TC14433/A

3-1/2 Digit, Analog-to-Digital Converter

Features:

- Accuracy: ±0.05% of Reading ±1 Count
- Two Voltage Ranges: 1.999V and 199.9 mV
- Up to 25 Conversions Per Second
- Z_{IN} > 1000M Ohms
- Single Positive Voltage Reference
- Auto-Polarity and Auto-Zero
- Overrange and Underrange Signals Available
- Operates in Auto-Ranging Circuits
- Uses On-Chip System Clock or External Clock
- Wide Supply Range: ±4.5V to ±8V

Applications:

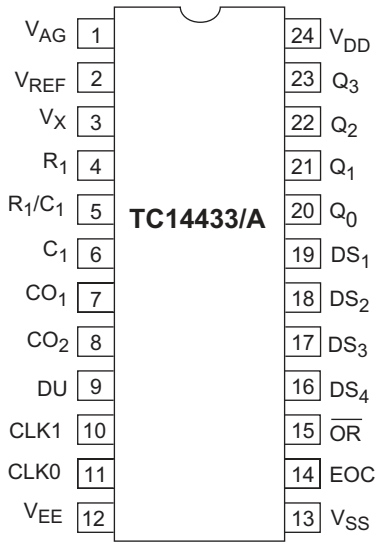
- Portable Instruments
- Digital Voltmeters
- Digital Panel Meters
- Digital Scales
- Digital Thermometers
- Remote A/D Sensing Systems
- MPU Systems

Device Selection Table

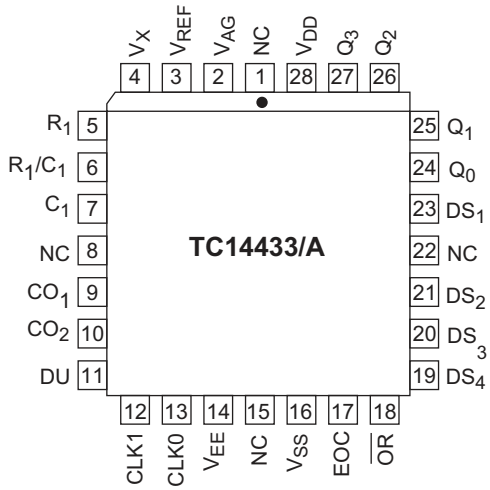
Part Number	Package	Temperature Range
TC14433AEJG	24-Pin CERDIP (Wide)	-40°C to +85°C
TC14433AELI	28-Pin PLCC	-40°C to +85°C
TC14433AEPG	24-Pin PDIP (Wide)	-40°C to +85°C
TC14433COG	24-Pin SOIC (Wide)	0°C to +70°C
TC14433EJG	24-Pin CERDIP (Wide)	-40°C to +85°C
TC14433ELI	28-Pin PLCC	-40°C to +85°C
TC14433EPG	24-Pin PDIP (Wide)	-40°C to +85°C

Package Type

24-Pin PDIP (Wide)
24-Pin CERDIP (Wide)
24-Pin SOIC (Wide)



28-Pin PLCC



Note 1: NC = No internal connection (In 28-Pin PLCC).

2: 24-Pin SOIC (Wide) package, only for TC14433 device.

