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# LTC2370/LTC2369/LTC2368/ LTC2367/LTC2364: 18-Bit/16-Bit, 2Msps/1.6Msps/1Msps/ 500ksps/250ksps Low Power, Low Noise ADCs

## DESCRIPTION

The LTC<sup>®</sup>2370/LTC2369/LTC2368/LTC2367/LTC2364 are low power, low noise ADCs with serial outputs that can operate from a single 2.5V supply. The following text refers to the LTC2369-18 but applies to all parts in the family, the only difference being the maximum sample rates and the number of bits. The LTC2369-18 supports a 0V to 5V pseudo-differential input range with a 96dB SNR, consumes only 18mW and achieves  $\pm 2$ LSB INL max with no missing codes at 18-bits. The DC1813A demonstrates the DC and AC performance of the LTC2369-18 in conjunction with the DC590 QuikEval<sup>™</sup> and DC718 QuikEval II data collection boards. Use the DC590 to demonstrate DC performance

such as peak-to-peak noise and DC linearity. Use the DC718 if precise sampling rates are required or to demonstrate AC performance such as SNR, THD, SINAD and SFDR. The DC1813A is intended to demonstrate recommended grounding, component placement and selection, routing and bypassing for this ADC. Several suggested driver circuits for the analog inputs will be presented.

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

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## BOARD PHOTO

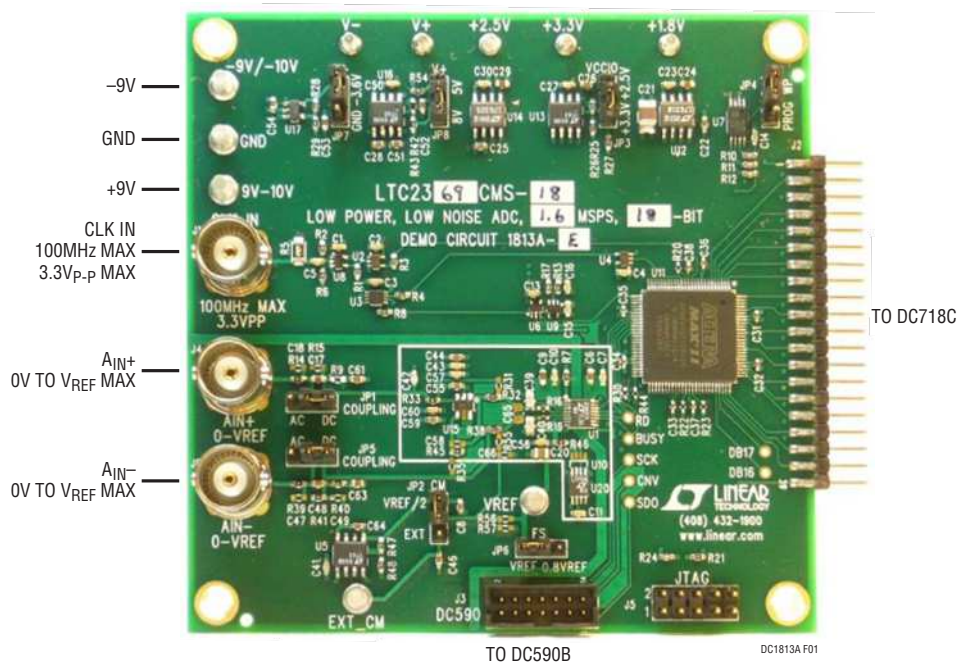


Figure 1. DC1813A Connection Diagram

## QUICK START PROCEDURE

Check to make sure that all switches and jumpers are set as shown in the connection diagram of Figure 1. The default connections configure the ADC to use the onboard reference and regulators to generate the required common mode voltages. The analog input is DC-coupled. Connect the DC1813A to a DC718 USB high speed data collection board using connector J2. Then, connect the DC718 to a host PC with a standard USB A/B cable. Apply  $\pm 9V$  to the indicated terminals. Then apply a low jitter signal source to J4. Connect a low jitter 99.2MHz 3.3V<sub>P-P</sub> sine wave or square wave to connector J1. Note that J1 has a 50 $\Omega$  termination resistor to ground.

Run the QuickEval II software (PScope.exe version K72 or later) supplied with the DC718 or download it from [www.linear.com](http://www.linear.com).

Complete software documentation is available from the Help menu. Updates can be downloaded from the Tools menu. Check for updates periodically as new features may be added.

The PScope™ software should recognize the DC1813A and configure itself automatically.

Click the Collect button (See Figure 6) to begin acquiring data. The Collect button then changes to Pause, which can be clicked to stop data acquisition.

