

# ADC08351

*ADC08351 8-Bit, 42 MSPS, 40 mW A/D Converter*



Literature Number: SNAS026D

# ADC08351

## 8-Bit, 42 MSPS, 40 mW A/D Converter

### General Description

The ADC08351 is an easy to use low power, low cost, small size, 42 MSPS analog-to-digital converter that digitizes signals to 8 bits. The ADC08351 uses an unique architecture that achieves 7.2 Effective Bits with a 4.4 MHz input and 42 MHz clock frequency and 6.8 Effective Bits with a 21 MHz input and 42 MHz clock frequency. Output formatting is straight binary coding.

To minimize system cost and power consumption, the ADC08351 requires minimal external components and includes input biasing to allow optional a.c. input signal coupling. The user need only provide a +3V supply and a clock. Many applications require no separate reference or driver components.

The excellent dc and ac characteristics of this device, together with its low power consumption and +3V single supply operation, make it ideally suited for many video and imaging applications, including use in portable equipment. Total power consumption is reduced to less than 7 mW in the power-down mode. Furthermore, the ADC08351 is resistant to latch-up and the outputs are short-circuit proof.

Fabricated on a 0.35 micron CMOS process, the ADC08351 is offered in TSSOP and LLP (a molded lead frame-based chip-scale package), and is designed to operate over the industrial temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

### Features

- Low Input Capacitance
- Internal Sample-and-Hold Function

- Single +3V Operation
- Power Down Feature
- TRI-STATE Outputs

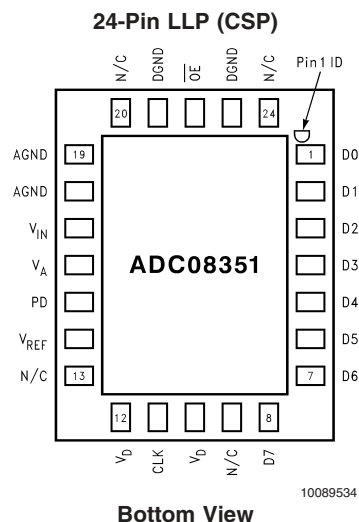
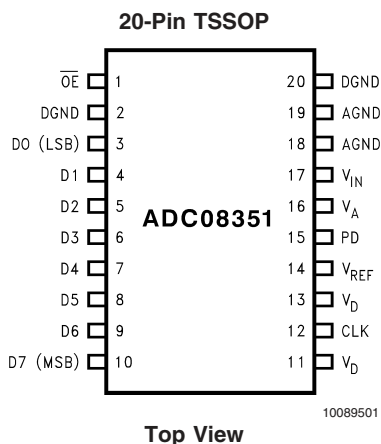
### Key Specifications

- |  |   |
|--|---|
| ■ Resolution   | 8 Bits  |
| ■ Maximum Sampling Frequency   | 42 MSPS (min)   |
| ■ ENOB @ $f_{\text{CLK}} = 42 \text{ MHz}$ , $f_{\text{IN}} = 4.4 \text{ MHz}$ | 7.2 Bits (typ)  |
| ■ Guaranteed No Missing Codes  |   |
| ■ Power Consumption  | 40 mW (typ); 48 mW (max)<br>(Excluding Reference Current) |

### Applications

- Video Digitization
- Digital Still Cameras
- Set Top Boxes
- Digital Camcorders
- Communications
- Medical Imaging
- Personal Computer Video
- CCD Imaging
- Electro-Optics

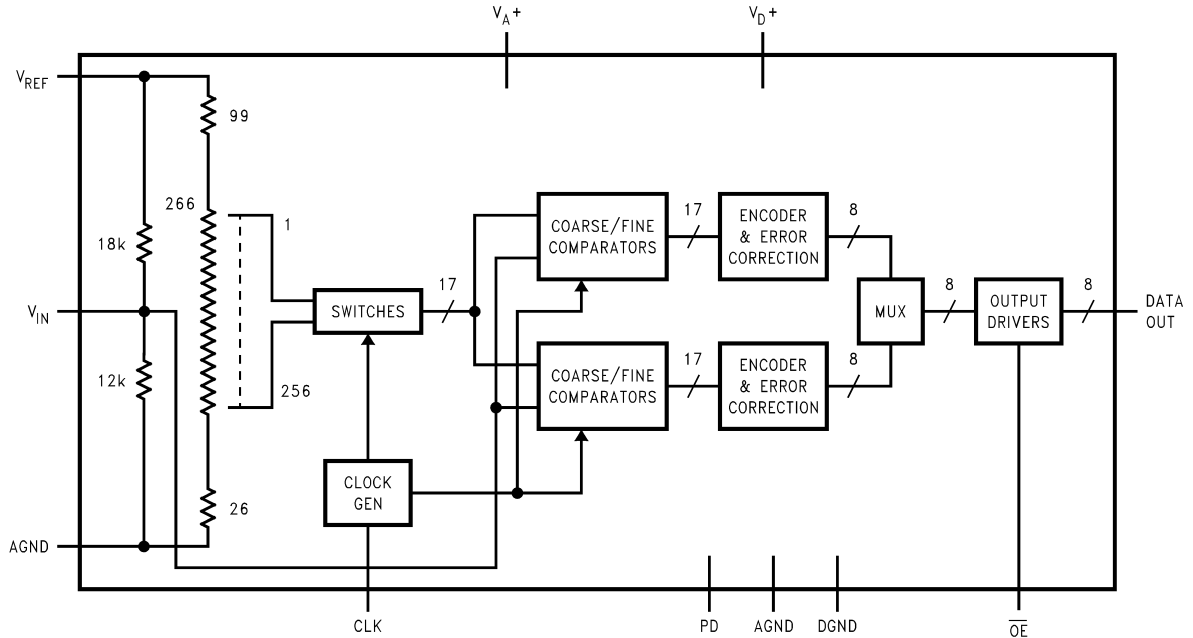
### Pin Configuration



## Ordering Information

ADC08351CIMTC	TSSOP
ADC08351CIMTCX	TSSOP (tape & reel)
ADC08351CILQ	LLP (tape & reel - 1, 000 units)
ADC08351CILQX	LLP (tape & reel - 4, 500 units)

## ADC08351 Block Diagram



10089502

## Pin Descriptions and Equivalent Circuits (LLP pins in parentheses)

Pin No.	Symbol	Equivalent Circuit	Description
17 (17)	$V_{IN}$		Analog signal input. Conversion range is $0.5 V_{P-P}$ to $0.68 V_A$ .
14 (14)	$V_{REF}$		Positive reference voltage input. Operating range of this voltage is $0.75V$ to $V_A$ . This pin should be bypassed with a $10 \mu F$ tantalum or aluminum electrolytic capacitor and a $0.1 \mu F$ ceramic chip capacitor.
1 (22)	$\overline{OE}$		CMOS/TTL compatible digital input that, when low, enables the digital outputs of the ADC08351. When high, the outputs are in a high impedance state.
12 (11)	CLK		CMOS/TTL compatible digital clock input. $V_{IN}$ is sampled on the falling edge of CLK input.
15 (15)	PD		CMOS/TTL compatible digital input that, when high, puts the ADC08351 into the power down mode, where it consumes minimal power. When this pin is low, the ADC08351 is in the normal operating mode.

## Pin Descriptions and Equivalent Circuits (LLP pins in parentheses) (Continued)

Pin No.	Symbol	Equivalent Circuit	Description
3 thru 10 (1 thru 8)	D0–D7		Conversion data digital output pins. D0 is the LSB, D7 is the MSB. Valid data is output just after the rising edge of the CLK input. These pins are enabled by bringing the $\overline{OE}$ pin low.
11, 13 (10, 12)	$V_D$		Positive digital supply pin. Connect to a clean, quiet voltage source of +3V. $V_A$ and $V_D$ should have a common supply and be separately bypassed with a 10 $\mu$ F tantalum or aluminum electrolytic capacitor and a 0.1 $\mu$ F ceramic chip capacitor. See Section 3.0 for more information.
2, 20 (21, 23)	DGND		The ground return for the digital supply. AGND and DGND should be connected together close to the ADC08351.
16 (16)	$V_A$		Positive analog supply pin. Connected to a clean, quiet voltage source of +3V. $V_A$ and $V_D$ should have a common supply and be separately bypassed with a 10 $\mu$ F tantalum or aluminum electrolytic capacitor and a 0.1 $\mu$ F ceramic chip capacitor. See Section 3.0 for more information.
18, 19 (18, 19)	AGND		The ground return for the analog supply. AGND and DGND should be connected together close to the ADC08351 package.