General Description

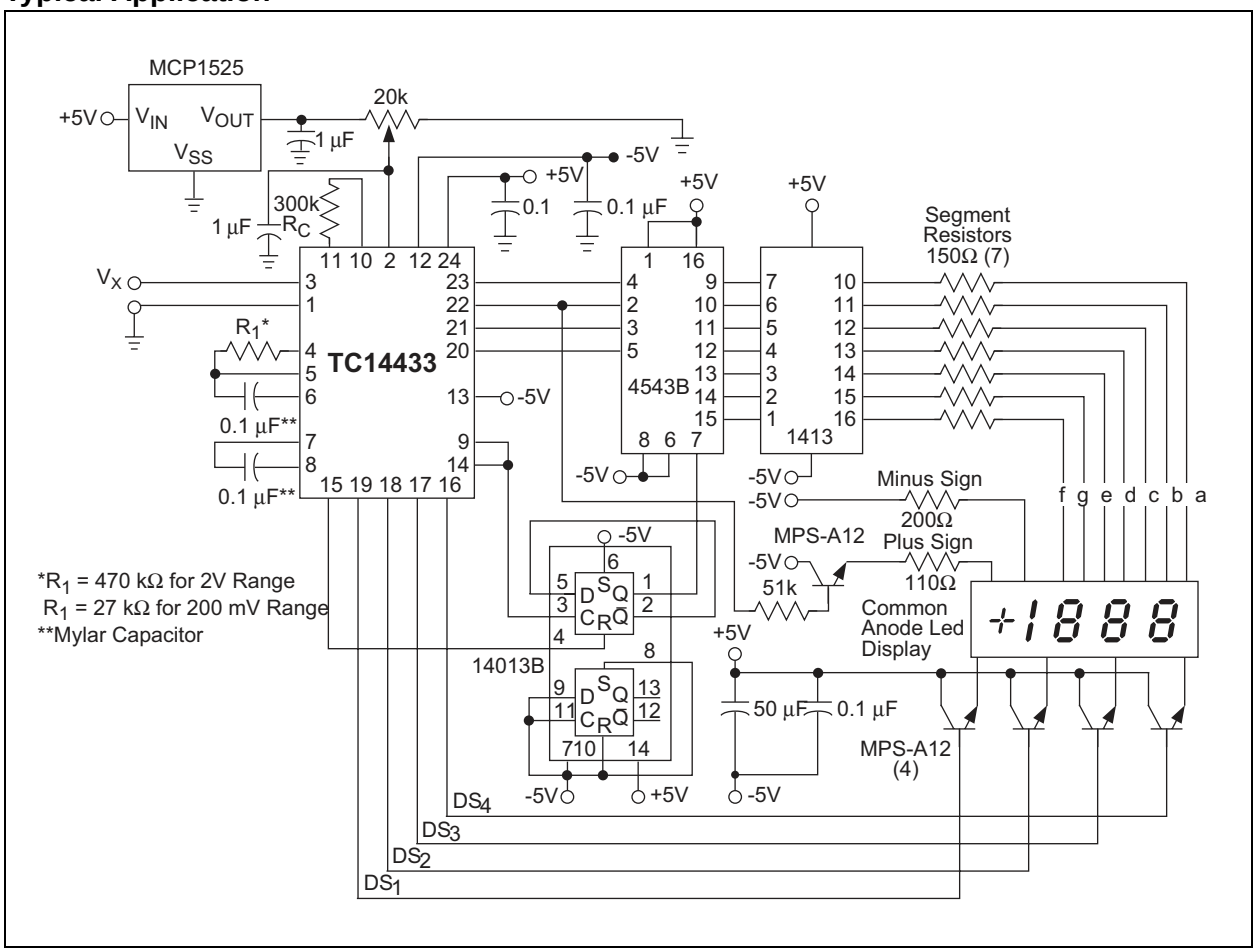
The TC14433 is a low-power, high-performance, monolithic CMOS 3-1/2 digit A/D converter. The TC14433 combines both analog and digital circuits on a single IC, thus minimizing the number of external components.

This dual slope A/D converter provides automatic polarity and zero correction with the addition of two external resistors and two capacitors. The full scale voltage range of this ratiometric IC extends from 199.9 millivolts to 1.999 volts. The TC14433 can operate over a wide range of power supply voltages, including batteries and standard 5-volt supplies.

The TC14433A features improved performance over the industry standard TC14433. Rollover, which is the measurement of identical positive and negative signals, is specified to have the same reading within one count for the TC14433A. Power consumption of the TC14433A is typically 4 mW, approximately one-half that of the industry standard TC14433.

The TC14433/A is available in 24-Pin PDIP, 24-Pin CERDIP, 24-Pin SOIC (TC14433 device only), and 28-Pin PLCC packages.

Typical Application



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

Supply Voltage (V_{DD} – V_{EE}) ..... -0.5V to +18V
Voltage on Any Pin:
Reference to V_{EE} ..... -0.5V to (V_{DD} + 0.5)
DC Current, Any Pin: ..... ±10 mA
Power Dissipation ($T_A \leq 70°C$):
Plastic PLCC 1.0W
Plastic PDIP 940W
SOIC 940W
CERDIP 1.45W
Operating Temperature Range ..... 0°C to +70°C
Storage Temperature Range ..... -65°C to +160°C

*Stresses above 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 above those indicated in the operation sections of the specifications is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

TABLE 1-1: TC14433/A ELECTRICAL SPECIFICATIONS

Electrical Characteristics: V_{DD} = +5V, V_{EE} = -5V, C_1 = 0.1 µF, (Mylar), C_0 = 0.1 µF, R_C = 300 kΩ, R_1 = 470 kΩ @ V_{REF} = 2V, R_1 = 27 kΩ @ V_{REF} = 200 mV, T_A = 25°C, unless otherwise specified.

