

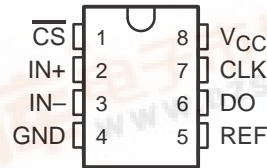
# TLC0831C, TLC0831I TLC0832C, TLC0832I

## 8-BIT ANALOG-TO-DIGITAL CONVERTERS WITH SERIAL CONTROL

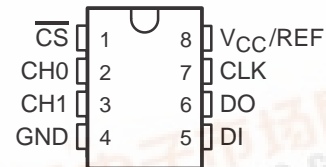
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- **8-Bit Resolution**
- **Easy Microprocessor Interface or Standalone Operation**
- **Operates Ratiometrically or With 5-V Reference**
- **Single Channel or Multiplexed Twin Channels With Single-Ended or Differential Input Options**
- **Input Range 0 to 5 V With Single 5-V Supply**
- **Inputs and Outputs Are Compatible With TTL and MOS**
- **Conversion Time of 32  $\mu$ s at  $f_{\text{clock}} = 250 \text{ kHz}$**
- **Designed to Be Interchangeable With National Semiconductor ADC0831 and ADC0832**
- **Total Unadjusted Error . . .  $\pm 1 \text{ LSB}$**

TLC0831 . . . D OR P PACKAGE  
(TOP VIEW)



TLC0832 . . . D OR P PACKAGE  
(TOP VIEW)



### description

These devices are 8-bit successive-approximation analog-to-digital converters. The TLC0831 has single input channels; the TLC0832 has multiplexed twin input channels. The serial output is configured to interface with standard shift registers or microprocessors.

The TLC0832 multiplexer is software configured for single-ended or differential inputs. The differential analog voltage input allows for common-mode rejection or offset of the analog zero input voltage value. In addition, the voltage reference input can be adjusted to allow encoding any smaller analog voltage span to the full 8 bits of resolution.

The operation of the TLC0831 and TLC0832 devices is very similar to the more complex TLC0834 and TLC0838 devices. Ratiometric conversion can be attained by setting the REF input equal to the maximum analog input signal value, which gives the highest possible conversion resolution. Typically, REF is set equal to  $V_{CC}$  (done internally on the TLC0832).

The TLC0831C and TLC0832C are characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ . The TLC0831I and TLC0832I are characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

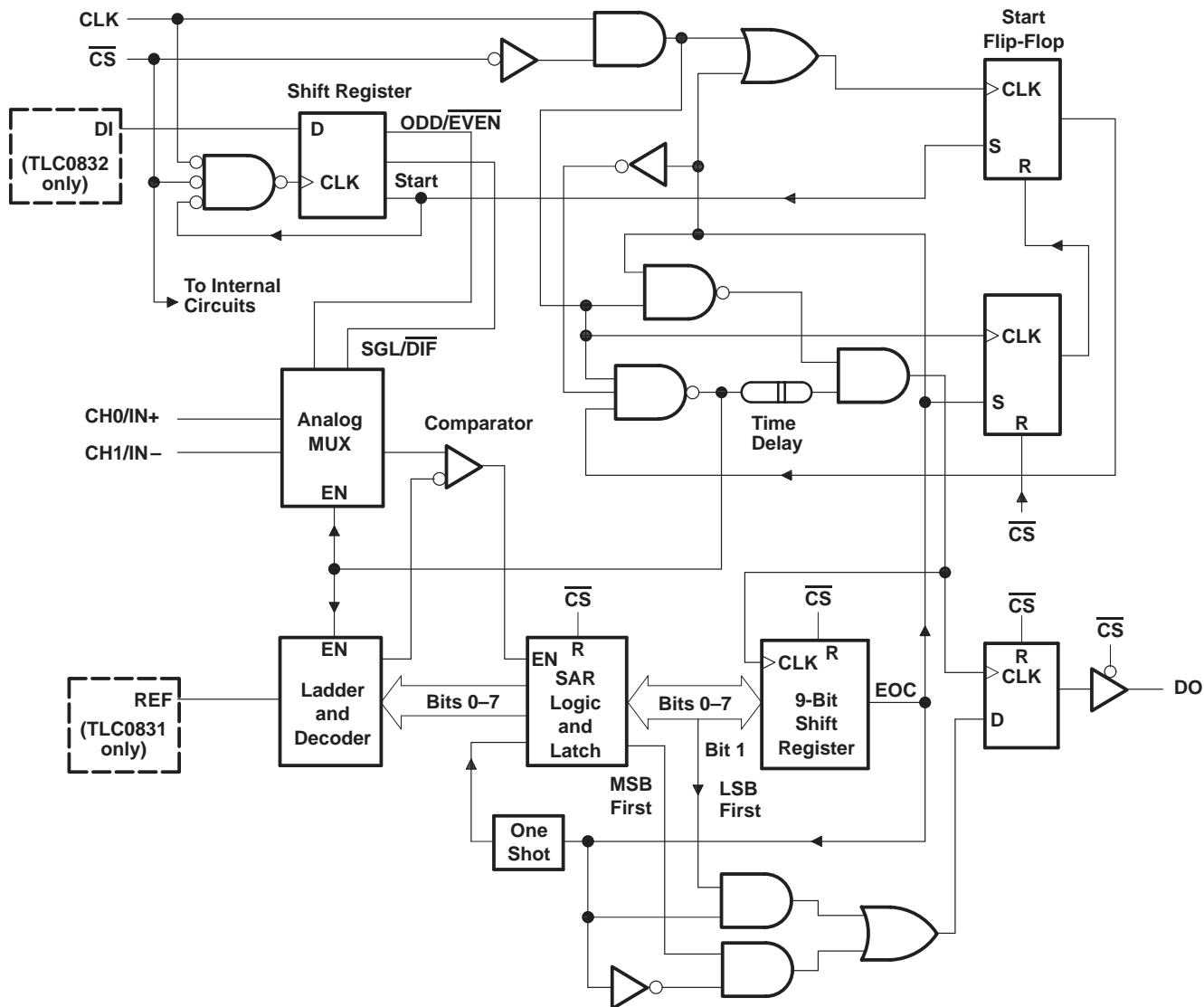
AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGE			
	SMALL OUTLINE (D)		PLASTIC DIP (P)	
$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$	TLC0831CD	TLC0832CD	TLC0831CP	TLC0832CP
$-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$	TLC0831ID	TLC0832ID	TLC0831IP	TLC0832IP