**Table 1. Assembly Options**

ASSEMBLY VERSION	U1 PART NUMBER	MAX CONVERSION RATE	NUMBER OF BITS	MAX CLK IN FREQUENCY
DC1813A-A	LTC2370CMS-16	2Msps	16	100MHz
DC1813A-B	LTC2368CMS-16	1Msps	16	50MHz
DC1813A-C	LTC2367CMS-16	500ksps	16	25MHz
DC1813A-D	LTC2364CMS-16	250ksps	16	12.5MHz
DC1813A-E	LTC2369CMS-18	1.6Msps	18	99.2MHz
DC1813A-F	LTC2368CMS-18	1Msps	18	62MHz
DC1813A-G	LTC2367CMS-18	500ksps	18	31MHz
DC1813A-H	LTC2364CMS-18	250ksps	18	15.5MHz

## DC590 SETUP

**IMPORTANT!** To avoid damage to the DC1813A, make sure that VCCIO (JP6 of the DC590) is set to 3.3V before connecting the DC590 to the DC1813A.

To use the DC590 with the DC1813A, it is necessary to apply  $-9V$  and ground to the  $-9V$  and GND terminals or disable amplifier U15 by moving R32 and R36 to R31 and R38 respectively. Connect the DC590 to a host PC with a standard USB A/B cable. Connect the DC1813A to a DC590

USB serial controller using the supplied 14-conductor ribbon cable. Apply a signal source to J4 or J4 and J8 depending on how the DC1813A is configured.

Run the evaluation software supplied with the DC590 or download it from [www.linear.com](http://www.linear.com). The correct control panel will be loaded automatically. Click the Collect button (Figure 7) to begin reading the ADC.

## DC1813A SETUP

### DC Power

The DC1813A requires  $\pm 9V_{DC}$  and draws 50mA. Most of the supply current is consumed by the CPLD, op amps, regulators and discrete logic on the board. The  $9V_{DC}$  input voltage powers the ADC through LT1763 regulators which provide protection against accidental reverse bias. Additional regulators provide power for the CPLD and op amps. See Figure 1 for connection details.

### Clock Source

You must provide a low jitter  $3.3V_{p-p}$  sine or square wave to J1. The clock input is AC-coupled so the DC level of the clock signal is not important. A generator like the HP8644 or the DC1216A-A is recommended. Even a good generator can start to produce noticeable jitter at low frequencies. Therefore it is recommended for lower sample rates to divide down a higher frequency clock to the desired sample rate. The ratio of clock frequency to conversion rate is 62:1 for 18-bit parts and 50:1 for 16-bit parts. If the clock input is to be driven with logic, it is recommended that the  $50\Omega$  terminator (R5) be removed. Slow rising edges may compromise the SNR of the converter in the presence of high amplitude higher frequency input signals.

### Data Output

Parallel data output from this board (0V to 3.3V default), if not connected to the DC718, can be acquired by a logic analyzer, and subsequently imported into a spreadsheet, or mathematical package depending on what form of digital signal processing is desired. Alternatively, the data can be fed directly into an application circuit. Use Pin 3 of J2 to latch the data. The data can be latched using either edge of this signal. The data output signal levels at J2 can also be reduced to 0V to 2.5V if the application circuit cannot tolerate the higher voltage. This is accomplished by moving JP3 to the 2.5V position.

### Reference

The default reference is a LTC6655 5V reference. Alternatively, if a lower power reference is desired, this reference (U20) can be removed and a LTC6652 5V reference can be installed in the U10 position. This will result in only a small loss in performance in applications where the ADC is continuously converting. If an external reference is used it must settle quickly in the presence of glitches on the REF pin.

## DC1813A SETUP

### Analog Input

The default driver for the analog inputs of the LTC2369-18 on the DC1813A is shown in Figure 2. This circuit band limits the input frequencies to approximately 800kHz. Alternatively, if you need to level shift the input signal, the circuit shown in Figure 3 can be used. The circuit in Figure 3 AC couples the input signal and is usable down to about 10kHz. The lower frequency limit can be extended by increasing C17.

AC-coupling the input may degrade the distortion performance of the ADC due to nonlinearity of the coupling capacitor (C17). The circuit in Figure 3 can be implemented on the DC1813A by putting JP1 in the AC position and adding a 1k $\Omega$  resistor at the R9 location.

One of the most asked for ADC driver circuits is one that allows the input voltage to swing below ground while using a single supply ADC. The input driver shown in Figure 4 accepts a true bipolar input voltage range of  $\pm 10V$  and converts it to the 0V to 5V input swing of the ADC. The circuit of Figure 4 can be implemented on the DC1813A by replacing R9 with 499 $\Omega$ , R15 with 2k $\Omega$ , R35 with 2k $\Omega$  and R45 with 499 $\Omega$ .

### Data Collection

For SINAD, THD or SNR testing a low noise, low distortion generator such as the B&K Type 1051 or Stanford Research DS360 should be used. A low jitter RF oscillator such as the HP8644 or DC1216A-A is used as the clock source.