**Absolute Maximum Ratings** (Notes 1,

2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage ( $V_A$ , $V_D$ )	4.2V
Voltage on Any Input or Output Pin	-0.3V to 4.2V
Ground Difference (AGND-DGND)	$\pm 100$ mV
CLK, $\overline{OE}$ Voltage Range	-0.5 to ( $V_A + 0.5$ V)
Digital Output Voltage ( $V_{OH}$ , $V_{OL}$ )	$V_D$ to DGND
Input Current at Any Pin (Note 3)	$\pm 25$ mA
Package Input Current (Note 3)	$\pm 50$ mA

Package Dissipation at $T_A = 25^\circ\text{C}$	(Note 4)
ESD Susceptibility (Note 5)	
Human Body Model	4000V
Machine Model	200V
Soldering Temp., Infrared, 10 sec. (Note 6)	235°C
Storage Temperature	-65°C to +150°C

**Operating Ratings** (Notes 1, 2)

Operating Temperature Range	-40°C $T_A \leq +85^\circ\text{C}$
Supply Voltage ( $V_A$ , $V_D$ )	+2.7V to +3.6V
Ground Difference	
IDGND-AGNDI	0V to 100 mV
$V_{IN}$ Voltage Range ( $V_{P-P}$ )	0.5V to 0.68 $V_A$

**Converter Electrical Characteristics**

The following specifications apply for  $V_A = V_D = +3.0$  V<sub>DC</sub>,  $V_{REF} = 2.4$ V,  $V_{IN} = 1.63$  V<sub>P-P</sub>,  $\overline{OE} = 0$ V,  $C_L = 20$  pF,  $f_{CLK} = 42$  MHz, 50% duty cycle, unless otherwise specified. **Boldface limits apply for  $T_A = T_{MIN}$  to  $T_{MAX}$ :** all other limits  $T_A = 25^\circ\text{C}$  (Notes 7, 8)

Symbol	Parameter	Conditions	Typical (Note 9)	Limits (Note 9)	Units (Limits)
<b>DC Accuracy</b>					
INL	Integral Non Linearity Error		$\pm 0.7$	<b><math>\pm 1.4</math></b>	LSB (max)
DNL	Differential Non Linearity		$\pm 0.6$	<b>+1.3</b> <b>-1.0</b>	LSB (max) LSB (min)
	Missing Codes			<b>0</b>	(max)
$E_Z$	Zero Scale Offset Error		-17		mV
$E_{FS}$	Full Scale Offset Error		-7		mV
<b>Video Accuracy</b>					
DP	Differential Phase Error	$f_{CLK} = 20$ MHz, Video Ramp Input	1.0		Degree
DG	Differential Gain Error	$f_{CLK} = 20$ MHz, Video Ramp Input	1.5		%
<b>Analog Input and Reference Characteristics</b>					
$C_{IN}$	$V_{IN}$ Input Capacitance	$V_{IN} = 1.5V + 0.7$ Vrms	(CLK LOW)	4	pF
			(CLK HIGH)	11	pF
$R_{IN}$	$R_{IN}$ Input Resistance		7.2		k $\Omega$
FPBW	Full-Power Bandwidth		120		MHz
$V_{REF}$	Reference Input Voltage	At pin 14	0.735		V
			$V_A$		V
$I_{REF}$	Reference Input Current		7.7		mA
<b>Power Supply Characteristics</b>					
$I_A$	Analog Supply Current	PD = Low	10.5		mA
		PD = High	1		mA
$I_D$	Digital Supply Current	PD = Low, No Digital Output Load	2.9		mA
		PD = High	0.5		mA
	Total Operating Current	Excluding Reference Current, $V_{IN} = 0$ V <sub>DC</sub>	13.4	<b>16</b>	mA (max)
	Power Consumption (active)	PD = Low (excluding reference current)	40.2	<b>48</b>	mW (max)
	Power Consumption (power down)	PD = High (excluding reference current)	<7		mW
<b>CLK, <math>\overline{OE}</math> Digital Input Characteristics</b>					
$V_{IH}$	Logical High Input Voltage	$V_D = V_A = 3V$		<b>2.0</b>	V (min)
$V_{IL}$	Logical Low Input Voltage	$V_D = V_A = 3V$		<b>1.0</b>	V (max)
$I_{IH}$	Logical High Input Current	$V_{IH} = V_D = V_A = 3.3V$	10		$\mu$ A
$I_{IL}$	Logic Low Input Current	$V_{IL} = 0V$ , $V_D = V_A = 3.3V$	-10		$\mu$ A

## Converter Electrical Characteristics (Continued)

The following specifications apply for  $V_A = V_D = +3.0 V_{DC}$ ,  $V_{REF} = 2.4V$ ,  $V_{IN} = 1.63 V_{P-P}$ ,  $\overline{OE} = 0V$ ,  $C_L = 20 pF$ ,  $f_{CLK} = 42 MHz$ , 50% duty cycle, unless otherwise specified. **Boldface limits apply for  $T_A = T_{MIN}$  to  $T_{MAX}$** : all other limits  $T_A = 25^\circ C$  (Notes 7, 8)

Symbol	Parameter	Conditions	Typical (Note 9)	Limits (Note 9)	Units (Limits)
$C_{IN}$	Logic Input Capacitance		10		pF
<b>Digital Output Characteristics</b>					
$I_{OH}$	High Level Output Current	$V_D = 2.7V$ , $V_{OH} = V_D - 0.5V$		<b>-1.1</b>	mA (min)
$I_{OL}$	Low Level Output Current	$V_D = 2.7V$ , $\overline{OE} = DGND$ , $V_{OL} = 0.4V$		<b>1.8</b>	mA (min)
$V_{OH}$	High Level Output Voltage	$V_D = 2.7V$ , $I_{OH} = -360 \mu A$	2.65		V
$V_{OL}$	Low Level Output Voltage	$V_D = 2.7V$ , $I_{OL} = 1.6 mA$	0.2		V
$I_{OZH}$ , $I_{OZL}$	TRI-STATE® Output Current	$\overline{OE} = V_D = 3.3V$ , $V_{OH} = 3.3V$ or $V_{OL} = 0V$	$\pm 10$		$\mu A$
<b>AC Electrical Characteristics</b>					
$f_{C1}$	Maximum Conversion Rate			<b>42</b>	MHz (min)
$f_{C2}$	Minimum Conversion Rate		2		MHz
$t_{OD}$	Output Delay	CLK High to Data Valid	14	<b>19</b>	ns (max)
	Pipeline Delay (Latency)		2.5		Clock Cycles
$t_{DS}$	Sampling (Aperture) Delay	CLK Low to Acquisition of Data	2		ns
$t_{OH}$	Output Hold Time	CLK High to Data Invalid	9		ns
$t_{EN}$	$\overline{OE}$ Low to Data Valid	Loaded as in <i>Figure 2</i>	14		ns
$t_{DIS}$	$\overline{OE}$ High to High Z State	Loaded as in <i>Figure 2</i>	10		ns
ENOB	Effective Number of Bits	$f_{CLK} = 30 MHz$ , $f_{IN} = 1 MHz$	7.2		Bits
		$f_{CLK} = 42 MHz$ , $f_{IN} = 4.4 MHz$	7.2		Bits
		$f_{CLK} = 42 MHz$ , $f_{IN} = 21 MHz$	6.8	<b>6.1</b>	Bits (min)
SINAD	Signal-to-Noise & Distortion	$f_{CLK} = 30 MHz$ , $f_{IN} = 1 MHz$	45		dB
		$f_{CLK} = 42 MHz$ , $f_{IN} = 4.4 MHz$	45		dB
		$f_{CLK} = 42 MHz$ , $f_{IN} = 21 MHz$	43	<b>38.5</b>	dB (min)
SNR	Signal-to-Noise Ratio	$f_{CLK} = 30 MHz$ , $f_{IN} = 1 MHz$	44		dB
		$f_{CLK} = 42 MHz$ , $f_{IN} = 4.4 MHz$	45		dB
		$f_{CLK} = 42 MHz$ , $f_{IN} = 21 MHz$	44	<b>41</b>	dB (min)
THD	Total Harmonic Distortion	$f_{CLK} = 30 MHz$ , $f_{IN} = 1 MHz$	-57		dB
		$f_{CLK} = 42 MHz$ , $f_{IN} = 4.4 MHz$	-51		dB
		$f_{CLK} = 42 MHz$ , $f_{IN} = 21 MHz$	-46	<b>-41</b>	dB (min)
SFDR	Spurious Free Dynamic Range	$f_{CLK} = 30 MHz$ , $f_{IN} = 1 MHz$	57		dB
		$f_{CLK} = 42 MHz$ , $f_{IN} = 4.4 MHz$	54		dB
		$f_{CLK} = 42 MHz$ , $f_{IN} = 21 MHz$	49	<b>41</b>	dB (min)

