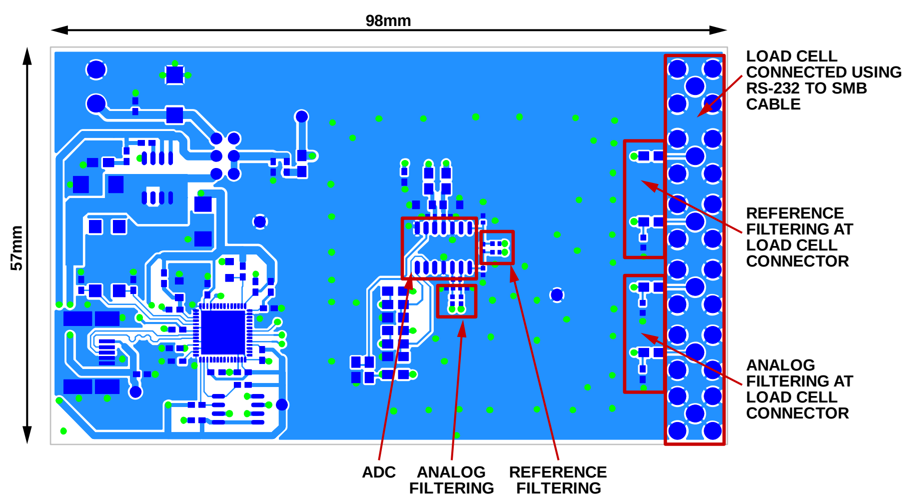

Figure 3. Top Side of AD7780 EMC Board

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 exceeded *e*. Figure 4 shows the conversions read from the AD7780 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 1.79 µV, which is higher than *e*. This is equivalent to 0.81 grams. However, the ADC continues to function while the RF interference is present and returns to within specification automatically once the interference is removed. Thus, the weigh scale system is Class B in terms of radiated immunity.

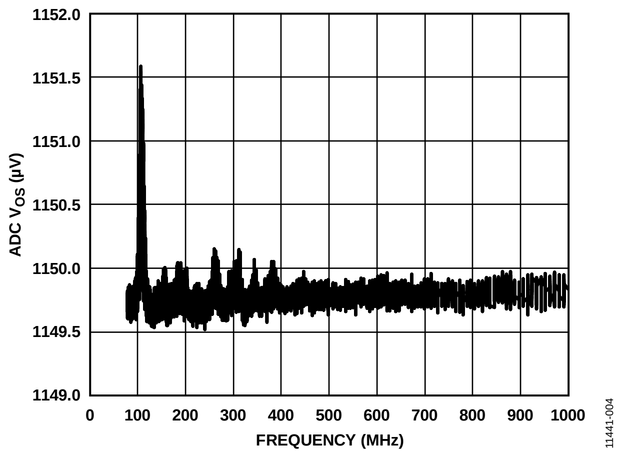

Figure 4. Error vs. Frequency of AD7780 EMC Board

For comparative reasons, Figure 5 shows the conversions read from the standard AD7780 evaluation board when tested for radiated immunity. The board has an error of 2101 µV when the RF interferer is present which is equivalent to 955 grams.

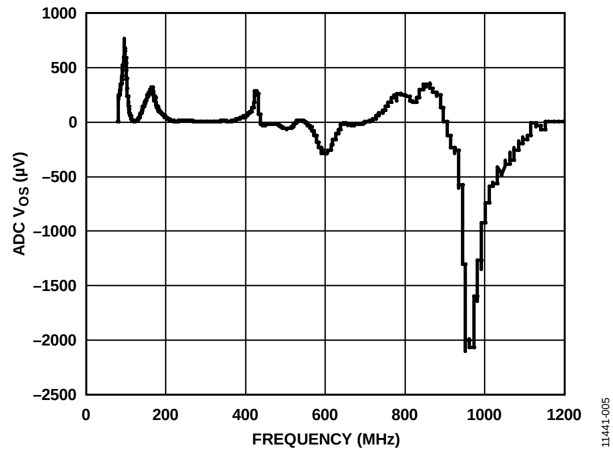

Figure 5. Radiated Immunity of AD7780 Evaluation Board

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 AD7780 and the auxiliary components. This improves the system's classification to Class A.

