ADS7881/ADS7891EVM

This users guide describes the characteristics, operation, and use of the ADS7881/ADS7891 12-Bit/14-Bit, parallel, analog-to-digital converter evaluation module. A complete circuit description, as well as schematic diagram, layout and bill of materials, are included.

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1 Related Documentation from Texas Instruments

To obtain a copy of any of the following TI documents, call the Texas Instruments Literature Response Center at (800) 477-8924 or the Product Information Center (PIC) at (972) 644-5580. When ordering, identify this booklet by its title and literature number. Updated documents can also be obtained through our website at www.ti.com.

Data Sheets:	Literature Number:
ADS7881	SLAS400
ADS7891	SLAS410
ADS8411	SLAS369
THS4031	SLOS224
OPA132	SBOS054
REF1004-2.5	SBVS032
SN74AHC138	SCLS258
SN74AHC245	SCLS230
SN74AHC1G04	SCLS318

2 EVM Overview

2.1 Features

- Full-featured Evaluation Board for the high speed SAR type ADS7881(12-bit 4MSPS) or ADS7891(14-bit 3MSPS) single channel, parallel interface Analog to Digital Converters.
- On board signal conditioning
- On board Reference
- Input and Output Digital Buffers
- On board decoding for stacking multiple EVMs.

3 Introduction

The ADS7881EVM and ADS7891EVM showcase the 12-bit 4-MSPS and 14-bit 3MSPS A-to-D converter. The ADS7881 and ADS7891 devices include a capacitor based SAR A/D converter with inherent sample and hold. The two devices offer either a 12-bit or 14-bit parallel interface. Both offer byte mode operation that enables easy interface with 8-bit processors. They also have a pseudo-differential input stage and a 2.5V internal reference.

This evaluation module serves as a reference design and a low cost method to test these converters in the users' application. The following sections will describe the pin outs of the various analog, power and digital connectors and power requirements.

4 Analog Interface

The ADS7881 and ADS7891 analog-to-digital converter has both a positive and negative analog input pin. The negative input pin, which has a range of -200mV up to 200mV is shorted on the board. A signal for the positive input pin can be applied at connector P1 pin 2(shown in Table 1) or at center pin of SMA connector J2.

Table 1. Analog Input Connector

Connector.Pin#[(1)]	Signal	Description
P1.2	+IN	Non-inverting input channel
P1.4	Reserved	
P1.6	Reserved	
P1.8	Reserved	
P1.10	Reserved	
P1.12	Reserved	
P1.14	Reserved	
P1.16	Reserved	
P1.18	Reserved	
P1.20	REF+	External reference input

(1) All odd numbered pins of P1 are tied to AGND.

4.1 Signal Conditioning

The factory recommends the analog input to any SAR type converter be buffered and low pass filtered. This input buffer on the ADS7881/ADS7891EVM utilizes the THS4031 configured as an INVERTING gain of one, as shown in Figure 1. It is important to note the amplifier is not stable at a gain of one, thus, it is configured in for inverting gain of one. The THS4031 was selected for its low noise, high slew rate and fast settling time. The low pass filter resistor and capacitor values were selected such that ADS7881/ADS7891EVM would meet the 1MHz AC performance specifications listed in the datasheet. The series resistor works in conjunction with the capacitor to filter the input signal, but also isolates the amplifier from the capacitive load. The capacitor to ground at the input of the A/D works in conjunction with the series resistor to filter the input signal, and acts like a charge reservoir. This external filter capacitor works with the amplifier to charge the internal sampling capacitor during sampling mode. Resistors R1 and R12 were selected to reduce offset.

The EVM has a provision to offset the input voltage by adjusting, R25, a 10k potentiometer.

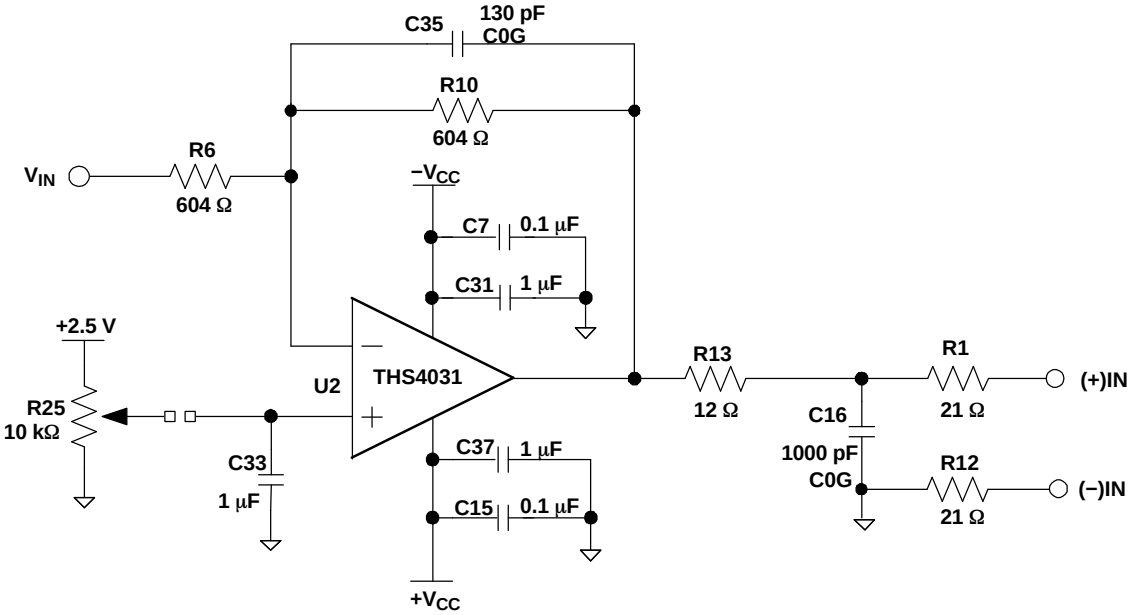

Figure 1. ADS7881 Input Buffer Circuit

4.2 Reference

The ADS7881/ADS7891EVM provides an onboard 2.5V reference circuit. The EVM also has the provision for users to supply a reference voltage via connecter P1 pin 20. This reference voltage can be filtered through amplifier U1. The converter itself has on-chip reference buffer, therefore it is not necessary to buffer externally. The reference buffer circuit on the EVM is used to generate the offset voltage for the input amplifier, U2.

The EVM allows users to select from three reference sources. Set SJP1, SJP2, and SJP4 to select on-board reference voltage (REF1004-2.5), ADC internal reference or a user supplied reference voltage via P1 pin 20. See Table 2 for jumper settings. See Appendix B for full schematic.