This demo board is tested in house by attempting to duplicate the FFT plot shown on the front page of the LTC2369-18

data sheet. This involves using a 100MHz clock source, along with a sinusoidal generator at a frequency of 2.0kHz. The input signal level is approximately -1dBfs. The input is level shifted and filtered with the circuit shown in Figure 5. A typical FFT obtained with DC1813A is shown in Figure 6. Note that to calculate the real SNR, the signal level (F1 amplitude = -1.037dB) has to be added back to the SNR that PScope (QuikEval II) displays. With the example shown in Figure 6 this means that the actual SNR would be 96.46dB instead of the 95.43dB that PScope displays. Taking the RMS sum of the recalculated SNR and the THD yields a SINAD of 96.16 dB which is fairly close to the typical number for this ADC.

There are a number of scenarios that can produce misleading results when evaluating an ADC. One that is common is feeding the converter with a frequency, that is a sub-multiple of the sample rate, and which will only exercise a small subset of the possible output codes. The proper method is to pick an M/N frequency for the input sine wave frequency. N is the number of samples in the FFT. M is a prime number between one and N/2. Multiply M/N by the sample rate to obtain the input sine wave frequency. Another scenario that can yield poor results is if you do not have a signal generator capable of ppm frequency accuracy or if it cannot be locked to the clock frequency. You can use an FFT with windowing to reduce the "leakage" or spreading of the fundamental, to get a close approximation of the ADC performance. If an amplifier or clock source with poor phase noise is used, the windowing will not improve the SNR.