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

**Note 2:** All voltages are measured with respect to GND = AGND = DGND = 0V, unless otherwise specified.

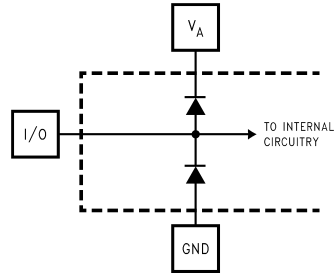
**Note 3:** When the input voltage at any pin exceeds the power supplies (that is, less than AGND or DGND, or greater than  $V_A$  or  $V_D$ ), the current at that pin should be limited to 25 mA. The 50 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 25 mA to two.

**Note 4:** The absolute maximum junction temperature ( $T_{Jmax}$ ) for this device is  $150^\circ C$ . The maximum allowable power dissipation is dictated by  $T_{Jmax}$ , the junction-to-ambient thermal resistance ( $\theta_{JA}$ ), and the ambient temperature ( $T_A$ ), and can be calculated using the formula  $P_{DMAX} = (T_{Jmax} - T_A)/\theta_{JA}$ . For the 20-pin TSSOP,  $\theta_{JA}$  is  $135^\circ C/W$ , so  $P_{DMAX} = 926 mW$  at  $25^\circ C$  and  $481 mW$  at the maximum operating ambient temperature of  $85^\circ C$ . Note that the power dissipation of this device under normal operation will typically be about 68 mW (40 mW quiescent power + 23 mW reference ladder power + 5 mW due to 1 TTL load on each digital output). The values for maximum power dissipation listed above will be reached only when the ADC08351 is operated in a severe fault condition (e.g., when input or output pins are driven beyond the power supply voltages, or the power supply polarity is reversed). Obviously, such conditions should always be avoided.

**Note 5:** Human body model is 100 pF capacitor discharged through a 1.5 k $\Omega$  resistor. Machine model is 220 pF discharged through ZERO Ohms.

**Note 6:** See AN-450, "Surface Mounting Methods and Their Effect on Product Reliability", or the section entitled "Surface Mount" found in any post 1986 National Semiconductor Linear Data Book, for other methods of soldering surface mount devices.

**Note 7:** All inputs are protected as shown below. Input voltage magnitudes up to 500 mV above the supply voltage or 500 mV below GND will not damage this device. However, errors in the A/D conversion can occur if the input goes above  $V_A$  or below AGND by more than 300 mV. As an example, if  $V_A$  is  $3.0 V_{DC}$ , the full-scale input voltage must be  $\leq 3.3 V_{DC}$  to ensure accurate conversions.



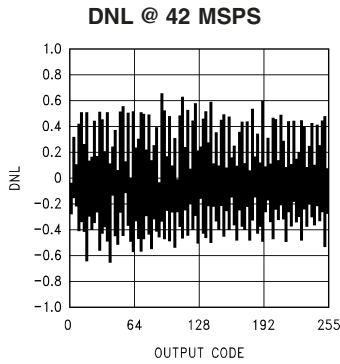
10089506

**Note 8:** To guarantee accuracy, it is required that  $V_A$  and  $V_D$  be well bypassed. Each  $V_A$  and  $V_D$  pin must be decoupled with separate bypass capacitors.

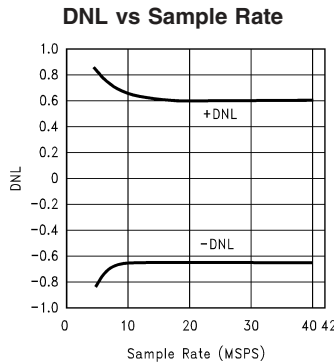
**Note 9:** Typical figures are at  $T_J = 25^\circ C$ , and represent most likely parametric norms. Test limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

## Typical Performance Characteristics

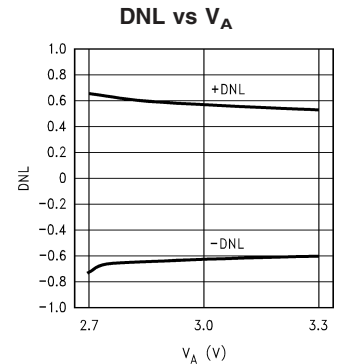
$V_A = V_D = V_{D\ I/O} = 3V$ ,  $f_{CLK} = 42\text{ MHz}$ , unless otherwise specified



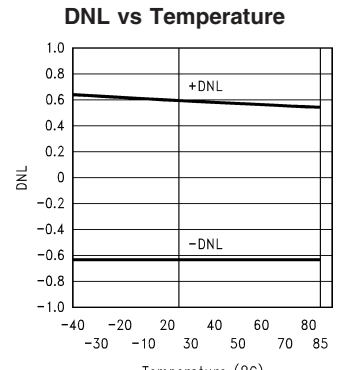
10089507



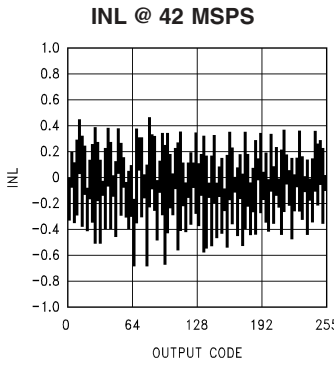
10089508



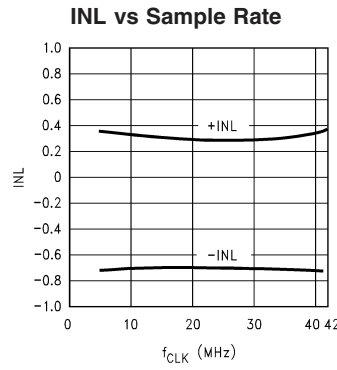
10089509



10089510

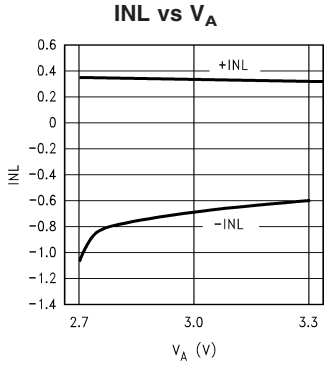


10089511

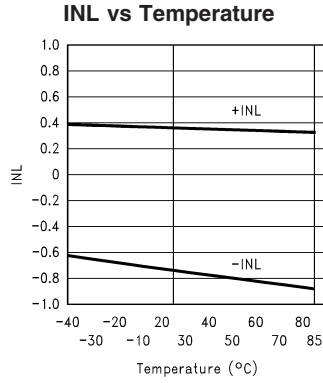


10089512

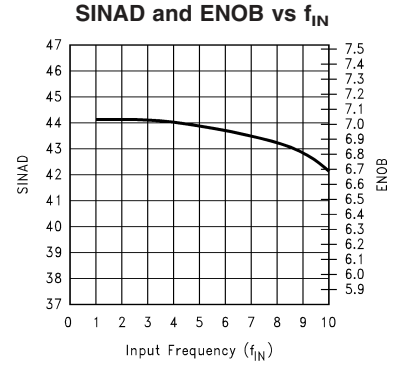
**Typical Performance Characteristics**  $V_A = V_D = V_{D\ I/O} = 3V$ ,  $f_{CLK} = 42\text{ MHz}$ , unless otherwise specified (Continued)