Table 2. Solder Short Jumper Setting

Reference Designator	Description	Pads	
		1–2	2–3
SJP1	Apply on-board reference directly to SJP2 pin 3	Installed(1)	
	Apply buffered reference voltage to SJP2 pin 3		Installed
SJP2	Apply internal reference to REFIN pin	Installed(1)	
	Apply external reference to REFIN pin		Installed
SJP4	Apply on-board reference to U1, reference buffer	Installed	
	Apply user supplied reference to U1, reference buffer		Installed
SJP5	Apply DC offset to input signal	Installed(1)	N/A
SJP6	Short to pin 4 of amplifier U1 to ground	Installed	
	Short to pin 4 of amplifier U1 to -VCC		Installed(1)
SJP7	Short to pin 4 of amplifier U2 to ground	Installed	
	Short to pin 4 of amplifier U2 to -VCC		Installed(1)

(1) Factory set condition

5 Digital Interface

The ADS7881/ADS7891EVM is designed for easy interfacing to multiple platforms. Samtec part numbers SSW-110-22-F-D-VS-K , TSM-110-01-T-DV-P, SSW-116-22-S-D-VS , and TSM-116-01-T-D-V-P provide a convenient dual row header/socket combination at P1, P2, P3, and J3. Please consult Samtec at www.samtec.com or 1-800-SAMTEC-9 for a variety of mating connector options.

Connectors P1, P2 and P3 allows the user to plug the EVM into the 5-6k interface card to interface directly with TMS320C5000 and TMS320C6000 series of DSP. See Table 3 for connector pin out.

Table 3. Pinout for Parallel Control Connector P2

Connector.Pin(1)	Signal	Description
P2.1	$\overline{\text{DC\_CS}}$	Daughter card Board Select pin
P2.3		
P2.5		
P2.7	A0	Address line from processor
P2.9	A1	Address line from processor
P2.11	A2	Address line from processor
P2.13		
P2.15		
P2.17		

(1) All even numbered pins of P2 are tied to DGND.

Table 3. Pinout for Parallel Control Connector P2 (continued)

Connector.Pin[1]	Signal	Description
P2.19	BUSY	Busy signal from converter. W4 must be shorted.

Read($\overline{RD}$), conversion start($\overline{CONVST}$) and reset ($\overline{RESET}$) signals to the converter can be assigned to two different addresses in memory via jumper settings. This allows for the stacking of up to two ADS7881EVM, and/or ADS7891EVMs into processor memory. See Table 4 for jumper settings. Note, the evaluation module does not allow chip select ($\overline{CS}$) line of the converter to be assigned to different memory locations. It is therefore suggested the $\overline{CS}$ line be grounded or wired to an appropriate signal of the user processor.

Table 4. Jumper Settings

Reference Designator	Description	Pins	
		1–2	2–3
W1	Short U8 pin 14 to Powerdown/Reset signal	Installed[1]	
	Short U8 pin 13 to Powerdown/Reset signal		Installed
W2	Short U8 pin 12 to $\overline{CONVST}$ signal	Installed[1]	
	Short U8 pin 11 to $\overline{CONVST}$ signal		Installed
W3	Short U8 pin 10 to $\overline{RD}$ signal	Installed[1]	
	Short U8 pin 8 to $\overline{RD}$ signal		Installed
W4	Short inverted BUSY to $\overline{INTC}$	Installed[1]	
	Short BUSY to $\overline{INTC}$		Installed
W5	Short +5VD to +BVDD	Installed[1]	
	Short +3.3VD to +BVDD		Installed

(1) Factory set condition

The data bus is available at connector P3, see table 4 for pin out information.

Table 5. Data Bus Connector P3

Connector.Pin[1]	Signal	Description
P3.1	D0	Buffered Data Bit 0 (LSB)
P3.3	D1	Buffered Data Bit 1
P3.5	D2	Buffered Data Bit 2
P3.7	D3	Buffered Data Bit 3
P3.9	D4	Buffered Data Bit 4
P3.11	D5	Buffered Data Bit 5
P3.13	D6	Buffered Data Bit 6
P3.15	D7	Buffered Data Bit 7
P3.17	D8	Buffered Data Bit 8
P3.19	D9	Buffered Data Bit 9
P3.21	D10	Buffered Data Bit 10
P3.23	D11	Buffered Data Bit 11 (MSB - ADS7881)
P3.25	D12	Buffered Data Bit 12
P3.27	D13	Buffered Data Bit 13 (MSB - ADS7891)
P3.29	D14	Not connected
P3.31	D15	Not connected

(1) All even numbered pins of P3 are tied to DGND.

This evaluation module provides direct access all the analog-to-digital converter control signals via connector J3, see Table 6.

Table 6. Pinout for Converter Control Connector J3

Connector.Pin(1)	Signal	Description
J3.1	$\overline{CS}$	Chip select pin. Active low.
J3.3	$\overline{RD}$	Read pin. Active low.
J3.5	$\overline{CONVST}$	Convert start pin. Active low.
J3.7	BYTE	BYTE mode pin. Used for 8-bit buses.
J3.9	$\overline{PWD/RST}$	Active low input, acts as device power down/device reset signal.
J3.11	$\overline{A\_PDWN}$	Nap mode enable, active low
J3.13	BUSY	Converter status output. High when a conversion is in progress.

(1) All even numbered pins of J3 are tied to DGND.

6 Power Supplies

The EVM accepts four power supplies.

- A dual ±Vs DC supply for the dual supply op-amps. Recommend ±12VDC supply.
- A single +5.0 V DC supply for analog section of the board (A/D + Reference).
- A single +5.0V or +3.3V DC supply for digital section of the board (A/D + address decoder + buffers).

There are two ways to provide these voltages.

- Wire in voltages at test points on the EVM. See Table below.

Table 7. Power Supply Test Points

Test Point	Signal	Description
TP11	+BVDD	Apply +3.3VDC or +5.0VDC. See respective ADC datasheet for full range.
TP10	+AVCC	Apply +5.0VDC.
TP12	+VA	Apply +12.0VDC. Positive supply for amplifier.
TP14	–VA	Apply -12.0VDC. Negative supply for amplifier.

- Use the power connector J1, and derive the voltages else where. The pin out for this connector is below. Set jumper W5 to short between pins 1-2 or pins 2-3 to short +3.3VD or +5VD, respectively, to be the buffer digital supply (+BVDD).

Table 8. Power Connector, J1, Pin Out

Signal	Power Connector - J1		Signal
+VA (+12VA)	1	2	–VA (–12VA)
+AVCC(+5VA)	3	4	N/C
N/C	5	6	AGND
N/C	7	8	N/C
+3.3VD	9	10	+5VD

7 Using the EVM

The ADS7881EVM/ADS7891EVM serves as a reference design, prototype board and as test platform for the software engineer to develop code.

As a reference design, the ADS7881EVM/ADS7891EVM contains the essential circuitry to showcase the analog-to-digital converter. This essential circuitry includes the input amplifier, reference circuit, and buffers. The EVM analog input circuit is optimized for 1 MHz sine wave, therefore users may need to adjust the resistor and capacitor values of the A/D input RC circuit. In ac type applications where signal distortion is concern, polypropylene capacitors should be used in the signal path. In applications were the input is multiplexed, the A/D input resistor and capacitor may need to adjusted or possibly removed altogether.