DC1813A SETUP

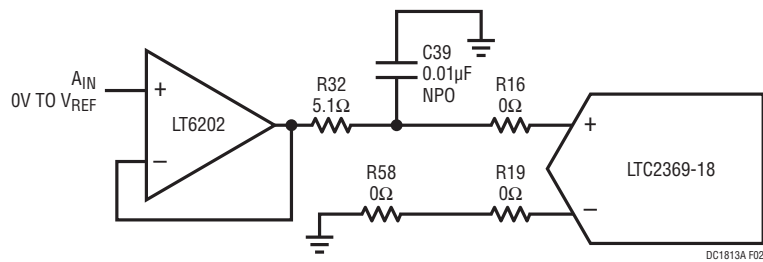


Figure 2. DC-Coupled LT6202 Driver

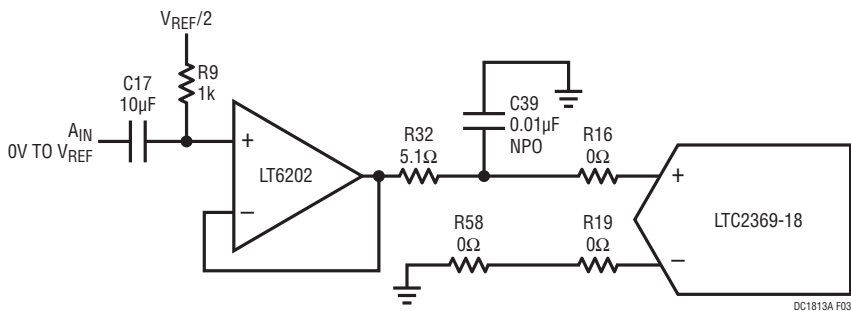


Figure 3. AC-Coupled LT6202 Driver

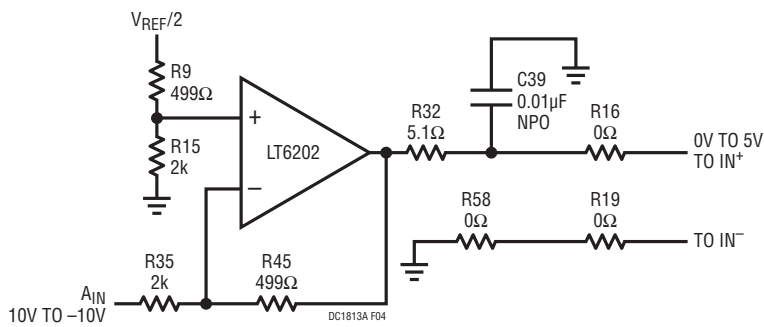


Figure 4. ±10V Into 0V to 5V DC-Coupled Driver

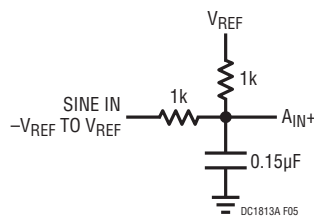


Figure 5. Level Shift and Filter Circuit Used for Board Testing

## DC1813A SETUP

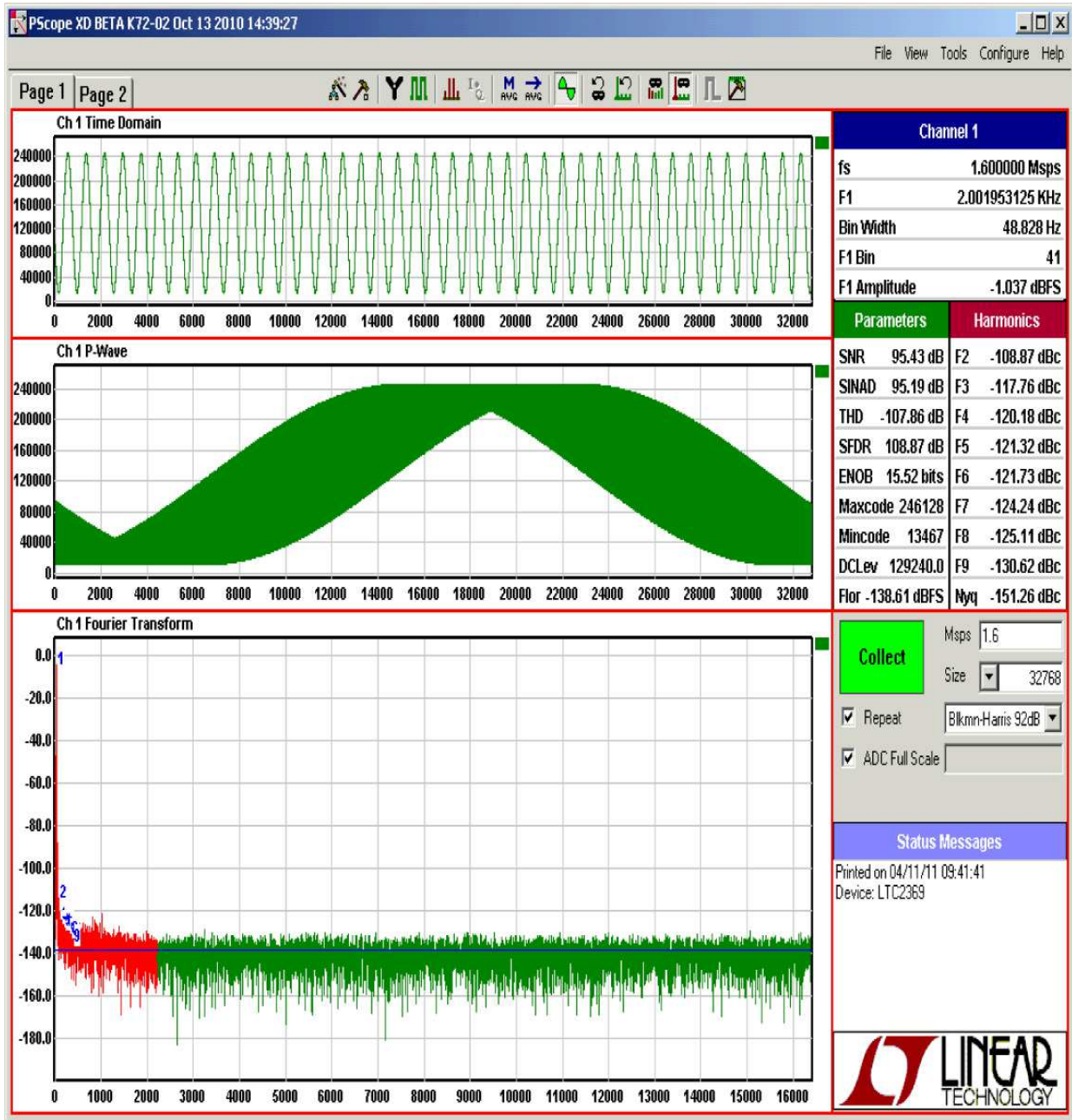


Figure 6. PScope (QuikEval II) Screen Shot

DC1813A SETUP

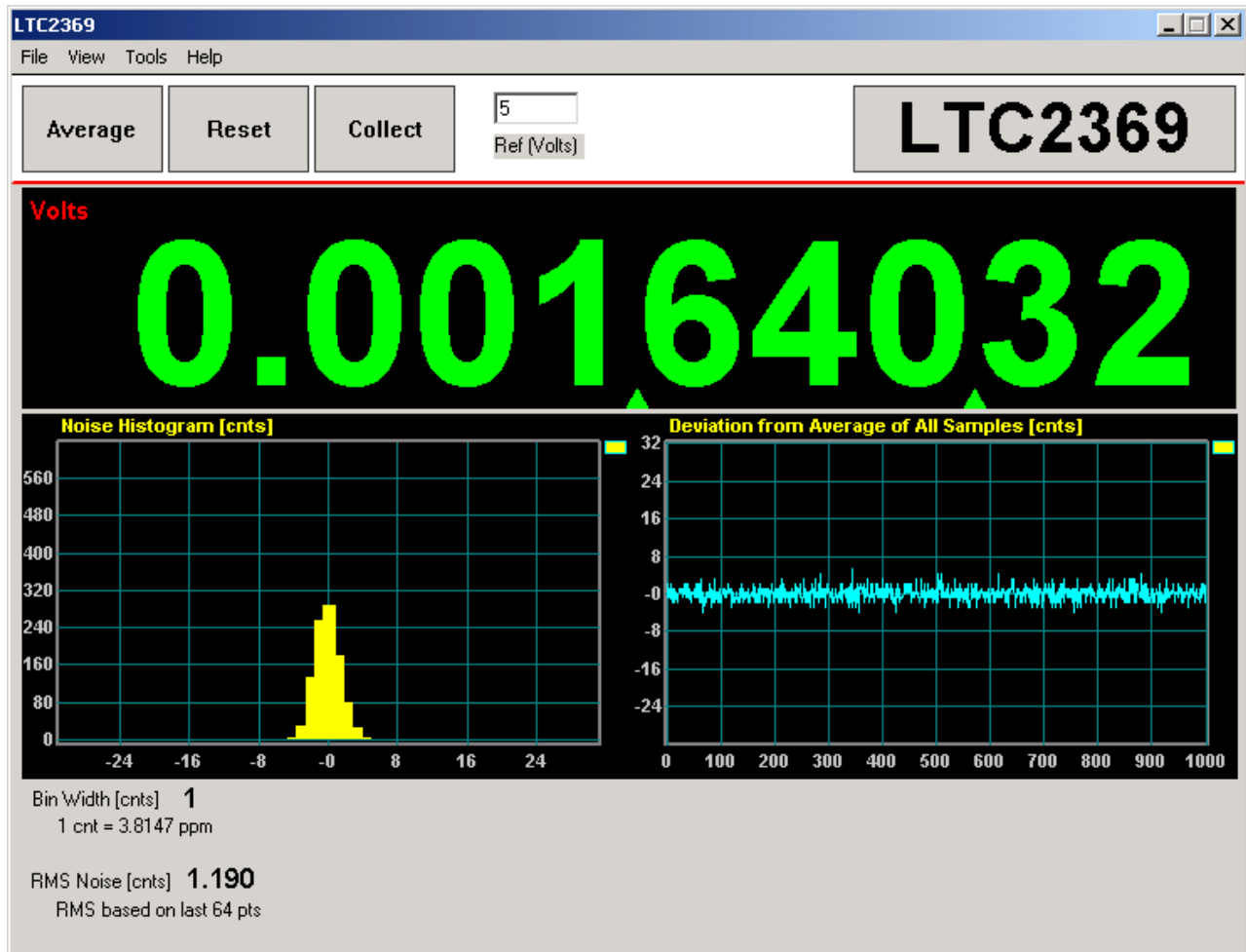


Figure 7. QuikEval Screen Shot



## DC1813A SETUP

### Layout

As with any high performance ADC, this part is sensitive to layout. The area immediately surrounding the ADC on the DC1813A should be used as a guideline for placement, and routing of the various components associated with the ADC. Here are some things to remember when laying out a board for the LTC2369-18. A ground plane is necessary to obtain maximum performance. Keep bypass capacitors as close to supply pins as possible. Use individual low impedance returns for all bypass capacitors. Use of a symmetrical layout around the analog inputs will minimize the effects of parasitic elements. Shield analog input traces with ground to minimize coupling from other traces. Keep traces as short as possible.