Symbol	Parameter	Min	Typ	Max	Min	Typ	Max	Units	Test Conditions
Analog Input									
SYE	Rollover Error (Positive) and Negative Full Scale Symmetry	-1	—	+1	—	—	—	Counts	200 mV Full Scale V_{IN} -V_{IN} = +V_{IN}
NL	Linearity Output Reading **(Note 1)**	-0.05	+0.05	+0.05	—	—	—	%rdg	V_{REF} = 2V
		-1 count	—	+1 count	—	—	—	%rdg	V_{REF} = 200 mV
SOR	Stability Output Reading **(Note 2)**	—	—	2	—	—	—	LSD	V_X = 1.99V, V_{REF} = 2V
		—	—	3	—	—	—	LSD	V_X = 199 mV, V_{REF} = 200 mV
ZOR	Zero Output Reading	—	0	0	—	—	—	LSD	V_X = 0V, V_{REF} = 2V
I_{IN}	Bias Current: Analog Input	—	±20	±100	—	—	—	pA	
	Reference Input	—	±20	±100	—	—	—	pA	
	Analog Ground	—	±20	±100	—	—	—	pA	
CMRR	Common mode Rejection	—	65	—	—	—	—	dB	V_X = 1.4V, V_{REF} = 2V, F_{OC} = 32 kHz

Note 1: Accuracy – The accuracy of the meter at full scale is the accuracy of the setting of the reference voltage. Zero is recalculated during each conversion cycle. The meaningful specification is linearity. In other words, the deviation from correct reading for all inputs other than positive full scale and zero is defined as the linearity specification.

2: The LSD stability for 200 mV scale is defined as the range that the LSD will occupy 95% of the time.

3: Pin numbers refer to 24-pin PDIP.

TABLE 1-1: TC14433/A ELECTRICAL SPECIFICATIONS (CONTINUED)

Electrical Characteristics: V_{DD} = +5V, V_{EE} = -5V, C_1 = 0.1 µF, (Mylar), C_0 = 0.1 µF, R_C = 300 kΩ, R_1 = 470 kΩ @ V_{REF} = 2V, R_1 = 27 kΩ @ V_{REF} = 200 mV, T_A = 25°C, unless otherwise specified.									
Symbol	**Parameter**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Units**	**Test Conditions**
Digital									
V_{OL}	Output Voltage (Pins 14 to 23) **(Note 3)**	—	0	0.05	—	—	0.05	V	V_{SS} = 0V, "0" Level
		—	-5	-4.95	—	—	-4.95	V	V_{SS} = -5V, "0" Level
V_{OH}	Output Voltage (Pins 14 to 23) **(Note 3)**	4.95	5	—	4.95	—	—	V	V_{SS} = 0V, "1" Level
		4.95	5	—	4.95	—	—	V	V_{SS} = -5V, "1" Level
I_{OH}	Output Current (Pins 14 to 23)	-0.2	-0.36	—	-0.14	—	—	mA	V_{SS} = 0V, V_{OH} = 4.6V Source
		- 0.5	-0.9	—	-0.35	—	—	mA	V_{SS} = -5V, V_{OH} = 5V Source
I_{OL}	Output Current (Pins 14 to 23)	0.51	0.88	—	0.36	—	—	mA	V_{SS} = 0V, V_{OL} = 0.4V Sink
		1.3	2.25	—	0.9	—	—	mA	V_{SS} = -5V, V_{OL} = -4.5V Sink
f_{CLK}	Clock Frequency	—	66	—	—	—	—	kHz	R_C = 300 kΩ
I_{DU}	Input Current -DU	—	±0.00 001	±0.3	—	—	±1	µA	
Power									
I_Q	Quiescent Current: 14433A:	—	—	—	—	—	—	—	V_{DD} to V_{EE}, I_{SS} = 0
		—	0.4	2	—	—	3.7	mA	V_{DD} = 5, V_{EE} = -5
		—	1.4	4	—	—	7.4	mA	V_{DD} = 8, V_{EE} = -8
	Quiescent Current: 14433:	—	—	—	—	—	—	—	V_{DD} to V_{EE}, I_{SS} = 0
		—	0.9	2	—	—	3.7	mA	V_{DD} = 5, V_{EE} = -5
		—	1.8	4	—	—	7.4	mA	V_{DD} = 8, V_{EE} = -8
PSRR	Supply Rejection	—	0.5	—	—	—	—	mV/V	V_{DD} to V_{EE}, I_{SS} = 0, V_{REF} = 2V, V_{DD} = 5, V_{EE} = -5

Note 1: Accuracy – The accuracy of the meter at full scale is the accuracy of the setting of the reference voltage. Zero is recalculated during each conversion cycle. The meaningful specification is linearity. In other words, the deviation from correct reading for all inputs other than positive full scale and zero is defined as the linearity specification.