As a prototype board, the buffer circuit consists of footprint is a standard 8 pin SOIC and resistor pads for inverting and non-inverting configurations. The ADS7881EVM/ADS7891EVM can be used to evaluate both dual and single supply amplifiers. The EVM comes installed with a dual supply amplifier as it allows the user to take advantage of the full input voltage range of the converter. For applications that require signal supply operation and smaller input voltage range, the THS4031 can be replaced with the single supply amplifier like OPA300. Pad jumper SJP7 should be shorted between pads 1 and 2, as it shorts the minus supply pin of the amplifier to ground. Positive supply voltage can be applied via test point TP12 or connector J1 pin 1.

As a software test platform, connectors P1, P2, P3 plug into the parallel interface connectors of the 5-6K interface card. The 5-6K interface card sits on the C5000 and C6000 Digital Signal Processor starter kit (DSK). The ADS7881EVM/ADS7891EVM is then mapped into the processor's memory space. This card also provides an area for signal conditioning. This area can be used to install application circuit(s) for digitization by the ADS7881 and/or ADS7891 analog-to-digital converter. Refer to the 5-6K interface card user's guide (SLAU104) for more information.

For the software engineer the ADS7881EVM/ADS7891EVM provides a simple platform for interfacing to the converter. The EVM provides standard 0.1" headers and sockets to wire into prototype boards. The user need only provide in 3 address lines (A2, A1, A0) and address valid line($\overline{DC\_CS}$) to connector P2, as shown in Figure 2. To choose which address combinations will generate $\overline{RD}$, $\overline{CONVST}$, and $\overline{RESET}$ set jumpers as shown in Table 4. Recall chip select ($\overline{CS}$) signal is not memory mapped or tied to P2, therefore it must be controlled via general purpose pin or shorted to ground at J3 pin 1. If address decoding is not required, the EVM provides direct access to converter data bus via P3 and control via J3.

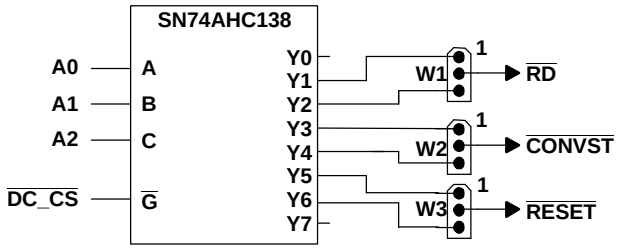

Figure 2. Decoding Control Signals Using the Address Bus

Appendix A ADS7881EVM/ADS7891EVM Bill of Materials

The following table contains a complete Bill of Materials for the ADS7881EVM/ADS7891EVM. The schematic diagram is also provided for reference. Contact the Product Information Center or e-mail dataconvapps@list.ti.com for questions regarding this EVM.

Table A-1. Bill of Materials

Item No.	Qty.	Value	Reference Designators	Footprint	Manufacturer	Manufacturer's Part Number	Description
1	2	21	R1 R12	805	Panasonic-ECG or Alternate	ERJ-6ENF21R	RES, 21.0 Ω, 1/10W, 1% 0805 SMD
2	3	NI	R2 R5 R11	805	NOT INSTALLED	NOT INSTALLED	
3	1	NI	R3	603	NOT INSTALLED	NOT INSTALLED	1/10W, 0805 Chip Resistor
4	3	100	R4 R14 R15	805	Panasonic-ECG or Alternate	ERJ-6ENF1000V	RES, 100 Ω, 1/10W, 1%, 0805 SMD
5	2	604	R6 R10	805	Panasonic-ECG or Alternate	ERJ-6ENF6040V	RES, 604 Ω, 1/10W, 1%, 0805 SMD
6	6	10k	R7 R16 R17 R18 R19 R20	603	Panasonic-ECG or Alternate	ERJ-3EKF1002V	RES, 10.0 kΩ, 1/16W, 1%, 0603 SMD
7	1	49.9	R8	1206	Panasonic-ECG or Alternate	ERJ-8ENF49R9V	RES, 49.9 Ω, 1/8W, 1%, 1206 SMD
8	1	49.9k	R9	805	Panasonic-ECG or Alternate	ERJ-6ENF4992V	RES, 49.9 kΩ, 1/10W, 1%, 0805 SMD
9	1	12	R13	805	Panasonic-ECG or Alternate	ERJ-6GEYJ120V	RES, 12 Ω, 1/8W, 5%, 0805 SMD
	1	10	R13(1)	805	Yageo America or Alternate	9C08052A10R0FKHFT	RES, 10 Ω, 1/8W, 1%, 0805 SMD
10	1	75	R21	805	Panasonic-ECG or Alternate	ERJ-6ENF75R0V	RES, 75.0 Ω, 1/10W, 1%, 0805 SMD
11	1	0	R24	603	Panasonic-ECG or Alternate	ERJ-3GEY0R00V	RES, 0 Ω, 1/16W, 5%, 0603 SMD
12	1	10k	R22	805	Panasonic-ECG or Alternate	ERJ-6ENF1002V	RES, 10.0 kΩ, 1/10W, 1%, 0805 SMD
13	1	10k	R25	BOURNS_ 32×4W	Bourns	3214W-1-103E	TRIMPOT, 10 kΩ, 4MM TOP ADJ SMD
14	4	10 µF	C1 C6 C12 C19	1206	TDK Corporation or Alternate	C3216X5R1C106KT	CAP, CER, 10 µF, 16V, X5R, 20%, 1206
15	2	1 µF	C2 C28	603	TDK Corporation or Alternate	C1608X5R1C105K	CAP, CER, 1.0 µF, 16V, X5R, 10%, 0603
16	5	1000 pF	C3 C5 C11 C16 C23	603	TDK Corporation or Alternate	C1608C0G1H102J	CAP, CER, 1000 pF, 50V, C0G, 5%, 0603
17	13	0.01 µF	C4 C10 C13 C20 C21C26 C41 C44 C46 C48 C50 C53 C56	603	TDK Corporation or Alternate	C1608X7R1H103KT	CAP, CER, 10000 pF, 50V, X7R, 10%, 0603
18	4	0.1 µF	C7 C15 C32 C36	805	TDK Corporation or Alternate	C1608X7R1E104K	CAP, CER, 0.10 µF, 25V X7R, 10%, 0603
19	8	2.2 µF	C8 C40 C42 C47 C51 C52 C54 C55	603	TDK Corporation or Alternate	C1608X5R1A225MT	CAP, CER, 2.2 µF, 6.3V, X5R, 20%, 0603
20	9	0.1 µF	C9 C18 C22 C25 C38 C43 C57 C58 C62	603	TDK Corporation or Alternate	C1608X7R1E104K	CAP, CER, 0.10 µF, 25V, X7R 10%, 0603
21	4	10 µF	C14 C24 C27 C29	6032	Panasonic-ECG or Alternate	ECS-T1EC106R	CAP, 10 µF, 25V, TANTALUM, TE, SMD
22	1	22 µF	C17	1206	Panasonic-ECG or Alternate	C3216XR0J226M	CAP, CER, 22 µF, 6.3V X5R, 20%, 1206
	1	1500 pF	C16(1)	603	TDK Corporation or Alternate	C1608C0G1H152J	CAP, CER, 1500 pF, 50V, C0G, 5%, 0603
23	4	NI	C30 C39 C61 C63	805	NOT INSTALLED	NOT INSTALLED	Multilayer Ceramic - 0805 Size
24	5	1 µF	C31 C33 C37 C59 C60	805	TDK Corporation or Alternate	C2012X7R1E105K	CAP, CER, 1.0 µF, 25V, X7R, 0805, T/R
25	1	130 pF	C35	805	TDK Corporation or Alternate	C2012C0G1H131	CAP, CER, 130 pF, 50V 5%, C0G, 0805
26	1	10 µF	C49	3528	Kemet or Alternate	T491B106K016AS	CAP, TANTALUM, 10 µF, 16V 10%, SMD

(1) Used for ADS7891EVM only.