### Component Selection

When driving a low noise, low distortion ADC such as the LTC2369-18, component selection is important so as to not degrade performance. Resistors should have low values to minimize noise and distortion. Metal film resistors are recommended to reduce distortion caused by self heating. Because of their low voltage coefficients, to further reduce distortion NPO or silver mica capacitors should be used. Any buffer used to drive the LTC2369-18 should have low distortion, low noise and a fast settling time such as the LT6202.

### Jumpers

**JP1:** Selects AC or DC coupling of  $A_{IN+}$ . The default setting is DC.

**JP2:**  $V_{CM}$  sets the DC bias for  $A_{IN+}$  and  $A_{IN-}$  when the inputs are AC coupled.  $V_{REF}/2$  is the default setting.

**JP3:**  $V_{CCIO}$  sets the output levels at J2 to either 3.3V or 2.5V. Use 3.3V to interface to the DC718 which is the default setting.

**JP5:** Selects AC or DC coupling of  $A_{IN-}$ . The default setting is DC.

**JP7:** Selects  $-3.6V$  or ground for  $V^-$ . The default is  $-3.6V$ . Setting JP7 to ground is useful for evaluating single supply operation of the buffer when operating the ADC with digital gain compression turned on.

**JP8:** Selects 8V or 5V for  $V^+$ . The default is 8V. Setting JP8 to 5V is useful for evaluating single 5V supply operation of the buffer when operating the ADC with digital gain compression turned on.