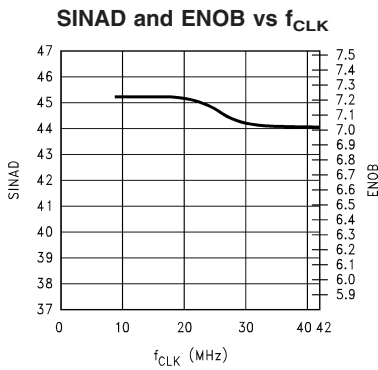
10089513



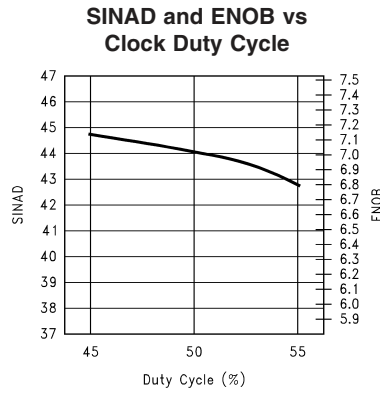
10089514



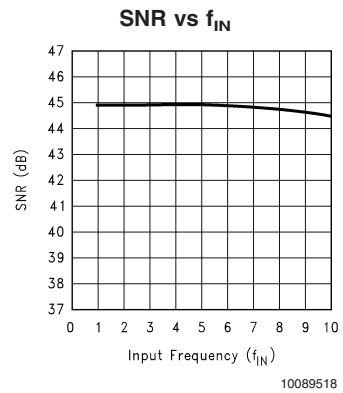
10089515



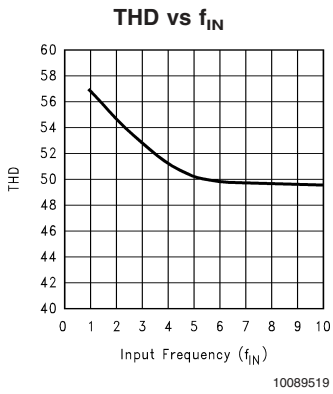
10089516



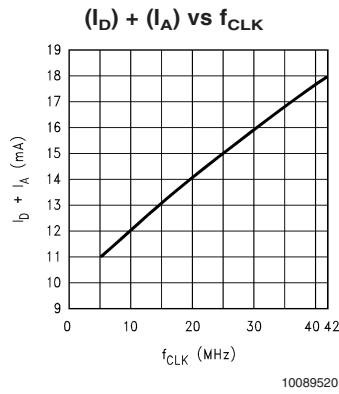
10089517



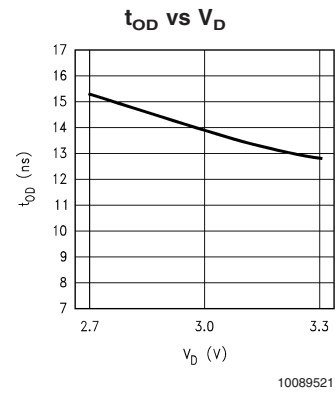
10089518



10089519

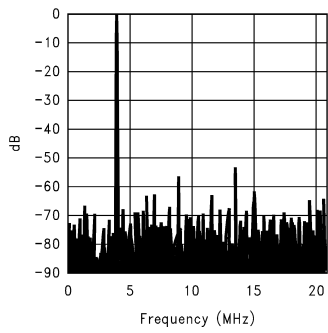


10089520



10089521

**Spectral Response @ 42 MSPS**



10089522



## Specification Definitions

**ANALOG INPUT BANDWIDTH** is a measure of the frequency at which the reconstructed output fundamental drops 3 dB below its low frequency value for a full scale input. The test is performed with  $f_{IN}$  equal to 100 kHz plus integer multiples of  $f_{CLK}$ . The input frequency at which the output is -3 dB relative to the low frequency input signal is the full power bandwidth.

**DIFFERENTIAL GAIN ERROR** is the percentage difference between the output amplitudes of a high frequency reconstructed sine wave at two different dc input levels.

**DIFFERENTIAL NON-LINEARITY (DNL)** is the measure of the maximum deviation from the ideal step size of 1 LSB.

**DIFFERENTIAL PHASE ERROR** is the difference in the output phase of a reconstructed small signal sine wave at two different dc input levels.

**EFFECTIVE NUMBER OF BITS (ENOB, or EFFECTIVE BITS)** is another method of specifying Signal-to-Noise and Distortion Ratio, or SINAD. ENOB is defined as  $(SINAD - 1.76)/6.02$  and says that the converter is equivalent to a perfect ADC of this (ENOB) number of bits.

**FULL POWER BANDWIDTH** is a measure of the frequency at which the reconstructed output fundamental drops 3 dB below its low frequency value for a full scale input. The test is performed with  $f_{IN}$  equal to 100kHz plus integer multiples of  $f_{CLK}$ . The input frequency at which the output is -3 dB relative to the low frequency input signal is the full power bandwidth.

**FULL SCALE OFFSET ERROR** is the difference between the analog input voltage that just causes the output code to transition to the full scale code (all 1's in the case of the ADC08351) and the ideal value of  $1\frac{1}{2}$  LSB below the value of  $V_{REF}$ .

**INTEGRAL NON-LINEARITY (INL)** is a measure of the deviation of each individual code from a line drawn from zero scale ( $\frac{1}{2}$  LSB below the first code transition) through positive full scale ( $\frac{1}{2}$  LSB above the last code transition). The deviation of any given code from this straight line is measured from the center of that code value. The end point test method is used.

tion of any given code from this straight line is measured from the center of that code value. The end point test method is used.

**OUTPUT DELAY** is the time delay after the rising edge of the input clock before the data update is present at the output pins.

**OUTPUT HOLD TIME** is the length of time that the output data is valid after the rise of the input clock.

**PIPELINE DELAY (LATENCY)** is the number of clock cycles between initiation of conversion and the availability of that conversion result at the output. New data is available at every clock cycle, but the data lags the conversion by the pipeline delay.

**SAMPLING (APERTURE) DELAY** is that time required after the fall of the clock input for the sampling switch to open. The sample is effectively taken this amount of time after the fall of the clock input.

**SIGNAL TO NOISE RATIO (SNR)** is the ratio of the rms value of the input signal to the rms value of the other spectral components below one-half the sampling frequency, not including harmonics or dc.

**SIGNAL TO NOISE PLUS DISTORTION (S/(N+D) or SINAD)** is the ratio of the rms value of the input signal to the rms value of all of the other spectral components below half the clock frequency, including harmonics but excluding dc.

**SPURIOUS FREE DYNAMIC RANGE (SFDR)** is the difference, expressed in dB, between the rms values of the input signal and the peak spurious signal, where a spurious signal is any signal present in the output spectrum that is not present at the input.

**TOTAL HARMONIC DISTORTION (THD)** is the ratio of the rms total of the first six harmonic components to the rms value of the input signal.

**ZERO SCALE OFFSET ERROR** is the difference between the analog input voltage that just causes the output code to transition to the first code and the ideal value of  $\frac{1}{2}$  LSB for that transition.

## Timing Diagram

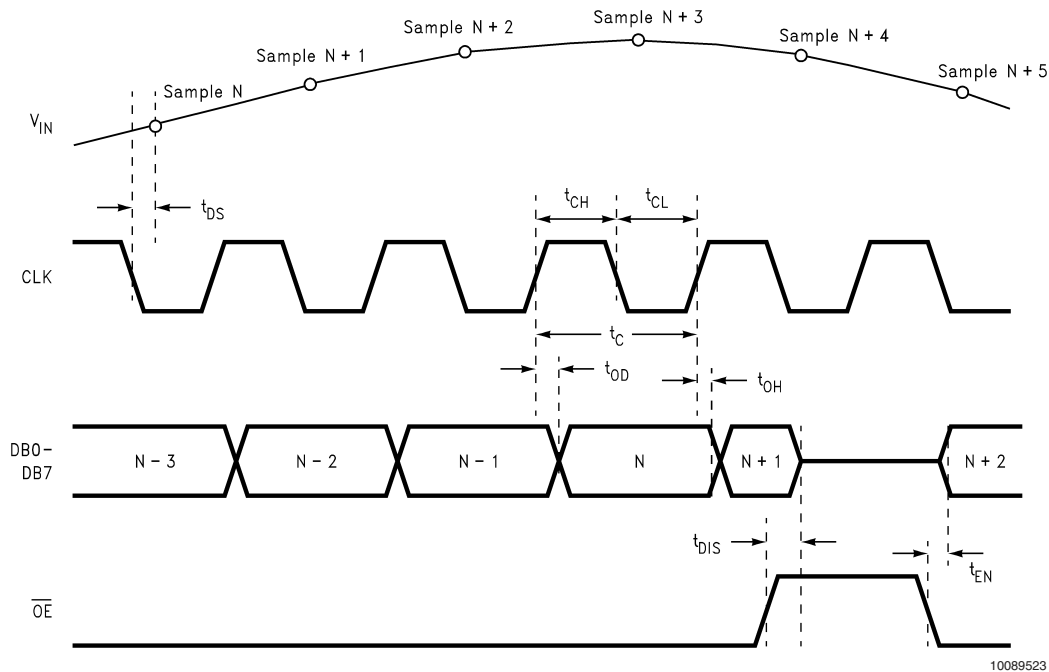
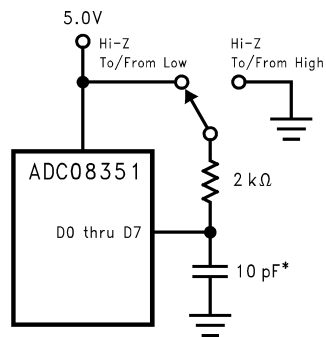