Table A-1. Bill of Materials (continued)

Item No.	Qty.	Value	Reference Designators	Footprint	Manufacturer	Manufacturer's Part Number	Description
27	2	1K	RP1 RP3	CTS_742	CTS Corporation	742C163102JTR	RES ARRAY, 1 kΩ, 16TERM 8RES SMD
28	1	100	RP2	CTS_742	CTS Corporation	742C163101JTR	RES ARRAY 100 Ω 16TRM, 8RES SMD
29	4		L1 L2 L3 L4	805	TDK Corporation	MMZ2012R601A	Ferrite chip, 600 Ω, 500 mA
30	1		U1	8-SOP(D)	Texas Instruments	OPA132UA	DiFet amplifier
31	1		U2	8-SOP(D)	Texas Instruments	THS4031IDR	100 MHz, low-noise, high-speed amplifier
32	1	NI	U3	3-SOT-23	NOT INSTALLED	NOT INSTALLED	REF3040, 50 ppm/–C, 50-A in SOT23-3 CMOS voltage reference
33	1	ADS7881	U4	SOCKET_48 QFPP	Texas Instruments	ADS7881IPFBT	ADS7881, 12-bit, 4 MSPS
		ADS7891	U4(1)			ADS7891IPFBT	ADS7891, 14-bit, 3 MSPS
34	3	SN74AHC245	U5 U6 U7	20-TSSOP(PW)	Texas Instruments	SN74AHC245PWR	Octal bus transceiver, 3-state
35	1	SN74AHC138	U8	16-TSSOP (PW)	Texas Instruments	SN74AHC138PWR	3-line to 8-line decoder/ demultiplexer
36	1	REF1004-2.5	U9	8-SOP(D)	Texas Instruments	REF1004-2.5	Micropower voltage reference
37	1	SN74AHC1G04	U12	5-SOT(DBV)	Texas Instruments	SN74AHC1G04DBVR	Single inverter gate
38	2	10×2×0.1	P1 P2	10×2×0.1_SMT_PLUG_& _SOCKET	Samtec	SSW-110-22-S-D-VS	0.025" SMT socket - bottom side of PWB
39	2				Samtec	TSM-107-01-T-D-V-P	0.025" SMT plug - top side of PWB
40	1	Data Bus	P3	10×2×0.1_SMT_PLUG_& _SOCKET	Samtec	SSW-116-22-S-D-VS	0.025" SMT socket - bottom side of PWB
41	1				Samtec	TSM-116-01-T-D-V-P	0.025" SMT plug - top side of PWB
42	1	Power Supply	J1	5×2×0.1_SMT_SOCKET	Samtec	SSW-105-22-S-D-VS	0.025" SMT socket - bottom side of PWB
43	1				Samtec	TSM-105-01-T-D-V-P	0.025" SMT plug - top side of PWB
44	1	SMA_PCB_MT	J2	SMA_JACK	Johnson Components Inc.	142-0701-301	Right angle SMA connector
45	1	7×2×0.1	J3	7×2×0.1_SMT_PLUG_&_ SOCKET	Samtec	SSW-107-22-S-D-VS	0.025" SMT socket - bottom side of PWB
46	1				Samtec	TSM-107-01-T-D-V-P	0.025" SMT plug - top side of PWB
47	1	SW-PB	S1	EVQ-PJ	Panasonic	EVQ-PJU04K	switch
48	5		W1 W2 W3 W4 W5	3POS_JUMPER	Samtec	TSW-103-07-L-S	3 Position jumper _ 0.1" spacing
49	1	SJP2	SJP5	SJP2	NOT INSTALLED	NOT INSTALLED	Pad 2 position jumper
50	5	SJP3	SJP1 SJP2 SJP4 SJP6 SJP7	SJP3	NOT INSTALLED	NOT INSTALLED	Pad 3 position jumper
51	1	TO_0.025	TP1	test_point2	Keystone Electronics	5002K-ND	Test point, PC, mini 0.040" D, white
52	10	TO_0.025	TP3 TP4 TP6 TP8 TP9 TP10 TP11 TP12 TP14 TP15	test_point2	Keystone Electronics	5000K-ND	Test point, PC, mini 0.040" D, red
53	4	TO_0.025	TP5 TP7 TP2 TP13	test_point2	Keystone Electronics	5001K-ND	Test point, PC, mini 0.040" D, black