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
1	17	C1–C5, C7, C10, C11, C13–C16, C41, C43, C56, C57, C60	Capacitor, X7R, 0.1µF, 16V,10%, 0603	AVX, 0603YC104KAT2A
2	11	C6, C9, C17, C24, C26, C29, C48, C52, C53, C61, C63	Capacitor, X5R, 10µF, 6.3V, 20%, 0603	AVX, 06036D106MAT2A
3	11	C8, C44, C46, C55, C59, C64, C22, C25, C28, C51, C54	Capacitor, X7R, 1µF, 16V,10%, 0603	AVX, 0603YC105KAT2A
4	0	C18, C47, C49, C58, C66 (Optional)	Capacitor, 0603	
5	1	C20	Capacitor, X5R, 47µF, 6.3V, 20%, 0805	Taiyo Yuden, JMK212BJ476MG-T
6	1	C21	Capacitor, X5R, 22µF, 16V, 20%, 1210	AVX, 1210YD226MAT2A
7	4	C23, C27, C30, C50	Capacitor, X7R, 0.01µF, 16V, 10%, 0603	AVX, 0603YC103KAT2A
8	8	C31–C38	Capacitor, X7R, 0.1µF, 16V,10%, 0402	AVX, 0402YC104KAT2A
9	1	C39	Capacitor, COG, 0.01µF, 50V, 10%, 1206	AVX, 12065C103KAT2A
9	0	C40 (Optional)	Capacitor, 1206	
10	1	C42	Capacitor, COG, 15pF, 50V, 10%, 0603	AVX, 06035A150JAT
11	0	C65 (Optional)	Capacitor, 0805	
12	5	E3, E4, E6, E7, E11	Testpoint, Turret, 0.094" PBF	Mill-Max, 2501-2-00-80-00-00-07-0
13	5	E5, E8, E9, E10, E12	Testpoint, Turret, 0.061" PBF	Mill-Max, 2308-2-00-80-00-00-07-0
14	7	JP1–JP5, JP7, JP8	3 Pin 0.100 Single-Row Header	Samtec, TSW-103-07-L-S
15	7	XJP1–XJP5, XJP7, XJP8	Shunt, 0.1" Center	Samtec, SNT-100-BK-G
16	1	JP6 (Pins 1–2, V <sub>REF</sub> )	Shunt, 0.1" Center, for Pins 1–2, V <sub>REF</sub>	Samtec, JL-100-25-T
17	3	J1, J4, J8	Connector, BNC-5 Pins	Connex, 112404
18	1	J2	Connector, 40 Pins SMT, CON-EDGE40-100	Samtec, TSW-120-07-L-D
19	1	J3	Header, 2×7, 0.079"	Molex, 87831-1420
20	1	J5	Header, 2×5, 0.100", HD2X5-100	Samtec, TSW-105-07-L-D
21	4	R1, R3, R4, R8	Resistor, Chip, 33, 1/10W, 5% 0603	NIC, NRC06J330TRF
22	5	R2, R6, R29, R43, R48	Resistor, Chip, 1.00k, 1/10W, 1% 0603	NIC, NRC06F1001TRF
23	1	R5	Resistor, Chip, 49.9, 1/4W, 1% 1206	NIC, NRC12F499TRF
24	3	R7, R13, R24	Resistor, Chip, 1k, 1/10W, 5% 0603	NIC, NRC06J102TRF
25	3	R10, R11, R12	Resistor, Chip, 4.99k, 1/10W, 1% 0603	NIC, NRC06F4991TRF
26	6	R14, R33, R39, R45, R46, R58	Resistor, Chip, 0, 1/10W, 0603	NIC, NRC06Z0TRF
27	0	R9, R15, R31, R35, R38, R40, R41, R55–R57, R59 (Optional)	Resistor, 0603	
28	2	R16, R19	Resistor, Chip, 0, 1/16W, 0402	NIC, NRC04Z0TRF
29	1	R17	Resistor, Chip, 2k, 1/10W, 5% 0603	NIC, NRC06F202TRF
30	3	R20, R22, R23	Resistor, Chip, 1k, 1/16W, 5% 0402	NIC, NRC04J102TRF
31	1	R21	Resistor, Chip, 10k, 1/16W, 5% 0603	
32	1	R25	Resistor, Chip, 1.69k, 1/10W, 1% 0603	NIC, NRC06F1691FM
33	1	R26	Resistor, Chip, 1.54k, 1/10W, 1% 0603	NIC, NRC06F1541FM
34	1	R27	Resistor, Chip, 2.80k, 1/10W, 1% 0603	NIC, NRC06F2801TRF
35	1	R28	Resistor, Chip, 2.0k, 1/10W, 1% 0603	NIC, NRC06F2001TRF
36	1	R30	Resistor, Chip, 10k, 1/16W, 1% 0402	NIC, NRC04F1002TRF
37	1	R42	Resistor, Chip, 5.62k, 1/10W, 1% 0603	NIC, NRC06F5621TRF
38	1	R47	Resistor, Chip, 1.05k, 1/10W, 1% 0603	NIC, NRC06F1051TRF