FIGURE 1. ADC08351 Timing Diagram



\* Includes stray and distributed capacitance

10089524

FIGURE 2.  $t_{EN}$ ,  $t_{DIS}$  Test Circuit

## Functional Description

The ADC08351 achieves 6.8 effective bits at 21 MHz input frequency with 42 MHz clock frequency digitizing to eight bits the analog signal at  $V_{IN}$  that is within the nominal voltage range of  $0.5 V_{P-P}$  to  $0.68 V_A$ .

Input voltages below 0.0665 times the reference voltage will cause the output word to consist of all zeroes, while input voltages above  $\frac{3}{4}$  of the reference voltage will cause the output word to consist of all ones. For example, with a  $V_{REF}$  of 2.4V, input voltages below 160 mV will result in an output word of all zeroes, while input voltages above 1.79V will result in an output word of all ones.

The output word rate is the same as the clock frequency. Data is acquired at the falling edge of the clock and the digital equivalent of that data is available at the digital out-

puts 2.5 clock cycles plus  $t_{OD}$  later. The ADC08351 will convert as long as the clock signal is present at the  $CLK$  pin, but the data will not appear at the outputs unless the  $\overline{OE}$  pin is low. The digital outputs are in the high impedance state when the  $\overline{OE}$  pin or when the  $PD$  pin is high.

## Applications Information (All schematic pin numbers refer to the TSSOP.)

### 1.0 THE ADC REFERENCE AND THE ANALOG INPUT

The capacitance seen at the input changes with the clock level, appearing as 4 pF when the clock is low, and 11 pF when the clock is high. Since a dynamic capacitance is more difficult to drive than is a fixed capacitance, choose an amplifier that can drive this type of load. The CLC409,

## Applications Information (All schematic pin numbers refer to the TSSOP.) (Continued)

CLC440, LM6152, LM6154, LM6181 and LM6182 are good devices for driving analog input of the ADC08351. Do not drive the input beyond the supply rails.

The maximum peak-to-peak input level without clipping of the reconstructed output is determined by the values of the resistor string between  $V_{REF}$  and AGND. The bottom of the reference ladder has a voltage of 0.0665 times  $V_{REF}$ , while the top of the reference ladder has a voltage of 0.7468 times  $V_{REF}$ . The maximum peak-to-peak input level works out to be about 68% of the value of  $V_{REF}$ . The relationship between the input peak-to-peak voltage and  $V_{REF}$  is

$$V_{REF} = \frac{391 \times V_{IN (P-P)}}{266}$$

We do not recommend operating with input levels below 1  $V_{P-P}$  because the signal-to-noise ratio will degrade considerably due to the quantization noise. However, the ADC08351 will give adequate results in many applications with signal levels down to about 0.5  $V_{P-P}$  ( $V_{REF} = 0.735V$ ). Very good performance can be obtained with reference voltages up to the supply voltage ( $V_A = V_{REF} = 3V$ , 2.04  $V_{P-P}$ ).

As with all sampling ADCs, the opening and closing of the switches associated with the sampling causes an output of energy from the analog input,  $V_{IN}$ . The reference ladder also has switches associated with it, so the reference source must be able to supply sufficient current to hold  $V_{REF}$  steady.

The analog input of the ADC08351 is self-biased with an 18 k $\Omega$  pull-up resistor to  $V_{REF}$  and a 12 k $\Omega$  pull-down resistor to AGND. This allows for either a.c. or d.c. coupling of the input signal. These two resistors provide a convenient way to ensure a signal that is less than full scale will be centered within the input common mode range of the converter. However, the high values of these resistors and the energy coming from this input means that performance will be improved with d.c. coupling.

The driving circuit at the signal input must be able to sink and source sufficient current at the signal frequency to prevent distortion from being introduced at the input.

### 2.0 POWER SUPPLY CONSIDERATIONS

A tantalum or aluminum electrolytic capacitor of 5  $\mu F$  to 10  $\mu F$  should be placed within a centimeter of each of the A/D power pins, with a 0.1  $\mu F$  ceramic chip capacitor placed within 1/2 centimeter of each of the power pins. Leadless chip capacitors are preferred because they provide lower lead inductance than do their leaded counterparts.

While a single voltage source should be used for the analog and digital supplies of the ADC08351, these supply pins should be decoupled from each other to prevent any digital noise from being coupled to the analog power pins. A ferrite bead between the analog and digital supply pins would help to isolate the two supplies.

The converter digital supply should **not** be the supply that is used for other digital circuitry on the board. It should be the same supply used for the A/D analog supply, decoupled from the A/D analog supply pin, as described above. A common analog supply should be used for both  $V_A$  and  $V_D$ , and each of these pins should be separately bypassed with a 0.1  $\mu F$  ceramic capacitor and with low ESR a 10  $\mu F$  capacitor.

As is the case with all high speed converters, the ADC08351 is sensitive to power supply noise. Accordingly, the noise on the analog supply pin should be minimized, keeping it below 200 mV $_{P-P}$  at 100 kHz. Of course, higher frequency noise on the power supply should be even more severely limited.

No pin should ever have a voltage on it that is in excess of the supply voltages. This can be a problem upon application of power to a circuit. Be sure that the supplies to circuits driving the CLK,  $\overline{OE}$ , analog input and reference pins do not come up any faster than does the voltage at the ADC08351 power pins.

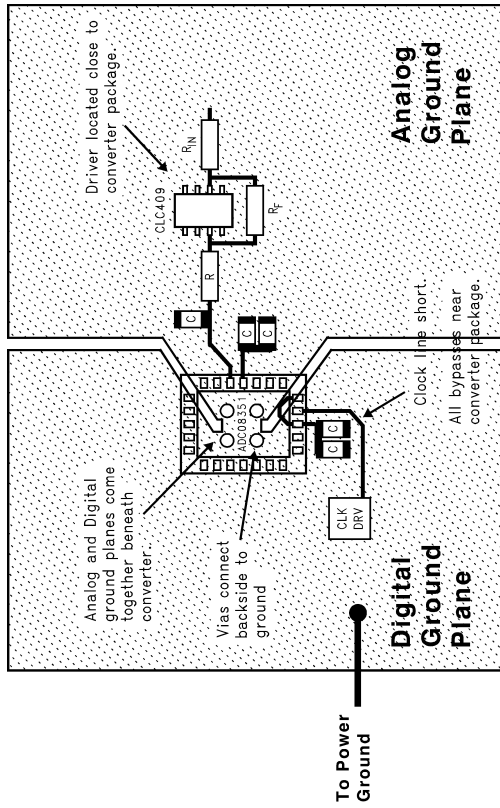
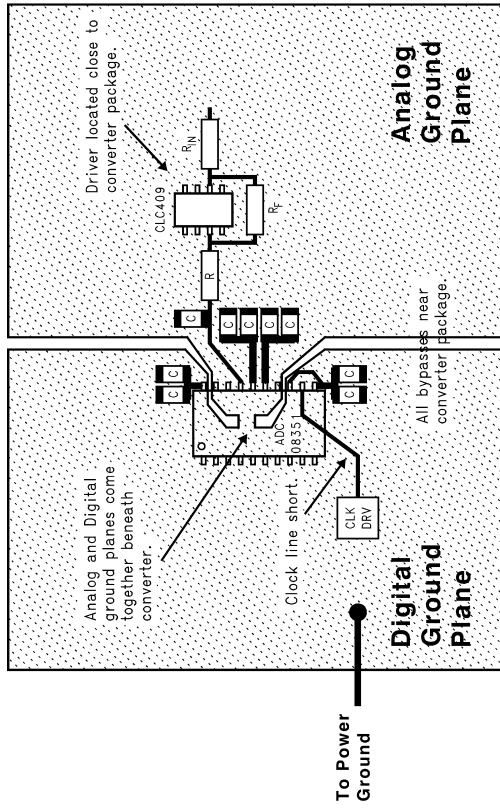
### 3.0 LAYOUT AND GROUNDING

Proper grounding and proper routing of all signals is essential to ensure accurate conversion. Separate analog and digital ground planes that are connected beneath the ADC08351 are required to meet data sheet limits. The analog and digital grounds may be in the same layer, but should be separated from each other and should **never** overlap each other.