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 B as per IEC 61000-4-3. The weigh scale system continues to function when the RF interference is present, but the accuracy of the system is outside its specification. When the RF interference is removed, the weigh scale system's accuracy is within specification again automatically. The radiated immunity can be increased to Class A using a copper shield.

EVALUATION BOARD SCHEMATICS AND ARTWORK

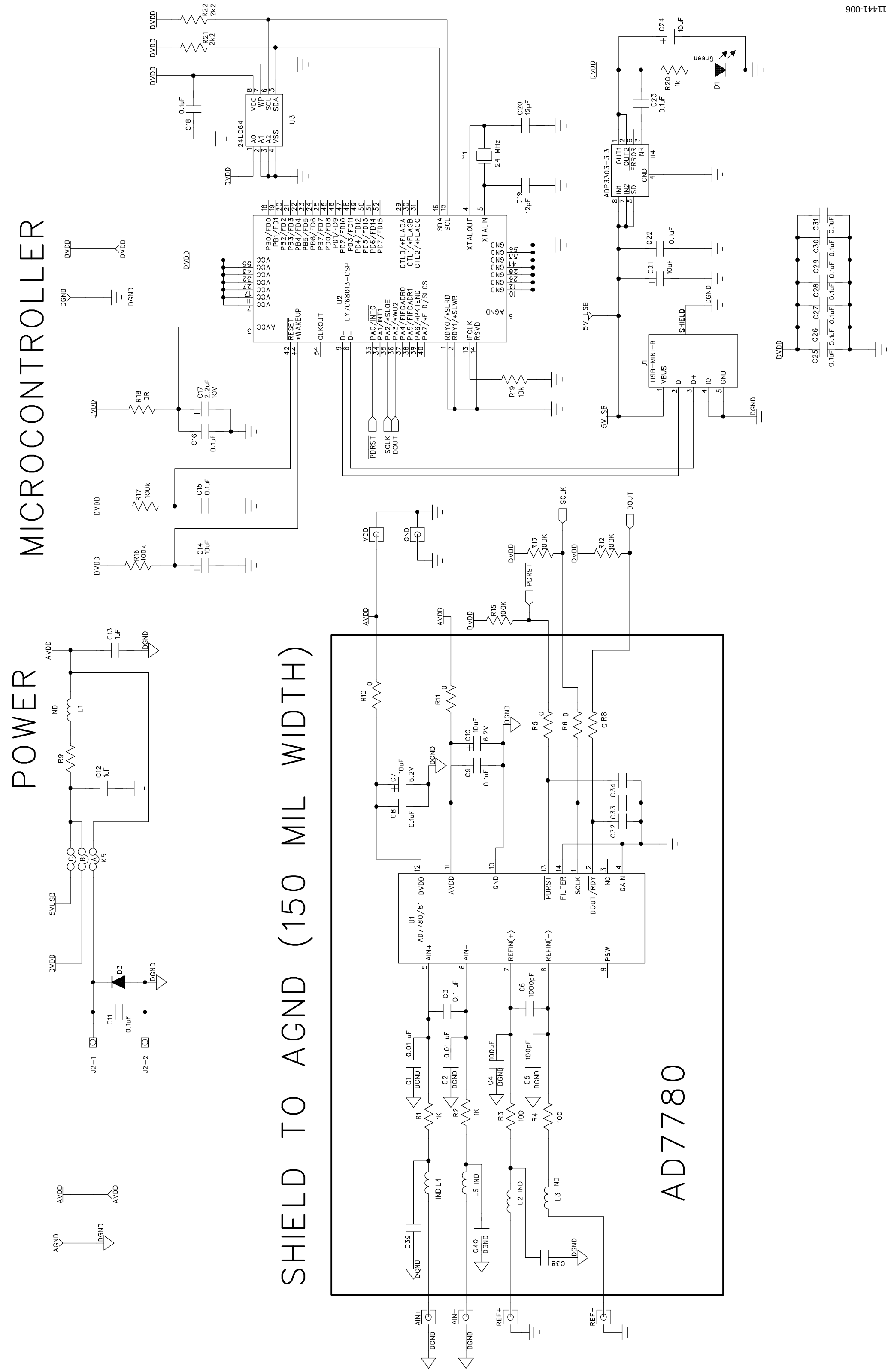

Figure 6. Schematics

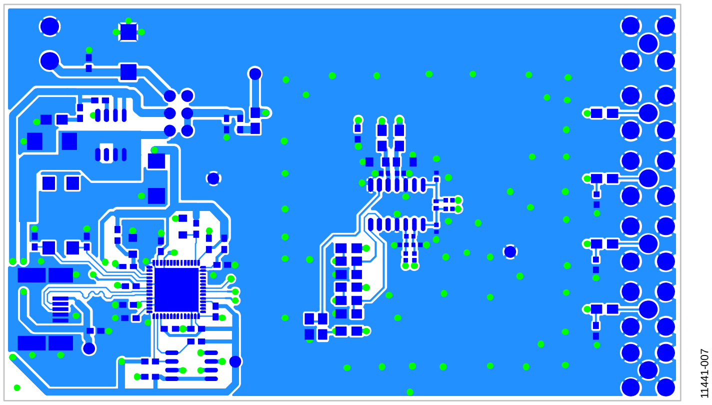

Figure 7. Layer 1

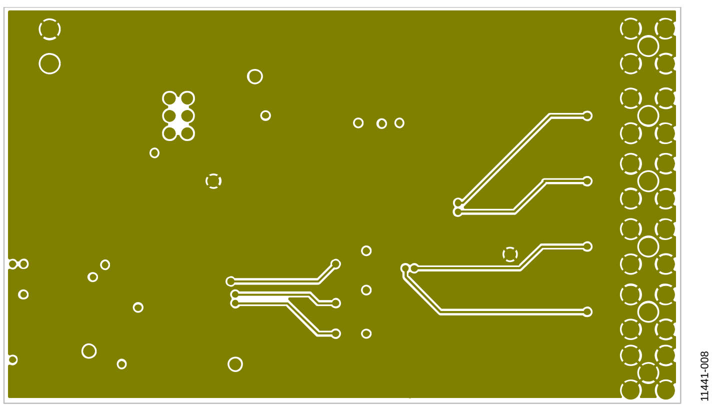

Figure 8. Layer 2

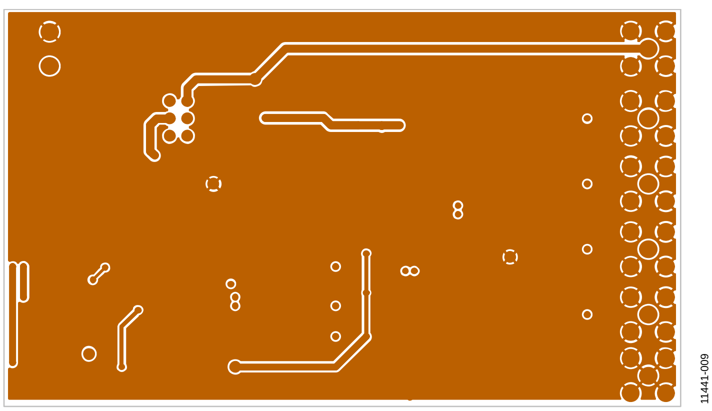

Figure 9. Layer 3

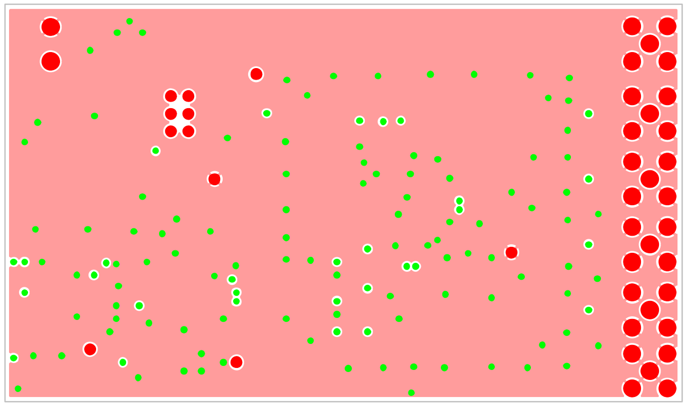

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Figure 10. Layer 4

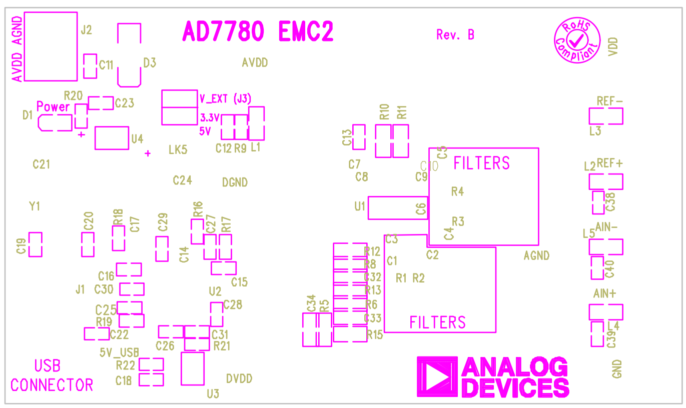