Appendix B ADS7881EVM/ADS7891EVM Layout

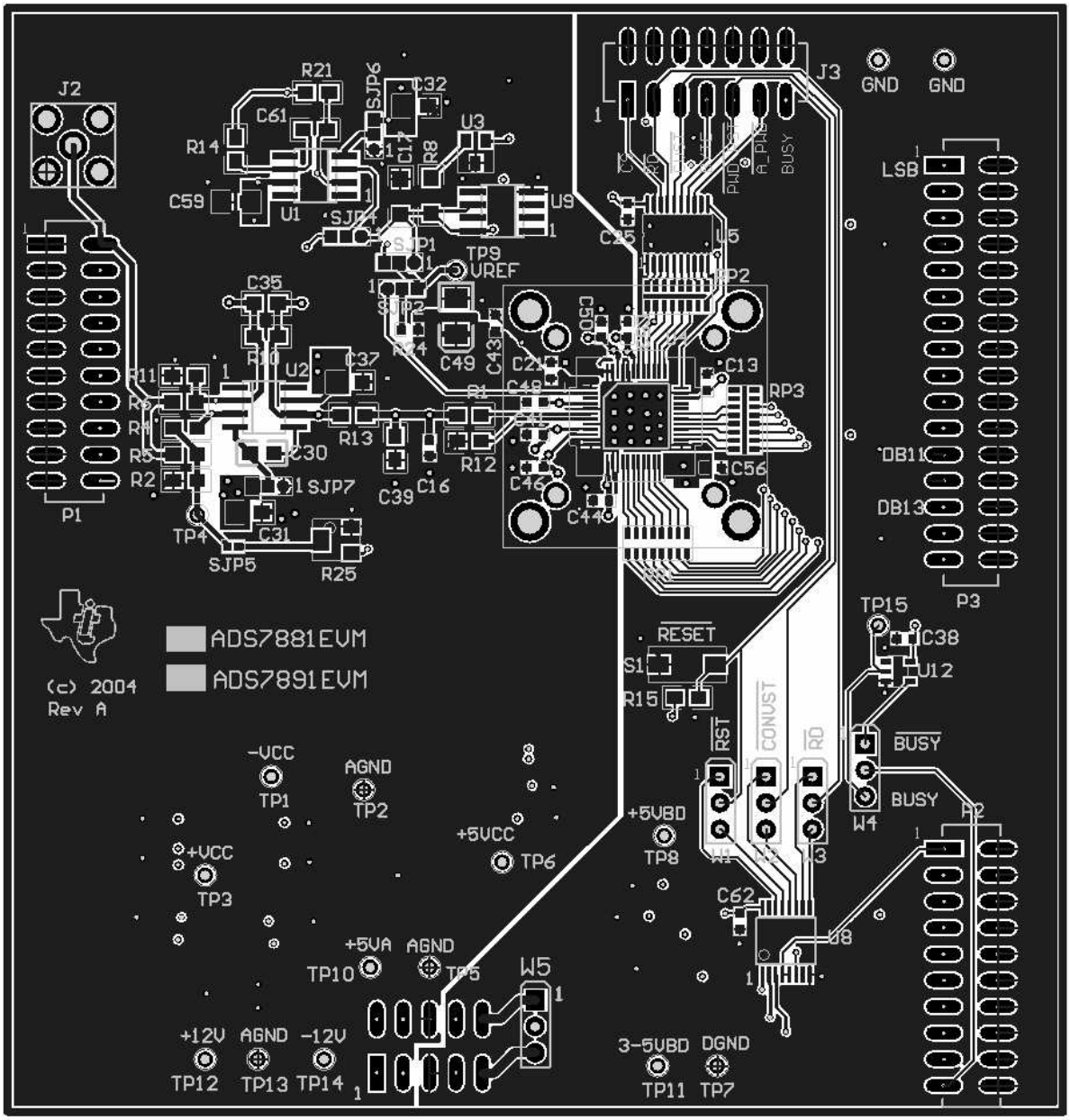

Figure B-1. Top Layer – Layer 1

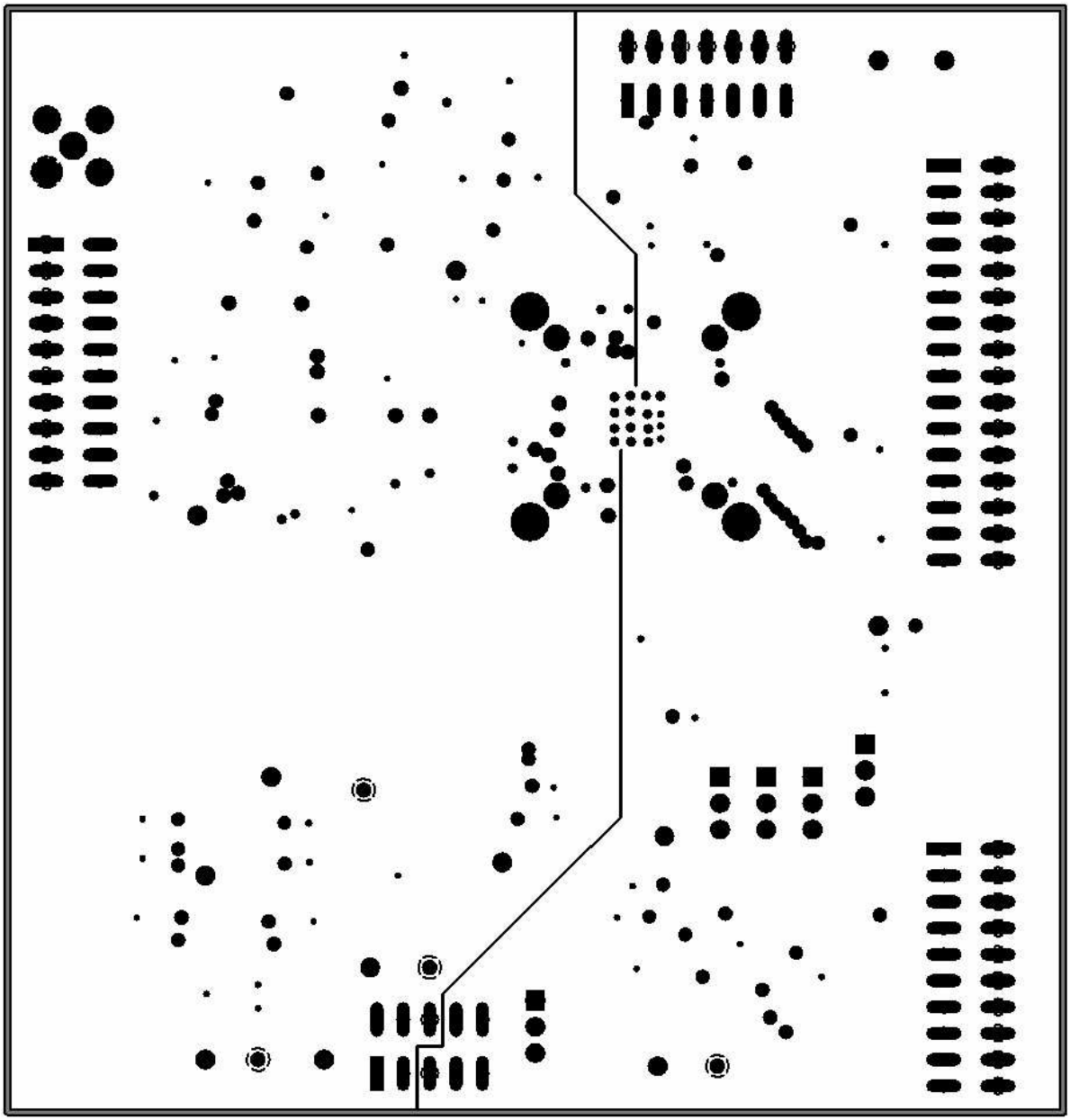

Figure B-2. Ground Plane – Layer 2

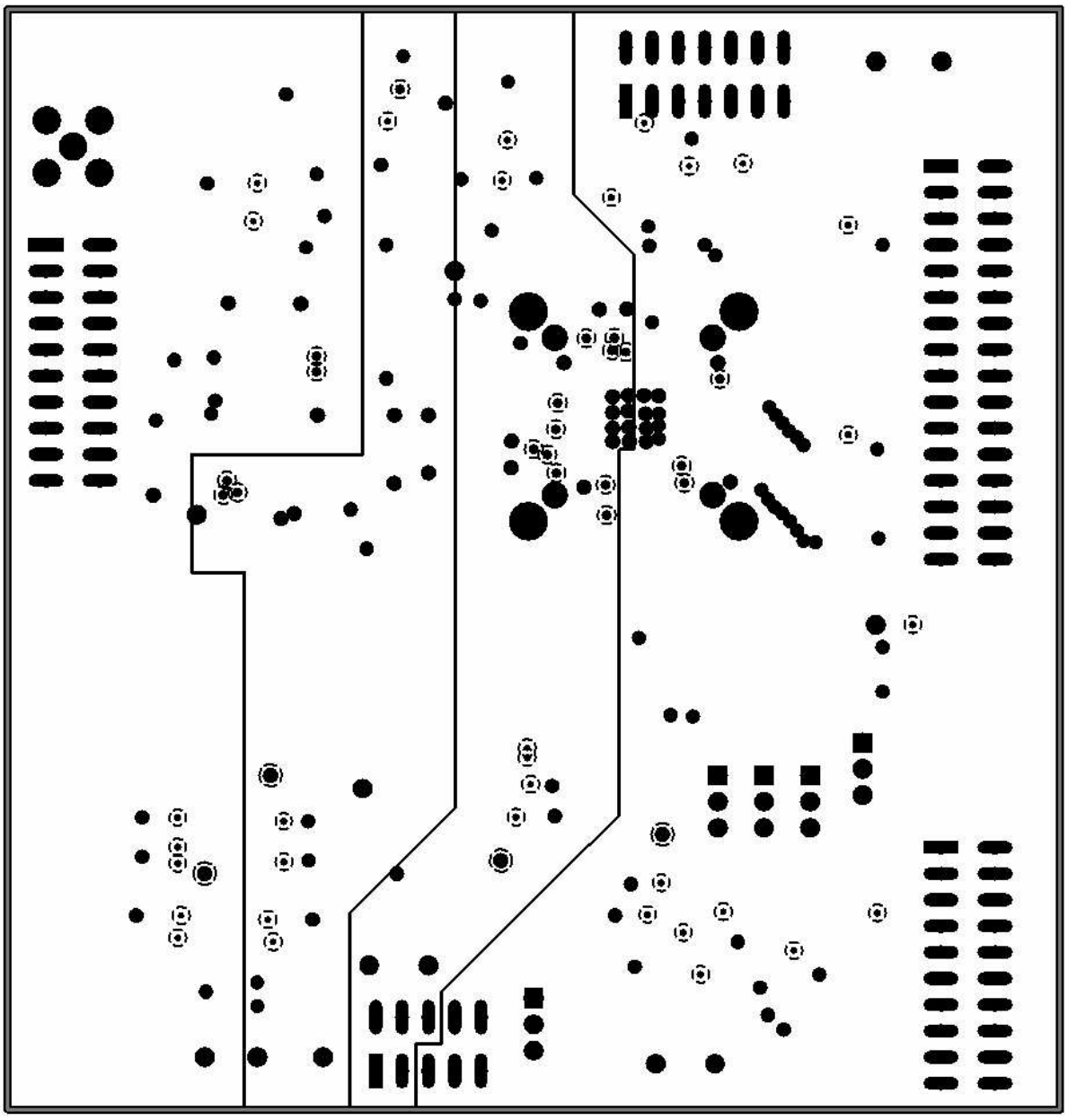