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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**functional block diagram**



TLC0831C, TLC0831I  
TLC0832C, TLC0832I  
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## functional description

The TLC0831 and TLC0832 use a sample-data-comparator structure that converts differential analog inputs by a successive-approximation routine. The input voltage to be converted is applied to an input terminal and is compared to ground (single ended), or to an adjacent input (differential). The TLC0832 input terminals can be assigned a positive (+) or negative (–) polarity. The TLC0831 contains only one differential input channel with fixed polarity assignment; therefore it does not require addressing. The signal can be applied differentially, between IN+ and IN–, to the TLC0831 or can be applied to IN+ with IN– grounded as a single ended input. When the signal input applied to the assigned positive terminal is less than the signal on the negative terminal, the converter output is all zeros.

Channel selection and input configuration are under software control using a serial-data link from the controlling processor. A serial-communication format allows more functions to be included in a converter package with no increase in size. In addition, it eliminates the transmission of low-level analog signals by locating the converter at the analog sensor and communicating serially with the controlling processor. This process returns noise-free digital data to the processor.

A conversion is initiated by setting  $\overline{CS}$  low, which enables all logic circuits.  $\overline{CS}$  must be held low for the complete conversion process. A clock input is then received from the processor. An interval of one clock period is automatically inserted to allow the selected multiplexed channel to settle. DO comes out of the high-impedance state and provides a leading low for one clock period of multiplexer settling time. The SAR comparator compares successive outputs from the resistive ladder with the incoming analog signal. The comparator output indicates whether the analog input is greater than or less than the resistive-ladder output. As the conversion proceeds, conversion data is simultaneously output from DO, with the most significant bit (MSB) first. After eight clock periods, the conversion is complete. When  $\overline{CS}$  goes high, all internal registers are cleared. At this time, the output circuits go to the high-impedance state. If another conversion is desired,  $\overline{CS}$  must make a high-to-low transition followed by address information.