Capacitive coupling between the typically noisy digital ground plane and the sensitive analog circuitry can lead to poor performance that may seem impossible to isolate and remedy. The solution is to keep the analog circuitry well separated from the digital circuitry and from the digital ground plane.

The back of the LLP package has a large metal area inside the area bounded by the pins. This metal area is connected to the die substrate (ground). This pad may be left floating if desired. If it is connected to anything, it should be to ground near the connection between analog and digital ground planes. Soldering this metal pad to ground will help keep the die cooler and could yield improved performance because of the lower impedance between die and board grounds. However, a poor layout could compromise performance.

**Applications Information** (All schematic pin numbers refer to the TSSOP.) (Continued)



10089525

FIGURE 3. Layout examples showing separate analog and digital ground planes connected below the ADC08351.

## Applications Information (All schematic pin numbers refer to the TSSOP.) (Continued)

Generally, analog and digital lines should cross each other at 90 degrees to avoid getting digital noise into the analog path. To maximize accuracy in video (high frequency) systems, however, avoid crossing analog and digital lines altogether. Furthermore, it is important to keep any clock lines isolated from ALL other lines, including other digital lines. Even the generally accepted 90 degree crossing should be avoided as even a little coupling can cause problems at high frequencies.

Best performance at high frequencies and at high resolution is obtained with a straight signal path. That is, the signal path through all components should form a straight line wherever possible.

Be especially careful with the layout of inductors. Mutual inductance can change the characteristics of the circuit in which they are used. Inductors should not be placed side by side, even with just a small part of their bodies beside each other.

The analog input should be isolated from noisy signal traces to avoid coupling of spurious signals into the input. Any external component (e.g., a filter capacitor) connected between the converter's input and ground should be connected to a very clean point in the analog ground plane.

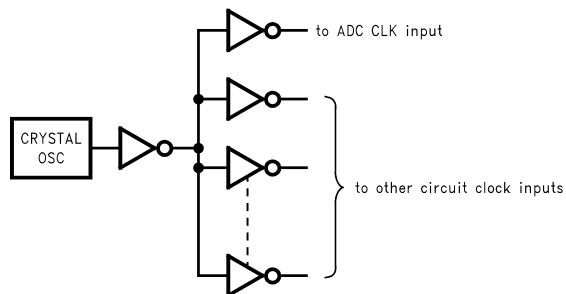
Figure 3 gives an example of a suitable layout. All analog circuitry (input amplifiers, filters, reference components, etc.) should be placed on or over the analog ground plane. All digital circuitry and I/O lines should be placed over the digital ground plane.

All ground connections should have a low inductance path to ground.

### 4.0 DYNAMIC PERFORMANCE

The ADC08351 is ac tested and its dynamic performance is guaranteed. To meet the published specifications, the clock source driving the CLK input must be free of jitter. For best ac performance, isolating the ADC clock from any digital circuitry should be done with adequate buffers, as with a clock tree. See Figure 4.

It is good practice to keep the ADC clock line as short as possible and to keep it well away from any other signals. Other signals can introduce jitter into the clock signal. Even lines with 90° crossings have capacitive coupling, so try to avoid even these 90° crossings of the clock line.



10089526

**FIGURE 4. Isolating the ADC Clock from Digital Circuitry**

Digital circuits create substantial supply and ground current transients. The logic noise thus generated could have sig-

nificant impact upon system noise performance. The best logic family to use in systems with A/D converters is one which employs non-saturating transistor designs, or has low noise characteristics, such as the 74HC(T) and 74AC(T)Q families. The worst noise generators are logic families that draw the largest supply current transients during clock or signal edges, like the 74F and the 74AC(T) families. In general, slower logic families, such as 74LS and 74HC(T) will produce less high frequency noise than do high speed logic families, such as the 74F and 74AC(T) families.

Since digital switching transients are composed largely of high frequency components, total ground plane copper weight will have little effect upon the logic-generated noise. This is because of the skin effect. Total surface area is more important than is total ground plane volume.

An effective way to control ground noise is by connecting the analog and digital ground planes together beneath the ADC with a copper trace that is narrow compared with the rest of the ground plane. This narrowing beneath the converter provides a fairly high impedance to the high frequency components of the digital switching currents, directing them away from the analog pins. The relatively lower frequency analog ground currents do not create a significant variation across the impedance of this relatively narrow ground connection.

### 5.0 TYPICAL APPLICATION CIRCUITS

Figure 5 shows a simple interface for a low impedance source located close to the converter. As discussed in Section 1.0, the series capacitor is optional. Notice the isolation of the ADC clock signal from the clock signals going elsewhere in the system. The reference input of this circuit is shown connected to the 3V supply.

Video ADCs tend to have input current transients that can upset a driving source, causing distortion of the driving signal. The resistor at the ADC08351 input isolates the amplifier's output from the current transients at the input to the converter.

When the signal source is not located close to the converter, the signal should be buffered. Figure 6 shows an example of an appropriate buffer. The amplifier provides a gain of two to compensate for transmission losses.

Operational amplifiers have better linearity when they operate with gain, so the input is attenuated with the 68Ω and 30Ω resistors at the non-inverting input. The 330Ω resistor in parallel with these two resistors provides for a 75Ω cable termination. Replacing this 330Ω resistor with one of 100Ω will provide a 50Ω termination.

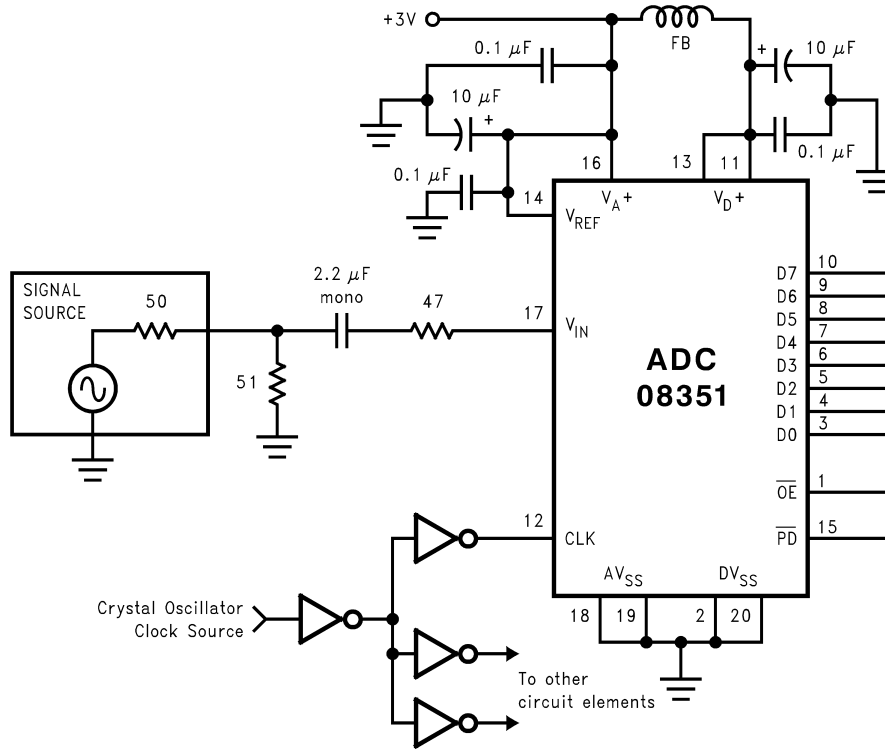
The circuit shown has a nominal gain of two. You can provide a gain adjustment by changing the 110Ω feedback resistor to a 100Ω resistor in series with a 20Ω potentiometer.