Figure B-3. Power Plane – Layer 3

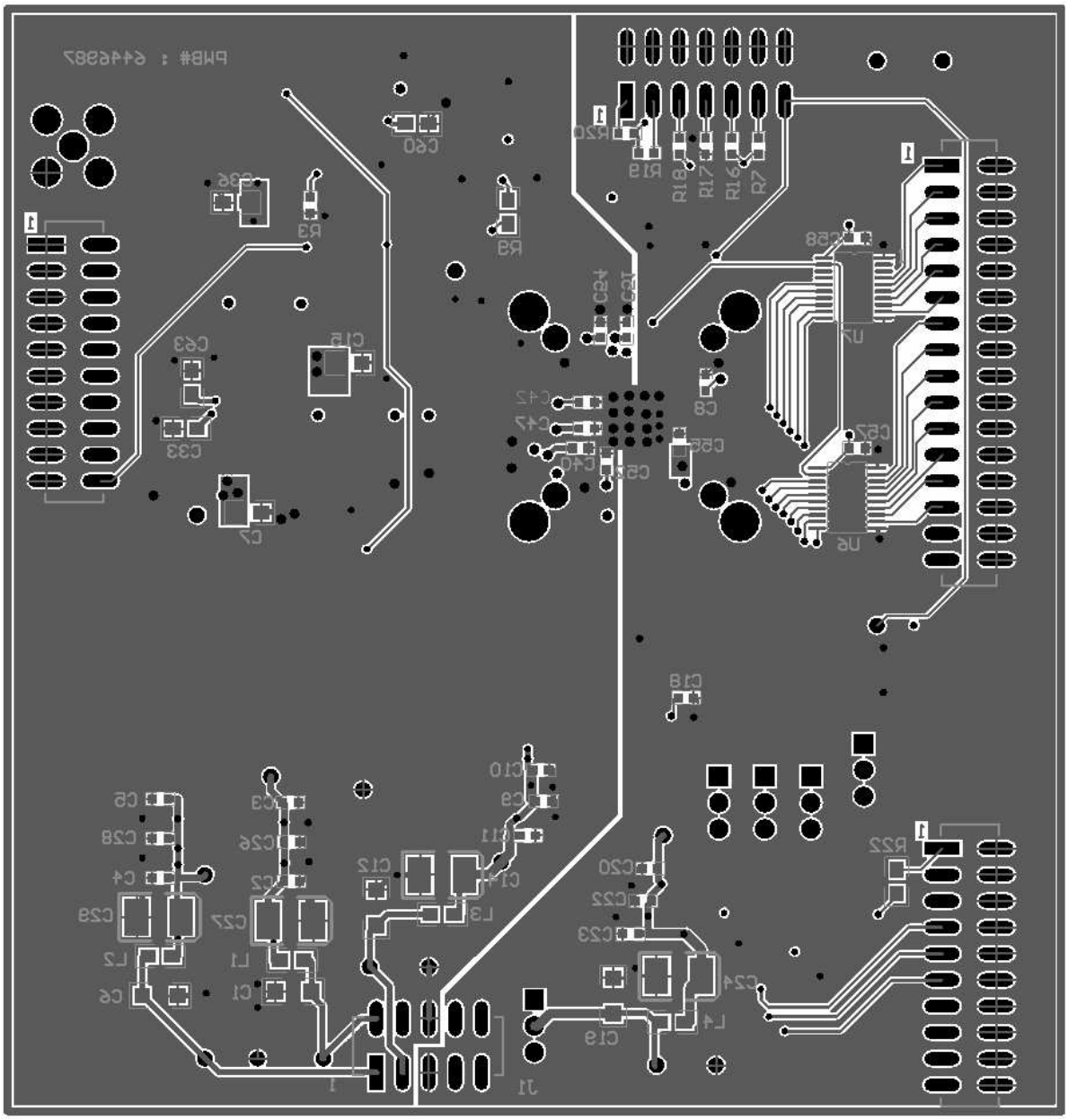

Figure B-4. Bottom Layer – Layer 4

Appendix C ADS7881EVM/ADS7891EVM Schematic

See attachment for schematic drawings.