# DEMO MANUAL DC1813A

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
39	1	R54	Resistor, Chip, 6.49K, 1/10W, 1% 0603	NIC, NRC06F6491TRF
40	2	U2, U4	IC, Tinylogic ULP-A Unbuffered Inverter, SC70-5	Fairchild, NC7SVU04P5X
41	1	U3	IC, Single D Flip Flop, US8	On Semiconductor, NL17SZ74
42	3	U5, U13, U16	IC, LT1763CS8, S08	Linear Technology, LT1763CS8
43	1	U6	IC, Single SPST Bus Switch, SC70-5	Fairchild, NC7SZ66P5X
44	1	U7	IC, SERIAL EEPROM, TSSOP	Microchip, 24LC024-I/ST
45	2	U8, U9	IC, Tinylogic UHS Inverter, SC70-5	Fairchild, NC7SZ04P5X
46	0	U10 (Optional)	IC, LTC6652AHMS8-5, MS8	
47	1	U11	IC, MAX II Family, TQFP100	Altera, EPM240GT100C5N
48	1	U12	IC, LT1763CS8-1.8, S08	Linear Technology, LT1763CS8-1.8
49	1	U14	IC, LT1763CS8-2.5, S08	Linear Technology, LT1763CS8-2.5
50	1	U15	IC, LTC6202CS5, TSOT-23, (5 Pin and 6 Pin)	Linear Technology, LTC6202CS5
51	1	U17	IC, LT1964ES5-SD, SOT23-5	Linear Technology, LT1964ES5-SD
52	1	U20	IC, LTC6655BHMS8-5, MS8	Linear Technology, LTC6655BHMS8-5
53	4	MH1-MH4	Stand-Off, Nylon 0.25"	Keystone, 8831(Snap On)
54	1	(For Inventory Only)	Cable Assy., 8" Strip	Linear Ribbon Cable CA-2440

### DC1813A-A

1	1	DC1813A	General BOM	
2	1	U1	IC, LTC2370CMS-16, MS16	Linear Technology, LTC2370CMS-16
3	1	R32	Resistor, Chip, 5, 1, 1/10W, 5% 0603	NIC, NRC06J5R1TRF
4	0	R44 (Optional)	Resistor, 0402	
5	1		FAB, Printed Circuit Board	DC1813A

### DC1813A-B

1	1	DC1813A	General BOM	
2	1	U1	IC, LTC2368CMS-16, MS16	Linear Technology, LTC2368CMS-16
3	1	R32	Resistor, Chip, 5, 1, 1/10W, 5% 0603	NIC, NRC06J5R1TRF
4	0	R44 (Optional)	Resistor, 0402	
5	1		FAB, Printed Circuit Board	DC1813A

### DC1813A-C

1	1	DC1813A	General BOM	
2	1	U1	IC, LTC2367CMS-16, MS16	Linear Technology, LTC2367CMS-16
3	1	R32	Resistor, Chip, 10, 1/10W, 5% 0603	
4	0	R44 (Optional)	Resistor, 0402	
5	1		FAB, Printed Circuit Board	DC1813A