The offset adjustment is used to bring the input signal within the common mode range of the converter. If a fixed offset is desired, the potentiometer and the 3.3k resistor may be replaced with a single resistor of 3k to 4k to the appropriate supply. The resistor value and the supply polarity used will depend upon the amount and polarity of offset needed.

The CLC409 shown in Figure 6 was chosen for a low cost solution with good overall performance.

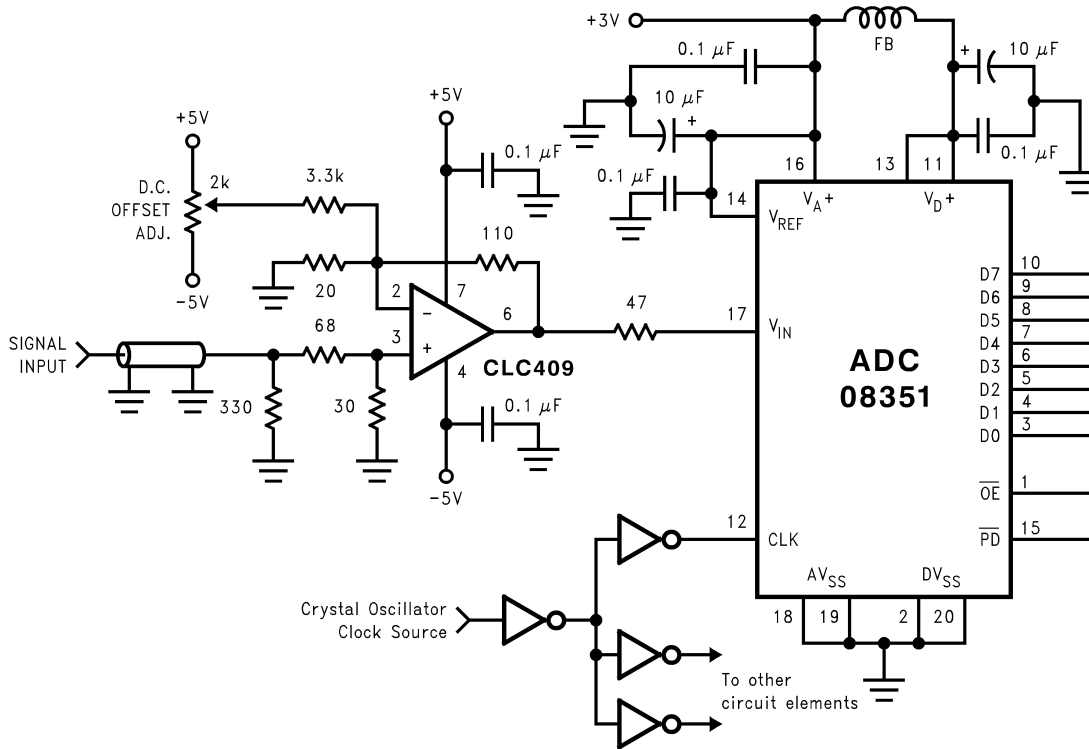
Figure 7 shows an inverting DC coupled circuit. The above comments regarding Figure 6 generally apply to this circuit as well.

**Applications Information** (All schematic pin numbers refer to the TSSOP.) (Continued)



10089527

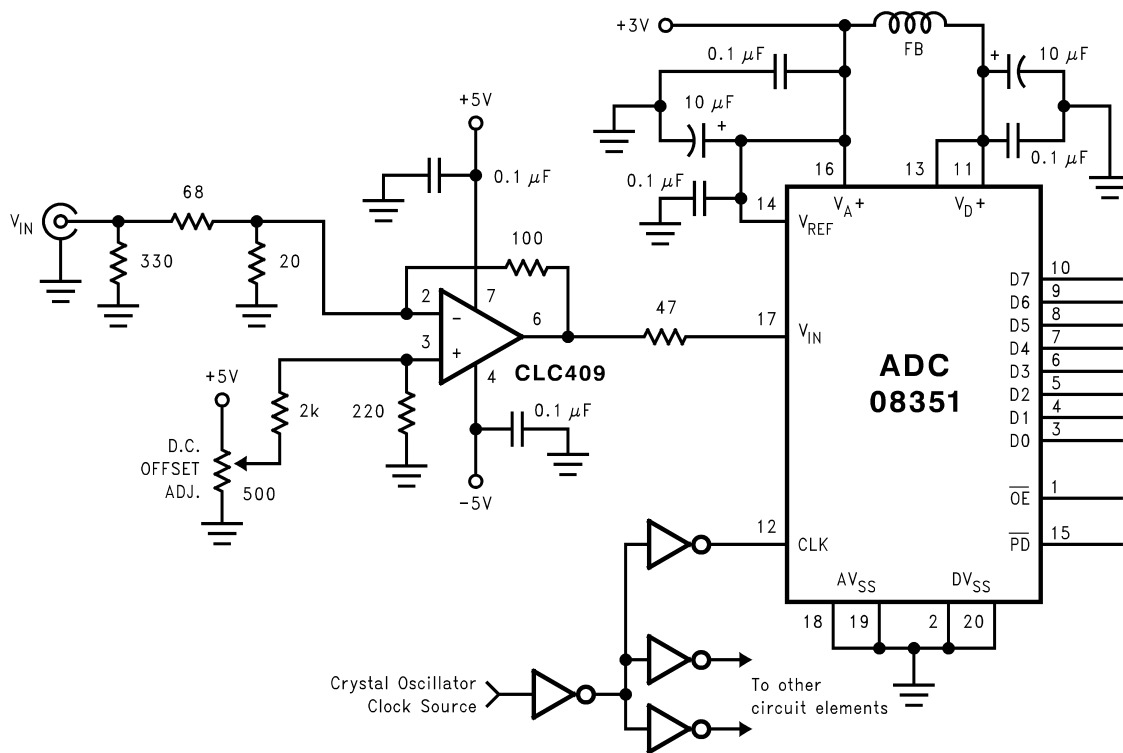
**FIGURE 5. AC Coupled Circuit for a Low Impedance Source Located Near the Converter**



10089528

**FIGURE 6. Non-inverting Input Circuit for Remote Signal Source**

**Applications Information** (All schematic pin numbers refer to the TSSOP.) (Continued)



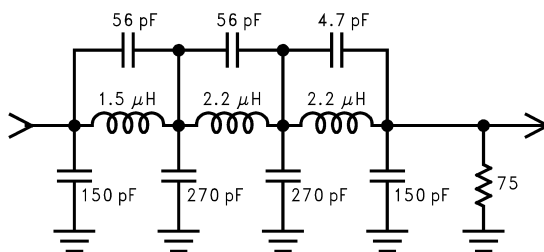
10089529

**FIGURE 7. Inverting Circuit with Bias Adjust**

**ACCURATELY EVALUATING THE ADC**

If a signal that is spectrally impure is presented to the ADC, the output from the ADC cannot be pure. Nearly all signal generators in use today produce signals that are not spectrally pure enough to adequately evaluate present-day ADCs. This is especially true at higher frequencies and at high resolutions.

To ensure that the signal you are presenting to the ADC being evaluated is spectrally pure, use a bandpass filter between the signal generator and the ADC input. One such possible filter is the elliptic filter shown in Figure 8.



10089531

**FIGURE 8. This elliptic filter has a cutoff frequency of about 11MHz and is suitable for input frequencies of 5MHz to 10MHz. It should be driven by a generator of 75Ω source impedance and terminated with 75Ω. This termination may be provided by the ADC evaluation circuit.**

In addition to being used to eliminate undesired frequencies from a desired signal, this filter can be used to filter a square wave, reducing 3rd and higher harmonics to negligible levels.

When evaluating dynamic performance of an ADC, repeatability of measurements could be a problem unless coherent sampling is used. and ADC08351 evaluation system is available that can simplify evaluation of this product.



## Applications Information (All schematic pin numbers refer to the TSSOP.) (Continued)

### 7.0 COMMON APPLICATION PITFALLS

**Driving the inputs (analog or digital) beyond the power supply rails.** For proper operation, all inputs should not go more than 300 mV beyond the supply rails. That is, more than 300 mV below the ground pins or 300 mV above the supply pins. Exceeding these limits on even a transient basis may cause faulty or erratic operation. It is not uncommon for high speed digital circuits (e.g., 74F and 74AC devices) to exhibit undershoot that goes more than a volt below ground or above the power supply. Since these conditions are of very short duration with very fast rise and fall times, they can inject noise into the system and may be difficult to detect with an oscilloscope. A resistor of about 50Ω to 100Ω in series with the offending digital input will usually eliminate the problem.