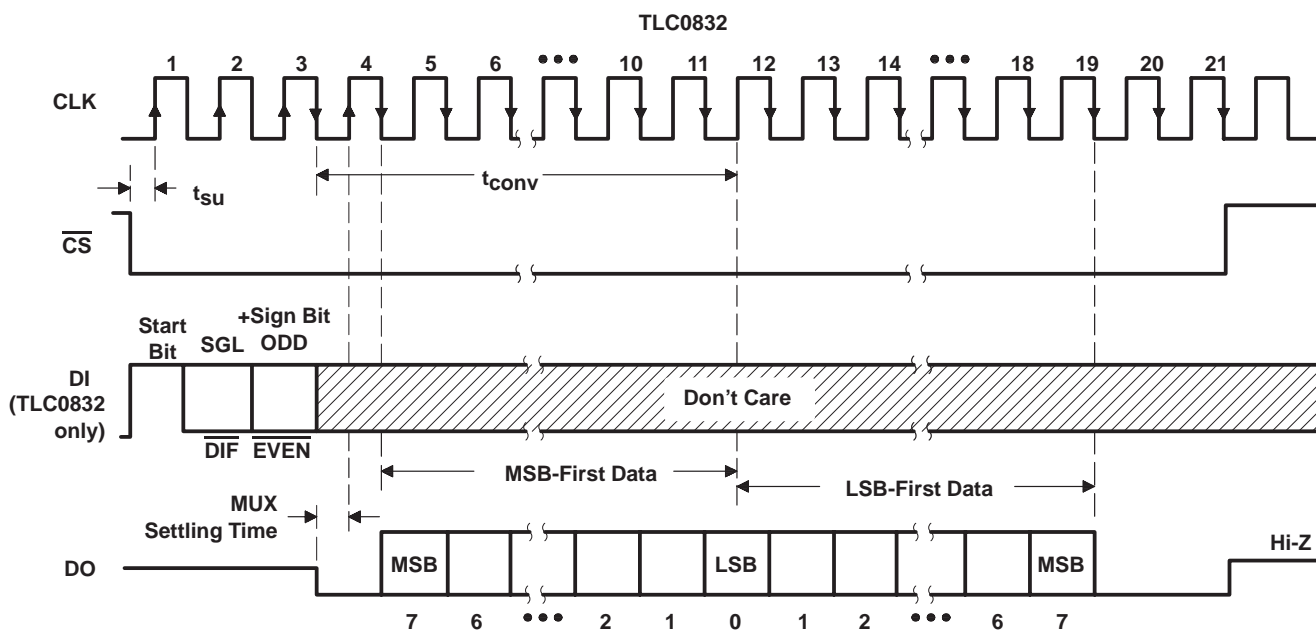
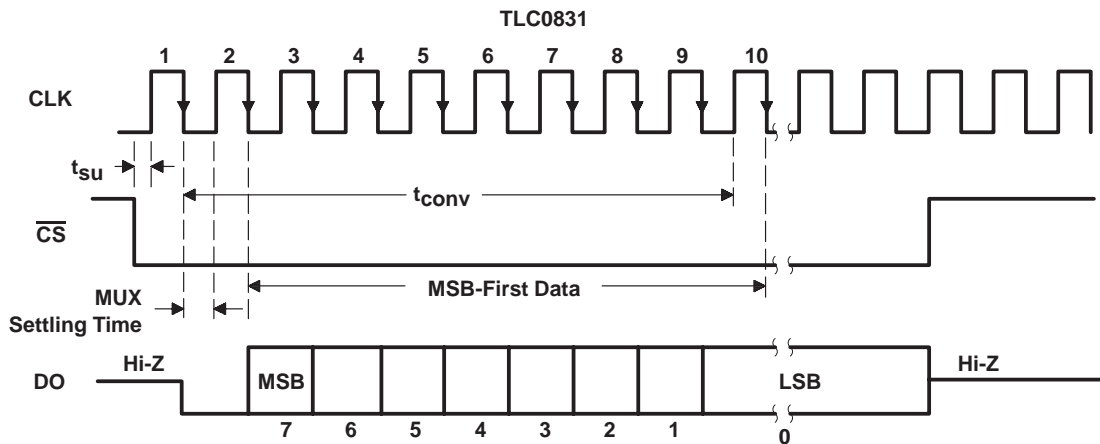
A TLC0832 input configuration is assigned during the multiplexer-addressing sequence. The multiplexer address shifts into the converter through the data input (DI) line. The multiplexer address selects the analog inputs to be enabled and determines whether the input is single ended or differential. When the input is differential, the polarity of the channel input is assigned. In addition to selecting the differential mode, the polarity may also be selected. Either channel of the channel pair may be designated as the negative or positive input.

On each low-to-high transition of the clock input, the data on DI is clocked into the multiplexer-address shift register. The first logic high on the input is the start bit. A 2-bit assignment word follows the start bit on the TLC0832. On each successive low-to-high transition of the clock input, the start bit and assignment word are shifted through the shift register. When the start bit is shifted into the start location of the multiplexer register, the input channel is selected and conversion starts. The TLC0832 DI terminal to the multiplexer shift register is disabled for the duration of the conversion.

The TLC0832 outputs the least-significant-bit (LSB) first data after the MSB-first data stream. The DI and DO terminals can be tied together and controlled by a bidirectional processor I/O bit received on a single wire. This is possible because DI is only examined during the multiplexer-addressing interval and DO is still in the high-impedance state.

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sequence of operation



TLC0832 MUX-ADDRESS CONTROL LOGIC TABLE

MUX ADDRESS		CHANNEL NUMBER	
SGL/ $\overline{DIF}$	ODD/ $\overline{EVEN}$	CH0	CH1
L	L	+	-
L	H	-	+
H	L	+	-
H	H	-	+

H = high level, L = low level,  
 - or + = terminal polarity for the selected input channel

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## 8-BIT ANALOG-TO-DIGITAL CONVERTERS WITH SERIAL CONTROL

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**absolute maximum ratings over recommended operating free-air temperature range (unless otherwise noted)†**

Supply voltage, $V_{CC}$ (see Note 1)	6.5 V
Input voltage range, $V_I$ : Logic	–0.3 V to $V_{CC} + 0.3$ V
Analog	–0.3 V to $V_{CC} + 0.3$ V
Input current, $I_I$	$\pm 5$ mA
Total input current	$\pm 20$ mA
Operating free-air temperature range, $T_A$ : C suffix	0°C to 70°C
I suffix	–40°C to 85°C
Storage temperature range, $T_{stg}$	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: P package	260°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: All voltage values, except differential voltages, are with respect to the network ground terminal.