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Figure 11. Silkscreen Top

BILL OF MATERIALS

Table 1. AD7780-EMC BOM

Name	Value	Tolerance	PCB Decal	Part Description	Manufacturer	Part Number	Stock Code
ADC							
U1	AD7780		SO14NB	AD7780, sigma-delta ADC	Analog Devices	AD7780BRZ	
ADC Reference Inputs (Filtering)							
C4	100 pF	10%	C0402	Capacitor ceramic, 50 V, NPO	AVX		FEC 1327627
C5	100 pF	10%	C0402	Capacitor ceramic, 50 V, NPO	AVX		FEC 1327627
C6	1000 pF	10%	C0402	Capacitor ceramic, 50 V, X7R	AVX		FEC 1327646
R3	100 Ω		R0402	Resistor			FEC 1697307
R4	100 Ω		R0402	Resistor			FEC 1697307
ADC Analog Inputs (Filtering)							
C1	0.01 uF		C0402	Capacitor ceramic	Kemet		FEC 1650807
C2	0.01 uF		C0402	Capacitor ceramic	Kemet		FEC 1650807
C3	0.1 uF		C0402	Capacitor ceramic, 16 V, X7R	AVX		FEC 1833861
R1	1 kΩ		R0402	Resistor			FEC 1174154
R2	1 kΩ		R0402	Resistor			FEC 1174154
Load Cell Connector							
AIN+	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
AIN-	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
REF+	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
REF+	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
AVDD	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
GND	SMB		SMB	Connector, 50 Ω, straight	Amphenol	SMB1251B1-3GT30G-50	FEC 111-1349
Load Cell Connector Reference Lines (Filtering)							
C38	1 nF	10%	C0603	Ceramic capacitor, C0G, 50 V	Murata	GRM1885C1H102JA01	FEC 8819920
L2	100 Ω		R0402	Resistor			FEC 1127365
L3	100 Ω		R0402	Resistor			FEC 1127365
Load Cell Connector Analog Inputs Lines (Filtering)							
C39	1 nF	10%	C0603	Ceramic capacitor, C0G, 50 V	Murata	GRM1885C1H102JA01	FEC 8819920
C40	1 nF	10%	C0603	Ceramic capacitor, C0G, 50 V	Murata	GRM1885C1H102JA01	FEC 8819920
L4	100 Ω		R0402	Resistor			FEC 1127365
L5	100 Ω		R0402	Resistor			FEC 1127365