Revision History		
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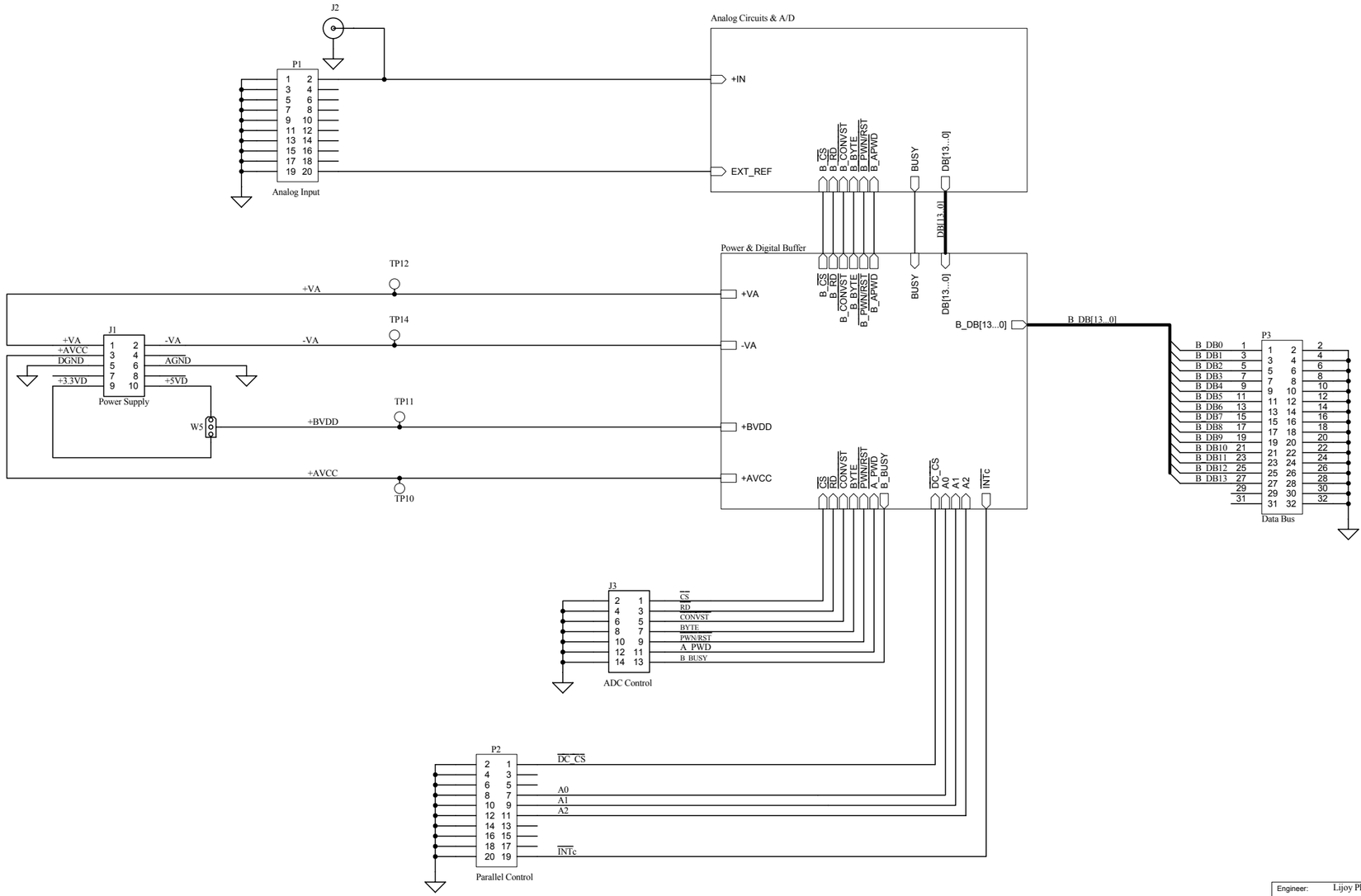
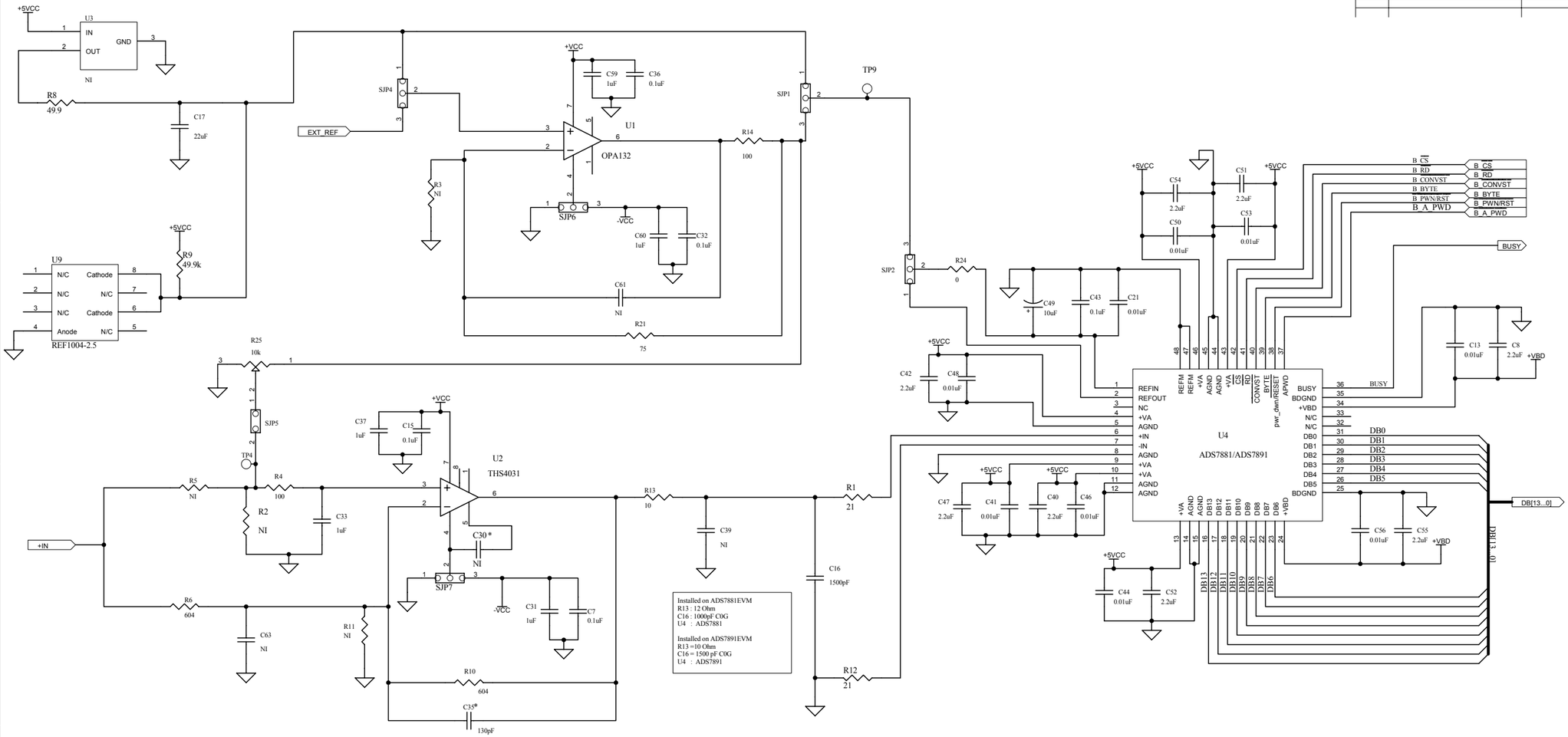