2: The LSD stability for 200 mV scale is defined as the range that the LSD will occupy 95% of the time.

3: Pin numbers refer to 24-pin PDIP.

2.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 2-1.

TABLE 2-1: PIN FUNCTION TABLE

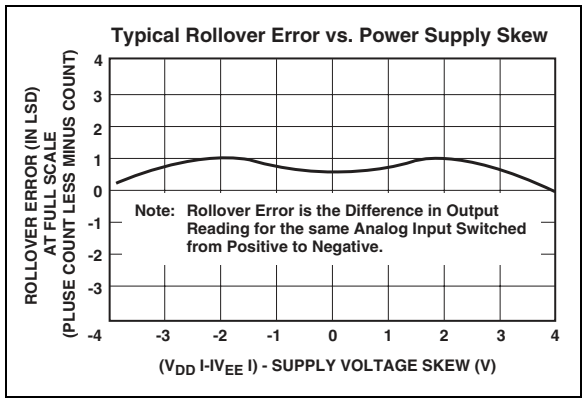
Pin No. (24-Pin PDIP) (24-Pin CERDIP) (24-Pin SOIC)	Pin No. (28-Pin PLCC)	Symbol	Description
1	2	V_{AG}	This is the analog ground. It has a high input impedance. The pin determines the reference level for the unknown input voltage (V_X) and the reference voltage (V_{REF}).
2	3	V_{REF}	Reference voltage – Full scale output is equal to the voltage applied to V_{REF}. Therefore, full scale voltage of 1.999V requires 2V reference and 199.9 mV full scale requires a 200 mV reference. V_{REF} functions as system reset also. When switched to V_{EE}, the system is reset to the beginning of the conversion cycle.
3	4	V_X	The unknown input voltage (V_X) is measured as a ratio of the reference voltage (V_{REF}) in a ratiometric A/D conversion.
4	5	R_1	This pin is for external components used for the integration function in the dual slope conversion. Typical values are 0.1 µF (Mylar) capacitor for C_1.
5	6	R_1/C_1	R_1 = 470 kΩ (resistor) for 2V full scale.
6	7	C_1	R_1 = 27 kΩ (resistor) for 200 mV full scale. Clock frequency of 66 kHz gives 250 msec conversion time.
7	9	CO_1	These pins are used for connecting the offset correction capacitor. The recommended value is 0.1 µF.
8	10	CO_2	These pins are used for connecting the offset correction capacitor. The recommended value is 0.1 µF.
9	11	DU	Display update input pin. When DU is connected to the EOC output, every conversion is displayed. New data will be strobed into the output latches during the conversion cycle if a positive edge is received on DU, prior to the ramp down cycle. When this pin is driven from an external source, the voltage should be referenced to V_{SS}.
10	12	CLK_1	Clock input pins. The TC14433 has its own oscillator system clock. Connecting a single resistor between CLK_1 and CLK_0 sets the clock frequency.
11	13	CLK_0	A crystal or OC circuit may be inserted in lieu of a resistor for improved CLK_1, the clock input, can be driven from an external clock source, which need only have standard CMOS output drive. This pin is referenced to V_{EE} for external clock inputs. A 300 kΩ resistor yields a clock frequency of about 66 kHz. See **Section 3.0 "Typical Characteristics"**. (Also see Figure for alternate circuits.)
12	14	V_{EE}	Negative power current. Connection pin for the most negative supply. Please note the current for the output drive circuit is returned through V_{SS}. Typical supply current is 0.8 mA.
13	16	V_{SS}	Negative power supply for output circuitry. This pin sets the low voltage level for the output pins (BCD, Digit Selects, EOC, OR). When connected to analog ground, the output voltage is from analog ground to V_{DD}. If connected to V_{EE}, the output swing is from V_{EE} to V_{DD}. The recommended operating range for V_{SS} is between the V_{DD} -3 volts and V_{EE}.
14	17	EOC	End of conversion output generates a pulse at the end of each conversion cycle. This generated pulse width is equal to one half the period of the system clock.