### DC1813A-D

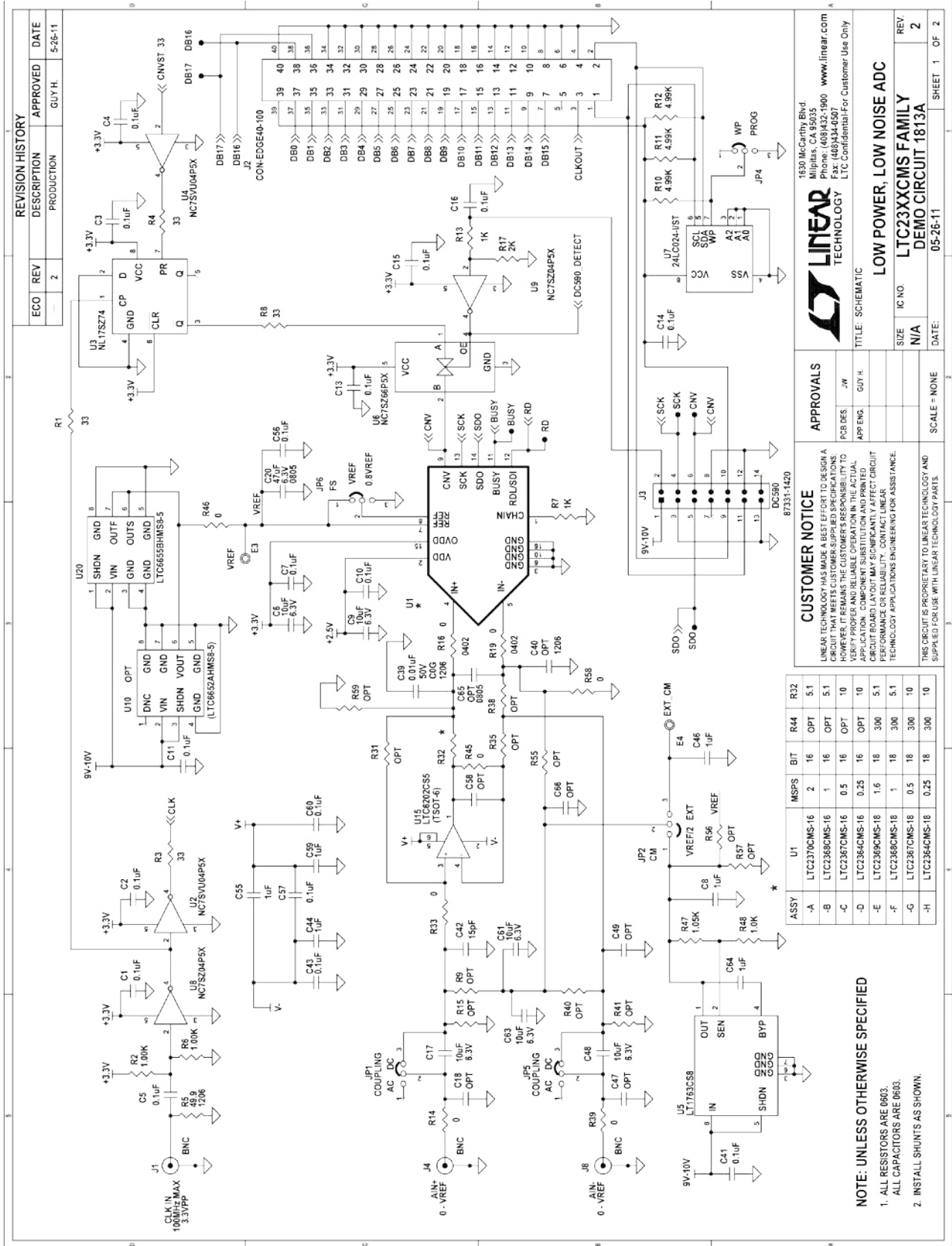
1	1	DC1813A	General BOM	
2	1	U1	IC, LTC2364CMS-16, MS16	Linear Technology, LTC2364CMS-16
3	1	R32	Resistor, Chip, 10, 1/10W, 5% 0603	
4	0	R44 (Optional)	Resistor, 0402	
5	1		FAB, Printed Circuit Board	DC1813A

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>DC1813A-E</b>				
1	1	DC1813A	General BOM	
2	1	U1	IC, LTC2369CMS-18, MS16	Linear Technology, LTC2369CMS-18
3	1	R32	Resistor, Chip, 5, 1, 1/10W, 5% 0603	NIC, NRC06J5R1TRF
4	1	R44	Resistor, Chip 300, 1/16W, 1% 0402	Panasonic ERJ-2RKF3000X
5	1		FAB, Printed Circuit Board	DC1813A
<b>DC1813A-F</b>				
1	1	DC1813A	General BOM	
2	1	U1	IC, LTC2368CMS-18, MS16	Linear Technology, LTC2368CMS-18
3	1	R32	Resistor, Chip, 5, 1, 1/10W, 5% 0603	NIC, NRC06J5R1TRF
4	1	R44	Resistor, Chip, 300, 1/16W, 1% 0402	Panasonic ERJ-2RKF3000X
5	1		FAB, Printed Circuit Board	DC1813A
<b>DC1813A-G</b>				
1	1	DC1813A	General BOM	
2	1	U1	IC, LTC2367CMS-18, MS16	Linear Technology, LTC2367CMS-18
3	1	R32	Resistor, Chip, 10, 1/10W, 5% 0603	
4	1	R44	Resistor, Chip, 300, 1/16W, 1% 0402	Panasonic ERJ-2RKF3000X
5	1		FAB, Printed Circuit Board	DC1813A
<b>DC1813A-H</b>				
1	1	DC1813A	General BOM	
2	1	U1	IC, LTC2364CMS-18, MS16	Linear Technology, LTC2364CMS-18
3	1	R32	Resistor, Chip, 10, 1/10W, 5% 0603	
4	1	R44	Resistor, Chip, 300, 1/16W, 1% 0402	Panasonic ERJ-2RKF3000X
5	1		FAB, Printed Circuit Board	DC1813A

# DEMO MANUAL DC1813A

## SCHEMATIC DIAGRAM





# DEMO MANUAL DC1813A

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If this evaluation kit does not meet the specifications recited in the DEMO BOARD manual the kit may be returned within 30 days from the date of delivery for a full refund. **THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY THE SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THIS INDEMNITY, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.**

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user releases LTC from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge. Also be aware that the products herein may not be regulatory compliant or agency certified (FCC, UL, CE, etc.).

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**Please read the DEMO BOARD manual prior to handling the product.** Persons handling this product must have electronics training and observe good laboratory practice standards. **Common sense is encouraged.**

This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact a LTC application engineer.

Mailing Address:

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