TEXAS INSTRUMENTS

12500 TI Boulevard. Dallas, Texas 75243

TITLE: ADS7881EVM/ADS7891EVM			
Engineer: Lijoy Philipose	DOCUMENT CONTROL #: 6456873		REV: A
Drawn By: Lijoy Philipose	DATE: 11-Nov-2004	SIZE:	SHEET: 1 OF: 3
FILE: BlockDiagram.sch			

Revision History		
REV	ECN Number	Approved



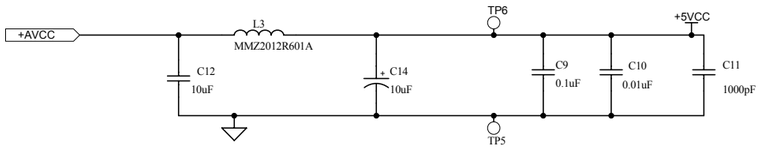
Engineer:	Lijoy Philipose
Drawn By:	Lijoy Philipose
FILE:	Analog-to-Digital Converter

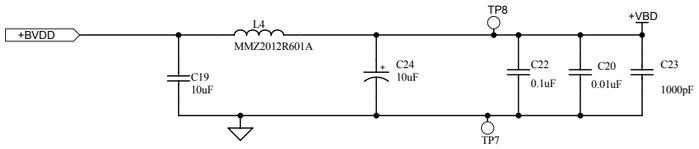
TEXAS INSTRUMENTS

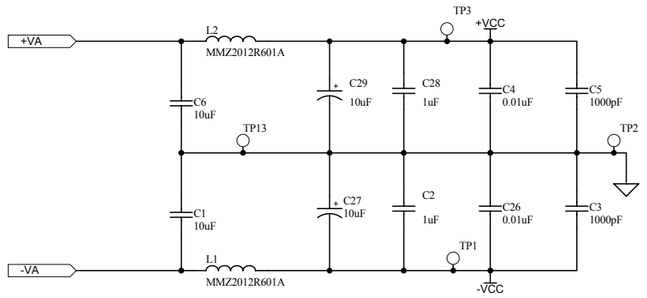
12500 TI Boulevard. Dallas, Texas 75243

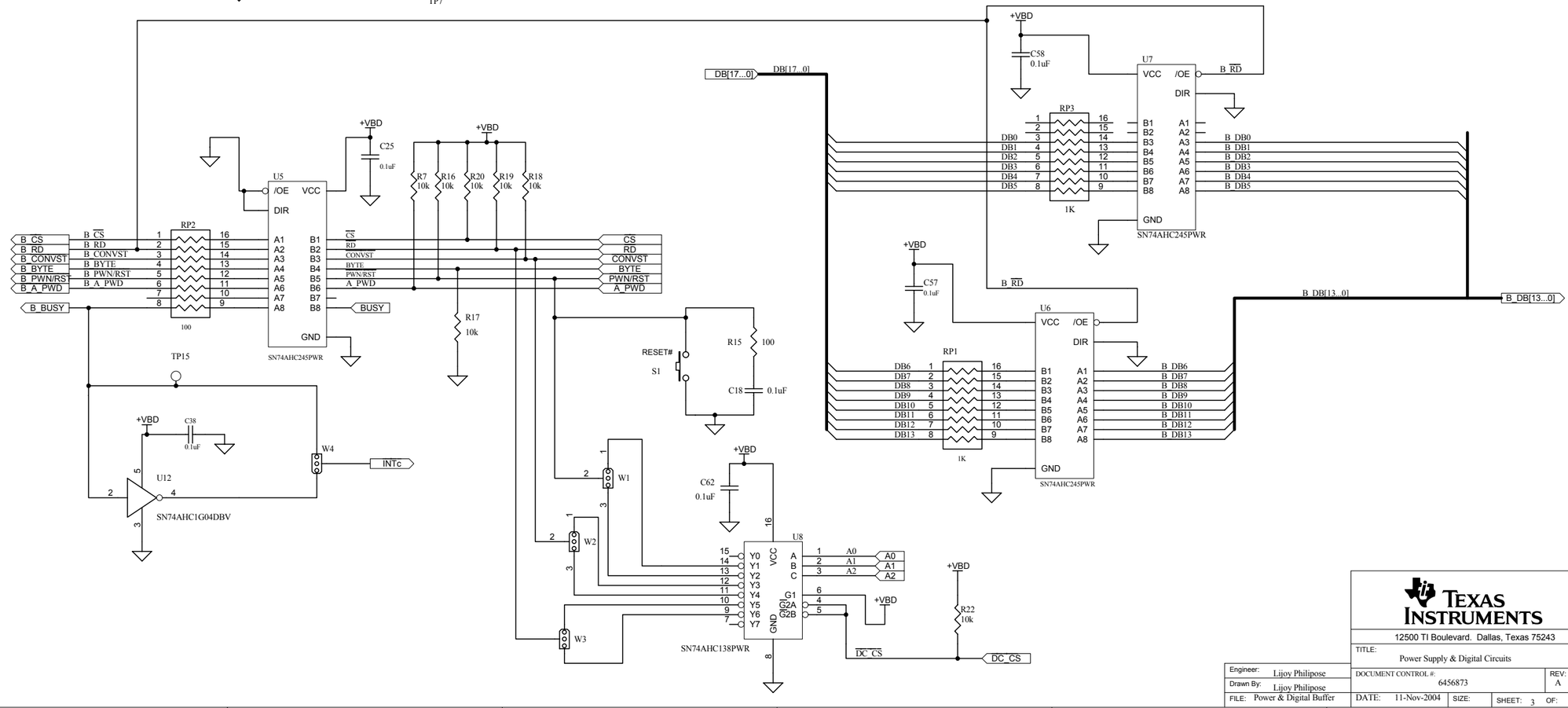
TITLE: Analog Circuits			
DOCUMENT CONTROL #: 6456873			REV: A
DATE: 11-Nov-2004	SIZE:	SHEET: 2	OF: 3

Revision History		
REV	ECN Number	Approved









Engineer:	Lijoy Philipose
Drawn By:	Lijoy Philipose
FILE:	Power & Digital Buffer

TEXAS INSTRUMENTS

12500 TI Boulevard. Dallas, Texas 75243

TITLE: Power Supply & Digital Circuits

DOCUMENT CONTROL #: 6456873 REV: A

DATE: 11-Nov-2004 SIZE: SHEET: 3 OF: 3

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