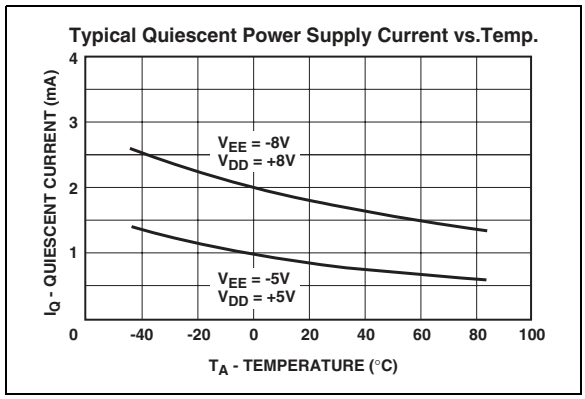
TABLE 2-1: PIN FUNCTION TABLE (CONTINUED)

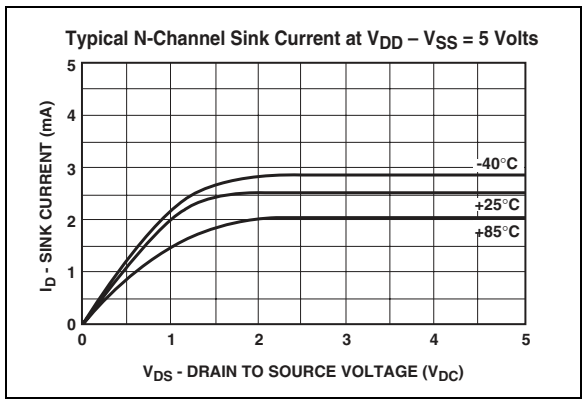
Pin No. (24-Pin PDIP) (24-Pin CERDIP) (24-Pin SOIC)	Pin No. (28-Pin PLCC)	Symbol	Description
15	18	OR	Overrange pin. Normally this pin is set high. When V_X exceeds V_{REF} the OR is low.
16	19	DS_4	Digit select pin. The digit select output goes high when the respective digit is selected. The MSD (1/2 digit turns on immediately after an EOC pulse).
17	20	DS_3	The remaining digits turn on in sequence from MSD to LSD.
18	21	DS_2	To ensure that the BCD data has settled, an inter digit blanking time of two clock periods is included.
19	23	DS_1	Clock frequency divided by 80 equals multiplex rate. For example, a system clock of 60 kHz gives a multiplex rate of 0.8 kHz.
20	24	Q_0	See Figure for digit select timing diagram.
21	25	Q_1	BCD data output pin. Multiplexed BCD outputs contain three full digits of information during digit select DS_2, DS_3, DS_4.
22	26	Q_2	During DS_1, the 1/2 digit, overrange, underrange and polarity information is available.
23	27	Q_3	Refer to the Truth Table 5-1.
24	28	V_{DD}	Positive power supply. This is the most positive power supply pin.
	1	NC	Not Used.
—	8	NC	Not Used.
—	15	NC	Not Used.
—	22	NC	Not Used.