Name	Value	Tolerance	PCB Decal	Part Description	Manufacturer	Part Number	Stock Code
ADC Power Supplies							
C7	10 µF		CAP\TAJ_A	Tantalum capacitor, TAJ series	AVX		FEC 197130
C8	0.1 µF		C0402	Ceramic capacitor, X7R, 16 V	AVX		FEC 1833861
C9	0.1 µF		C0402	Ceramic capacitor, X7R, 16 V	AVX		FEC 1833861
C10	10 µF		CAP\TAJ_A	Tantalum capacitor, TAJ series	AVX		FEC 197130
C11							Not inserted
C12	1 µF		C0603	Ceramic capacitor, 16 V	Yageo		FEC 3188840
C13	1 µF		C0603	Ceramic capacitor, 16 V	Yageo		FEC 3188840
R10	0 Ω		C0805	0.063W resistor			FEC 9331662
R11	0 Ω		C0805	0.063W resistor			FEC 9331662
R9	1.5 Ω	1%	R0603	Resistor	Phycomp	RC0603FR-071R5L	FEC 923-8140
L1	0 Ω		R0603	0.063W resistor	Multicomp		FEC 1193418
ADC SPI Lines							
C32	–	-	C0805	Capacitor ceramic, 50 V, X7R,			Not inserted
C33	–	-	C0805	Capacitor ceramic, 50 V, X7R,			Not inserted
C34	–	-	C0805	Capacitor ceramic, 50 V, X7R,			Not inserted
R5	0 Ω		R0805	Resistor			FEC 9331662
R6	0 Ω		R0805	Resistor			FEC 9331662
R8	0 Ω		R0805	Resistor			FEC 9331662
R12	100 kΩ		R0805	Resistor	Multicomp		FEC 9330402
R13	100 kΩ		R0805	Resistor	Multicomp		FEC 9330402
R15	100 kΩ		R0805	Resistor	Multicomp		FEC 9330402
Regulator							
U4			SO8NB	Voltage regulator 3.3 V	Analog Devices	ADP3303ARZ-3.3	
C21	10 µF		CAP\TAJ_C	Tantalum capacitor	AVX		FEC 9753907
C22	0.1 µF		C0603	Ceramic capacitor, 50 V, X7R	AVX		FEC 1216538
C23	0.1 µF		C0603	Ceramic capacitor, 50 V, X7R	AVX		FEC 1216538
C24	10 µF		CAP\TAJ_C	Tantalum capacitor	AVX		FEC 9753907
R20	1 kΩ			0.063W resistor	Multicomp		FEC 9330380
D1			LED-0805	Light emitting diode	Avago	HSMG-C170	FEC 579-0852
USB Interface/Microcontroller							
U2	CY7C68013		LFCSP-56_RP	Microcontroller, EZ-USB FX2LP	Cypress	CY7C68013-56LFXC	FEC 126-9133
U3	24LC64		DFN-8	EEPROM, I^2C, 64k	Microchip	24LC64-I/MC	FEC 133-1336
C14	10 µF		CAP\TAJ_A	Tantalum Capacitor, TAJ Series	AVX		FEC 197130
C15	0.1 µF		C0603	Capacitor ceramic, 16 V, X7R	AVX		FEC 1216538
C16	0.1 µF		C0603	Capacitor ceramic, 16 V, X7R	AVX		FEC 1216538
C17	2.2 µF		CAP\TAJ_A	Case A, 10 V	Kemet		FEC 9753796
C18	0.1 µF		C0603	Capacitor ceramic, 16 V, X7R	AVX		FEC 1216538
C25	0.1 µF		C0603	Capacitor ceramic, 16 V, X7R	AVX		FEC 1216538
C26	0.1 µF		C0603	Capacitor ceramic, 16 V, X7R	AVX		FEC 1216538
C27	0.1 µF		C0603	Capacitor ceramic, 16 V, X7R	AVX		FEC 1216538
C28	0.1 µF		C0603	Capacitor ceramic, 16 V, X7R	AVX		FEC 1216538
C29	0.1 µF		C0603	Capacitor ceramic, 16 V, X7R	AVX		FEC 1216538
C30	0.1 µF		C0603	Capacitor ceramic, 16 V, X7R	AVX		FEC 1216538

Name	Value	Tolerance	PCB Decal	Part Description	Manufacturer	Part Number	Stock Code
C31	0.1 µF		C0603	Capacitor ceramic, 16 V, X7R	AVX		FEC 1216538
D3				Diode			Not inserted
J1	Mini-USB		USB-OTG	Connector, USB	Molex	565790576	FEC 9786490
J2	1 × 2-pin		CON\POWER	2-pin terminal block (5 mm pitch)	Phoenix Contact	17 25 67 2	Not inserted (solder short used)
R16	100 kΩ	1%	R0603	Resistor	Multicomp		FEC 933-0402
R17	100 kΩ	1%	R0603	Resistor	Multicomp		FEC 933-0402
R18	0 Ω		R0603	Resistor			FEC 9331662
R19	10 Ω	1%	R0603	Resistor	Multicomp		FEC 933-0399
R21	2.2 kΩ	1%	R0603	Resistor	Multicomp		FEC 923-8727
R522	2.2 kΩ	1%	R0603	Resistor	Multicomp		FEC 923-8727
Crystal for Microcontroller							
Y1	24 MHz		XTAL_CM309S	Crystal	AEL Crystals		FEC 9509658
C19	12 pF	5%	C0603	Capacitor ceramic, 50V, COG	Phycomp	CC0603JRNPO9B N120	FEC 721979
C20	12 pF	5%	C0603	Capacitor ceramic, 50V, COG	Phycomp	CC0603JRNPO9B N120	FEC 721979