**recommended operating conditions**

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$	4.5	5	5.5	V
High-level input voltage, $V_{IH}$	2			V
Low-level input voltage, $V_{IL}$			0.8	V
Clock frequency, $f_{clock}$	10		600	kHz
Clock duty cycle (see Note 2)	40%		60%	
Pulse duration, $\overline{CS}$ high, $t_{WH}(CS)$	220			ns
Setup time, $\overline{CS}$ low or TLC0832 data valid before $CLK\uparrow$ , $t_{su}$	350			ns
Hold time, TLC0832 data valid after $CLK\uparrow$ , $t_h$	90			ns
Operating free-air temperature, $T_A$	C suffix		70	°C
	I suffix	–40	85	

NOTE 2: The clock-duty-cycle range ensures proper operation at all clock frequencies. When a clock frequency is used outside the recommended duty-cycle range, the minimum pulse duration (high or low) is 1  $\mu$ s.

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**electrical characteristics over recommended range of operating free-air temperature,  $V_{CC} = 5\text{ V}$ ,  $f_{\text{clock}} = 250\text{ kHz}$  (unless otherwise noted)**

**digital section**

PARAMETER	TEST CONDITIONS†	C SUFFIX			I SUFFIX			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{OH}$ High-level output voltage	$V_{CC} = 4.75\text{ V}$ , $I_{OH} = -360\text{ }\mu\text{A}$	2.8			2.4			V
	$V_{CC} = 4.75\text{ V}$ , $I_{OH} = -10\text{ }\mu\text{A}$	4.6			4.5			
$V_{OL}$ Low-level output voltage	$V_{CC} = 4.75\text{ V}$ , $I_{OL} = 1.6\text{ mA}$	0.34			0.4			V
$I_{IH}$ High-level input current	$V_{IH} = 5\text{ V}$		0.005	1		0.005	1	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_{IL} = 0$		-0.005	-1		-0.005	-1	$\mu\text{A}$
$I_{OH}$ High-level output (source) current	$V_{OH} = V_{O1A}$ , $T_A = 25^\circ\text{C}$	-6.5	-24		-6.5	-24		mA
$I_{OL}$ Low-level output (sink) current	$V_{OL} = V_{CC}$ , $T_A = 25^\circ\text{C}$	8	26		8	26		mA
$I_{OZ}$ High-impedance-state output current (DO)	$V_O = 5\text{ V}$ , $T_A = 25^\circ\text{C}$		0.01	3		0.01	3	$\mu\text{A}$
	$V_O = 0$ , $T_A = 25^\circ\text{C}$		-0.01	-3		-0.01	-3	
$C_i$ Input capacitance			5			5		pF
$C_o$ Output capacitance			5			5		pF

† All parameters are measured under open-loop conditions with zero common-mode input voltage.

‡ All typical values are at  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

**analog and converter section**

PARAMETER	TEST CONDITIONS†	MIN	TYP‡	MAX	UNIT
$V_{IC}$ Common-mode input voltage	See Note 3	-0.05 to $V_{CC}+0.05$			V
$I_{I(\text{stdby})}$ Standby input current (see Note 4)	On channel	$V_I = 5\text{ V}$		1	$\mu\text{A}$
	Off channel	$V_I = 0$		-1	
	On channel	$V_I = 0$		-1	
	Off channel	$V_I = 5\text{ V}$		1	
$r_{i(\text{REF})}$ Input resistance to REF		1.3	2.4	5.9	k $\Omega$

† All parameters are measured under open-loop conditions with zero common-mode input voltage.

‡ All typical values are at  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

NOTES: 3. When channel IN- is more positive than channel IN+, the digital output code is 0000 0000. Connected to each analog input are two on-chip diodes that conduct forward current for analog input voltages one diode drop above  $V_{CC}$ . Care must be taken during testing at low  $V_{CC}$  levels (4.5 V) because high-level analog input voltage (5 V) can, especially at high temperatures, cause the input diode to conduct and cause errors for analog inputs that are near full scale. As long as the analog voltage does not exceed the supply voltage by more than 50 mV, the output code is correct. To achieve an absolute 0- to 5-V input range requires a minimum  $V_{CC}$  of 4.95 V for all variations of temperature and load.

4. Standby input currents go in or out of the on or off channels when the A/D converter is not performing conversion and the clock is in a high or low steady-state conditions.

**total device**

PARAMETER	MIN	TYP‡	MAX	UNIT
$I_{CC}$ Supply current	TLC0831	0.6	1.25	mA
	TLC0832	2.5	4.7	

‡ All typical values are at  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ .

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**operating characteristics**  $V_{CC} = V_{ref} = 5\text{ V}$ ,  $f_{clock} = 250\text{ kHz}$ ,  $t_r = t_f = 20\text{ ns}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
Supply-voltage variation error		$V_{CC} = 4.75\text{ V to } 5.25\text{ V}$		$\pm 1/16$	$\pm 1/4$	LSB
Total unadjusted error (see Note 5)		$V_{ref} = 5\text{ V}$ , $T_A = \text{MIN to MAX}$			$\pm 1$	LSB
Common-mode error		Differential mode		$\pm 1/16$	$\pm 1/4$	LSB
$t_{pd}$	Propagation delay time, output data after $\text{CLK}\uparrow$ (see Note 6)	MSB-first data	$C_L = 100\text{ pF}$	650	1500	ns
		LSB-first data		250	600	
$t_{dis}$	Output disable time, DO after $\overline{\text{CS}}\uparrow$	$C_L = 10\text{ pF}$ , $R_L = 10\text{ k}\Omega$		125	250	ns
		$C_L = 100\text{ pF}$ , $R_L = 2\text{ k}\Omega$			500	
$t_{conv}$	Conversion time (multiplexer-addressing time not included)				8	clock periods

† All parameters are measured under open-loop conditions with zero common-mode input voltage. For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

NOTES: 5. Total unadjusted error includes offset, full-scale, linearity, and multiplexer errors.

6. The MSB-first data is output directly from the comparator and, therefore, requires additional delay to allow for comparator response time. LSB-first data applies only to TLC0832.

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PARAMETER MEASUREMENT INFORMATION

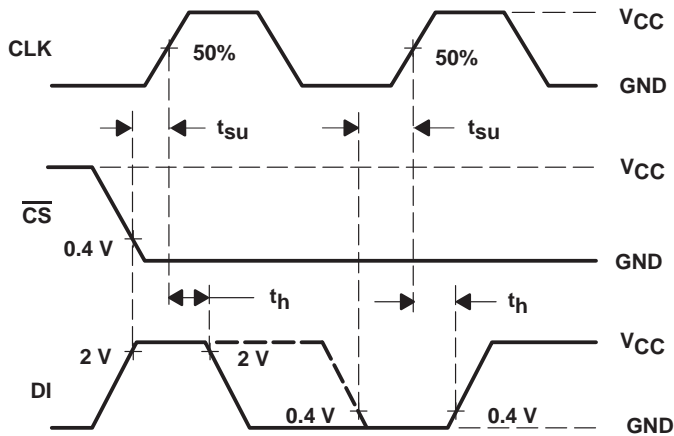


Figure 1. TLC0832 Data-Input Timing

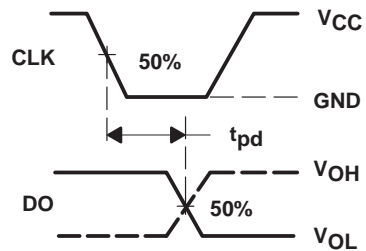
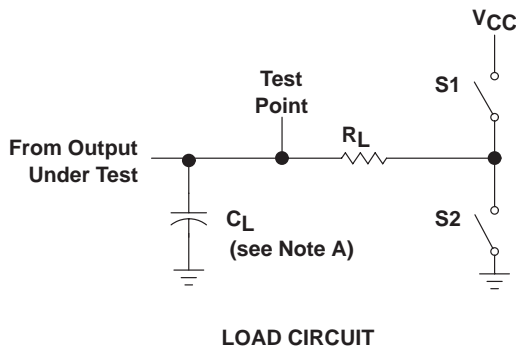
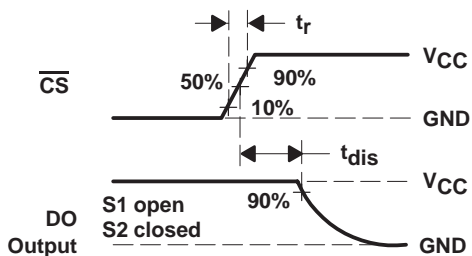


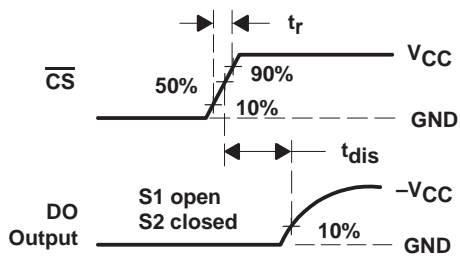
Figure 2. Data-Output Timing



LOAD CIRCUIT



VOLTAGE WAVEFORMS



VOLTAGE WAVEFORMS

NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 3. Output Disable Time Test Circuit and Voltage Waveforms