Care should be taken not to overdrive the inputs of the ADC08351 (or any device) with a device that is powered from supplies outside the range of the ADC08351 supply. Such practice may lead to conversion inaccuracies and even to device damage.

**Attempting to drive a high capacitance digital data bus.** The more capacitance the output drivers have to charge for each conversion, the more instantaneous digital current is required from  $V_D$  and DGND. These large charging current spikes can couple into the analog section, degrading dynamic performance. While adequate bypassing and maintaining separate analog and digital ground planes will reduce this problem on the board, this coupling can still occur on the ADC08351 die. Buffering the digital data outputs (with a 74ACQ541, for example) may be necessary if the data bus to be driven is heavily loaded.

Dynamic performance can also be improved by adding series resistors at each digital output, reducing the energy coupled back into the converter output pins by limiting the output slew rate. A reasonable value for these resistors is about 47Ω.

**Using an inadequate amplifier to drive the analog input.** As explained in Section 2.0, the capacitance seen at the input alternates between 4 pF and 11 pF with the clock. This dynamic capacitance is more difficult to drive than a fixed capacitance, so care should be taken in choosing a driving device. The CLC409, CLC440, LM6152, LM6154, LM6181 and LM6182 are good devices for driving the ADC08351. Also, an amplifier with insufficient gain-bandwidth may limit the overall frequency response of the overall circuit.

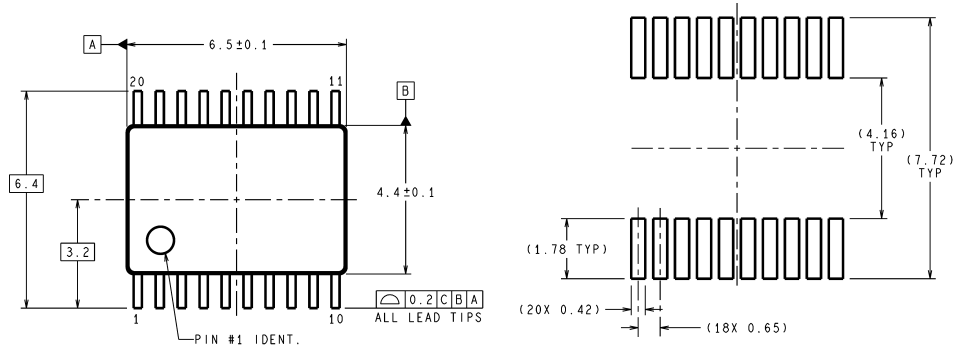
**Using an operational amplifier in an insufficient gain configuration to drive the analog input.** Operational amplifiers, while some may be unity gain stable, generally exhibit more distortion at low in-circuit gains than at higher gains.

**Using a clock source with excessive jitter, using excessively long clock signal trace, or having other signals coupled to the clock signal trace.** This will cause the sampling interval to vary, causing excessive output noise and a reduction in SNR performance. Simple gates with RC timing is generally inadequate.

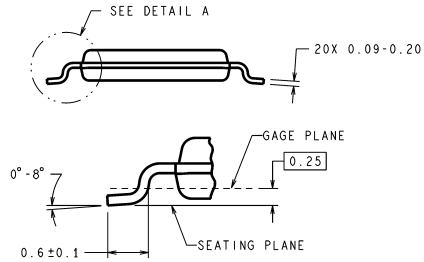
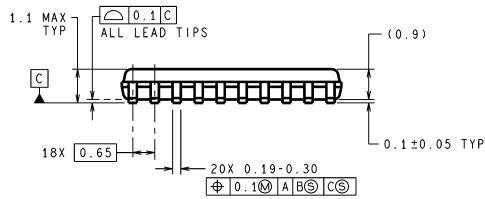
**Not considering the timing relationships, especially  $t_{OD}$ .** Timing is always important and gets more critical with higher speeds. If the output data is latched or looked at when that data is in transition, you may see excessive noise and distortion of the output signal.



**Physical Dimensions** inches (millimeters) unless otherwise noted



**LAND PATTERN RECOMMENDATION**

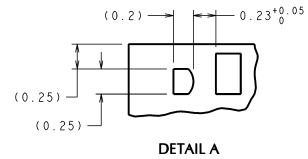
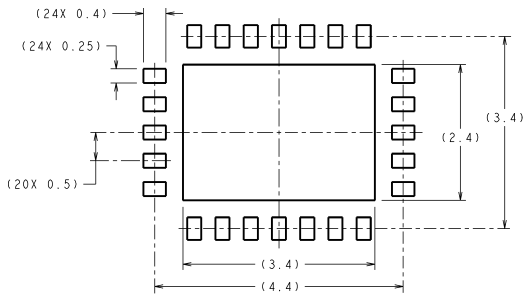


**DIMENSIONS ARE IN MILLIMETERS**

**DETAIL A**  
TYPICAL

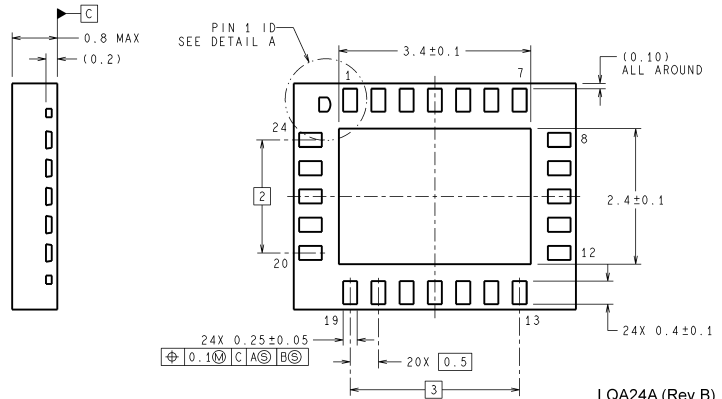
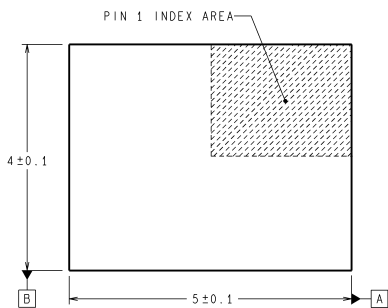
MTC20 (Rev E)

**20-Lead TSSOP**  
Order Number ADC08351CIMTC  
NS Package Number MTC20



**RECOMMENDED LAND PATTERN**  
1:1 RATIO WITH PKG SOLDER PADS

**DIMENSIONS ARE IN MILLIMETERS**  
DIMENSIONS IN ( ) FOR REFERENCE ONLY



**24-Lead Package LLP**  
Order Number ADC08351CILQX  
NS Package Number LQA24A

LQA24A (Rev B)

## Notes

### LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

- |  |   |
|--|---|
| <p>1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.</p> | <p>2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.</p> |
|--|---|

### BANNED SUBSTANCE COMPLIANCE

National Semiconductor certifies that the products and packing materials meet the provisions of the Customer Products Stewardship Specification (CSP-9-111C2) and the Banned Substances and Materials of Interest Specification (CSP-9-111S2) and contain no "Banned Substances" as defined in CSP-9-111S2.



**National Semiconductor**  
**Americas Customer**  
**Support Center**  
 Email: [new.feedback@nsc.com](mailto:new.feedback@nsc.com)  
 Tel: 1-800-272-9959

[www.national.com](http://www.national.com)

**National Semiconductor**  
**Europe Customer Support Center**  
 Fax: +49 (0) 180-530 85 86  
 Email: [europa.support@nsc.com](mailto:europa.support@nsc.com)  
 Deutsch Tel: +49 (0) 69 9508 6208  
 English Tel: +44 (0) 870 24 0 2171  
 Français Tel: +33 (0) 1 41 91 8790

**National Semiconductor**  
**Asia Pacific Customer**  
**Support Center**  
 Email: [ap.support@nsc.com](mailto:ap.support@nsc.com)

**National Semiconductor**  
**Japan Customer Support Center**  
 Fax: 81-3-5639-7507  
 Email: [jpn.feedback@nsc.com](mailto:jpn.feedback@nsc.com)  
 Tel: 81-3-5639-7560

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Mobile Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Transportation and Automotive	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

TI E2E Community Home Page

[e2e.ti.com](http://e2e.ti.com)

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2011, Texas Instruments Incorporated