TYPICAL CHARACTERISTICS

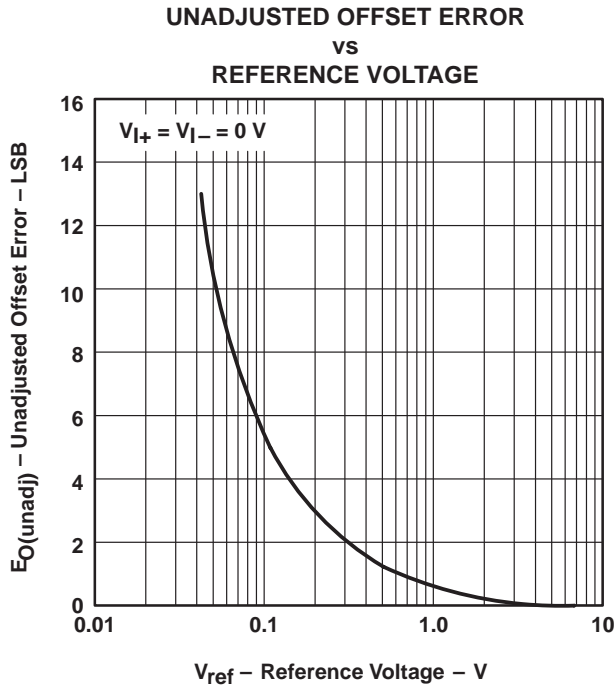


Figure 4

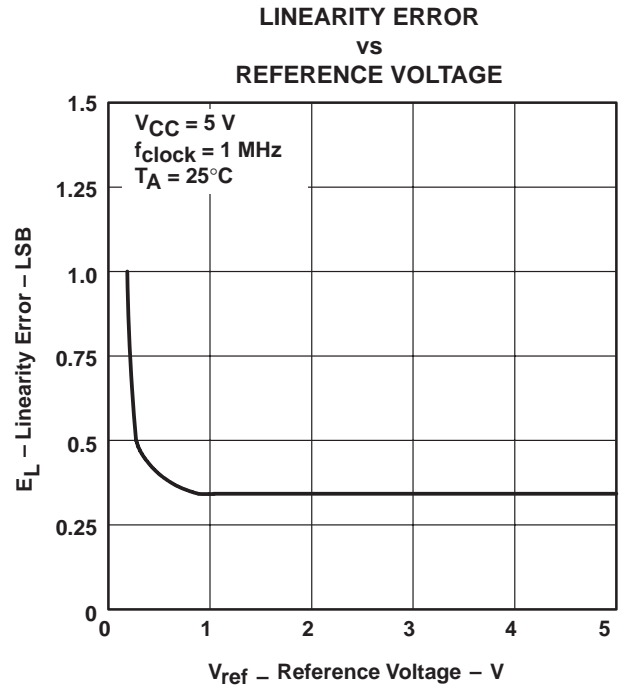


Figure 5

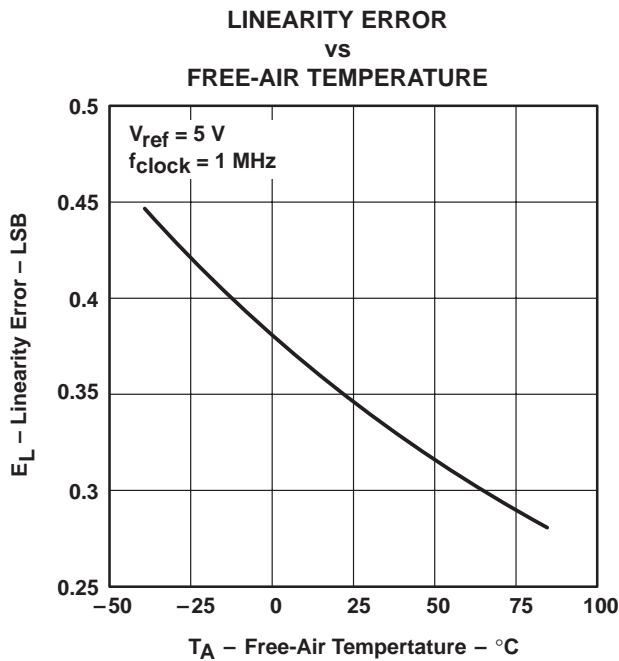


Figure 6

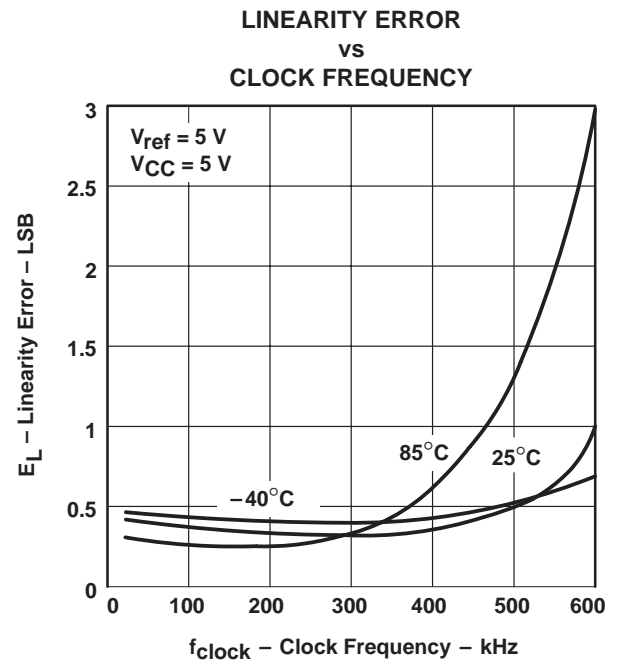


Figure 7

TYPICAL CHARACTERISTICS

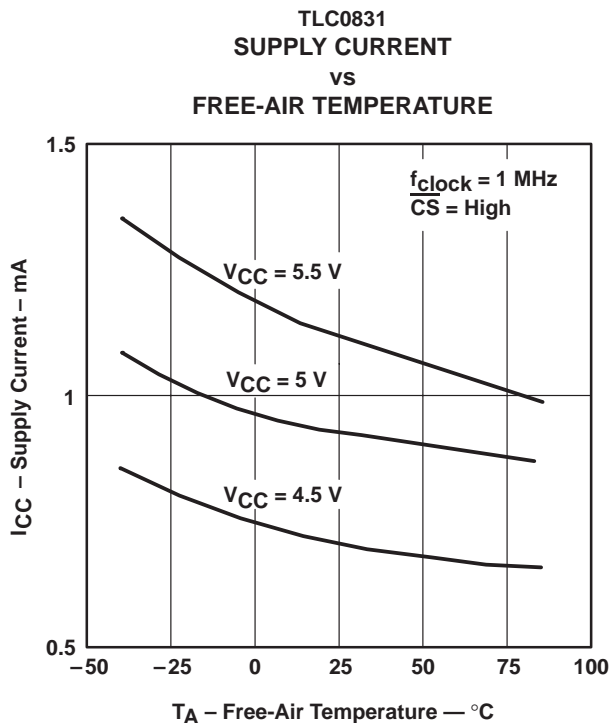


Figure 8

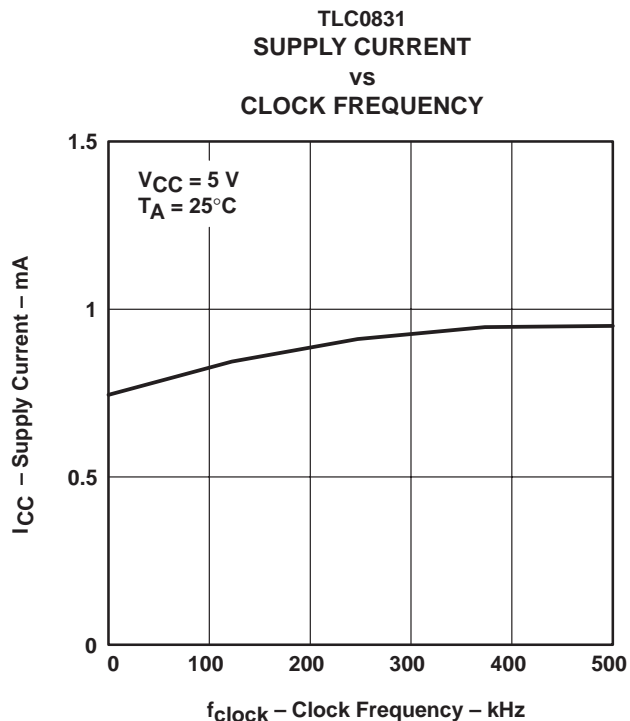


Figure 9

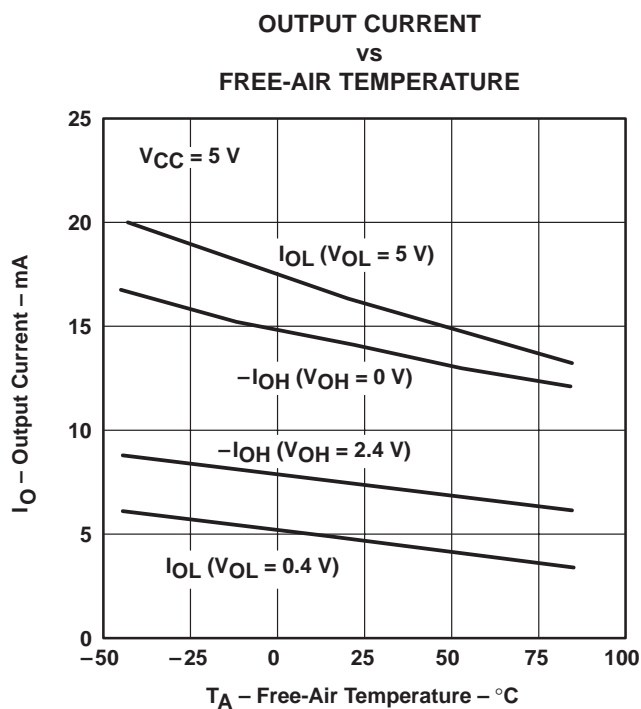


Figure 10

TYPICAL CHARACTERISTICS

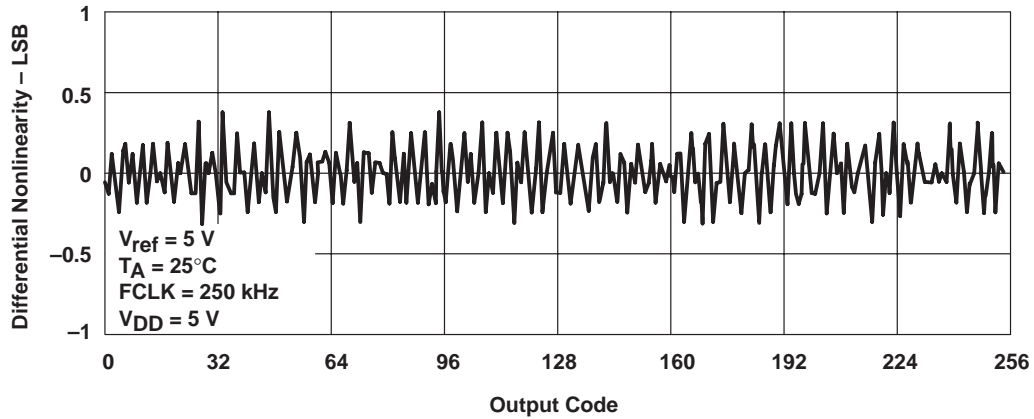


Figure 11. Differential Nonlinearity With Output Code

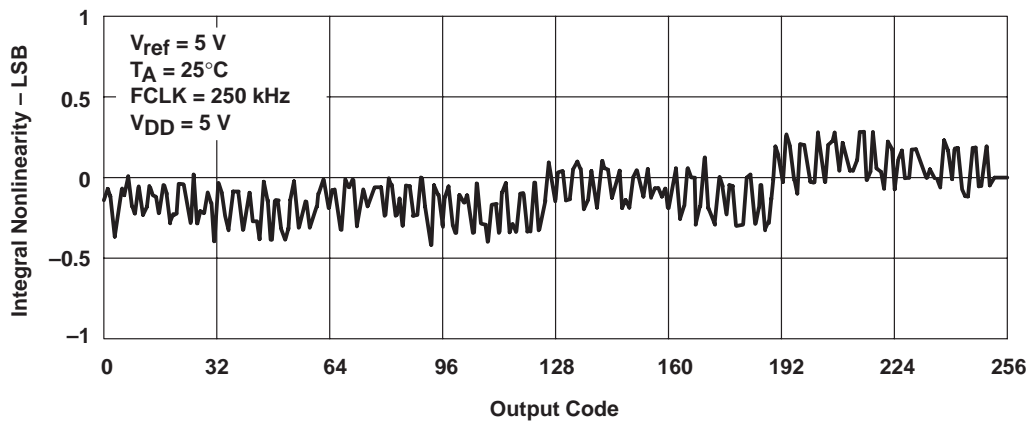


Figure 12. Integral Nonlinearity With Output Code

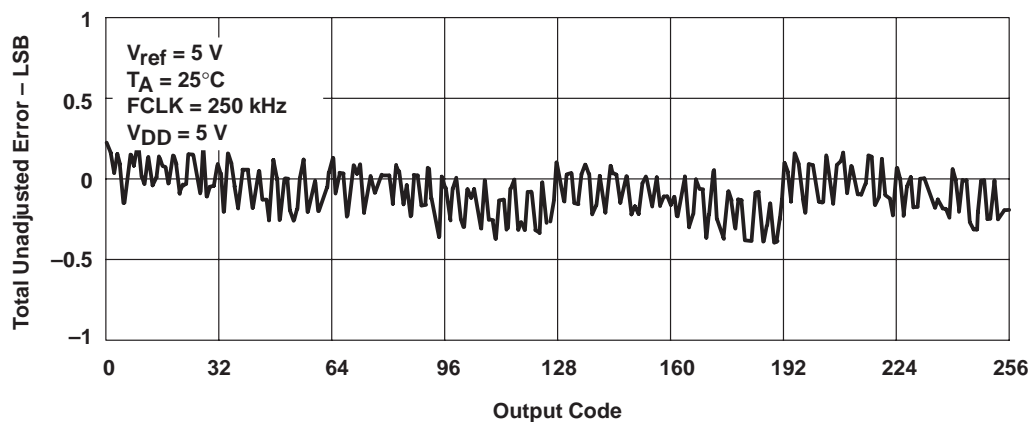


Figure 13. Total Unadjusted Error With Output Code

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