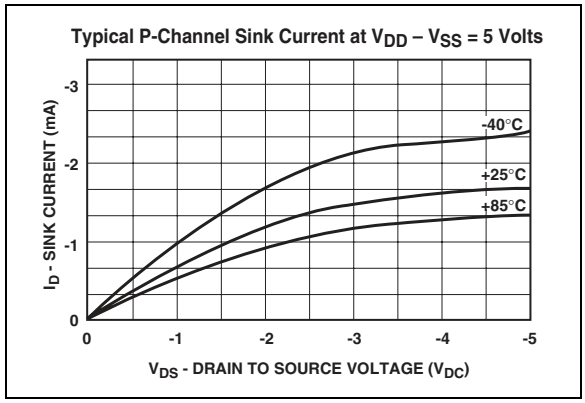
3.0 TYPICAL CHARACTERISTICS

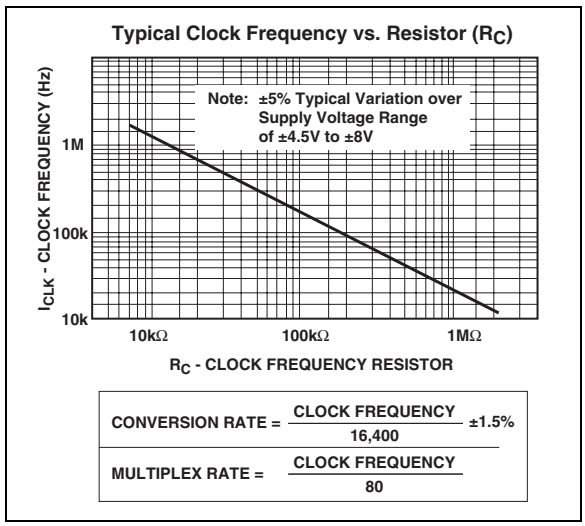
Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

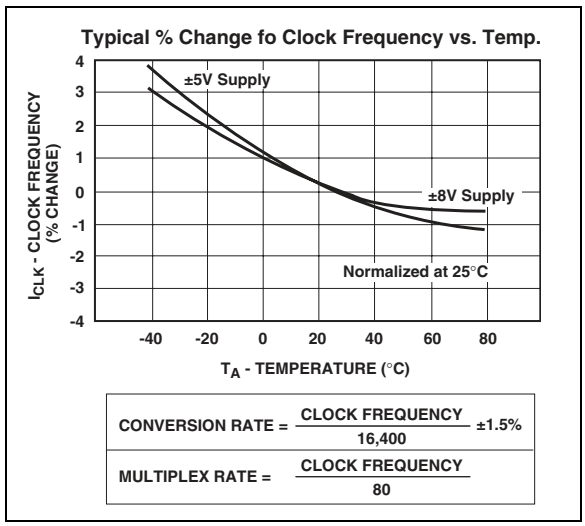












4.0 DETAILED DESCRIPTION

The TC14433 CMOS IC becomes a modified dual-slope A/D with a minimum of external components. This IC has the customary CMOS digital logic circuitry, as well as CMOS analog circuitry. It provides the user with digital functions such as (counters, latches, multiplexers), and analog functions such as (operational amplifiers and comparators) on a single chip. Refer to the Functional Block diagram, Figure .

Features of the TC14433/A include auto-zero, high input impedances and auto-polarity. Low power consumption and a wide range of power supply voltages are also advantages of this CMOS device. The system's auto-zero function compensates for the offset voltage of the internal amplifiers and comparators. In this "ratiometric system," the output reading is the ratio of the unknown voltage to the reference voltage, where a ratio of 1 is equal to the maximum count of 1999. It takes approximately 16,000 clock periods to complete one conversion cycle. Each conversion cycle may be divided into 6 segments. Figure shows the conversion cycle in 6 segments for both positive and negative inputs.

i

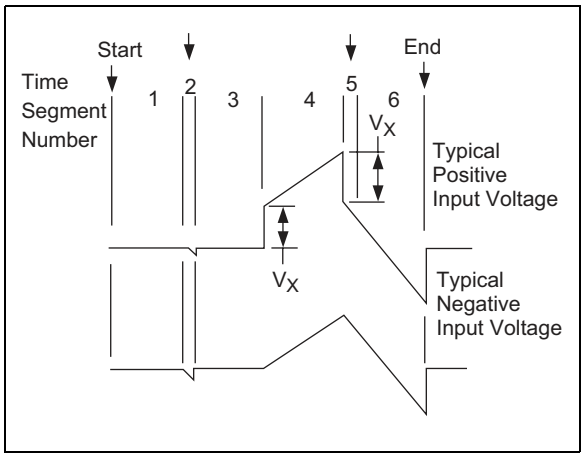


FIGURE 4-1: *Integrator Waveforms at Pin 6*

Segment 1 – The offset capacitor (C_O), which compensates for the input offset voltages of the buffer and integrator amplifiers, is charged during this period. However, the integrator capacitor is shorted. This segment requires 4000 clock periods.

Segment 2 – During this segment, the integrator output decreases to the comparator threshold voltage. At this time, a number of counts equivalent to the input offset voltage of the comparator is stored in the offset latches for later use in the auto-zero process. The time for this segment is variable and less than 800 clock periods.

Segment 3 – This segment of the conversion cycle is the same as Segment 1.

Segment 4 – Segment 4 is an up going ramp cycle with the unknown input voltage (V_X as the input to the integrator. Figure 4-2 shows the equivalent configuration of the analog section of the TC14433. The actual configuration of the analog section is dependent upon the polarity of the input voltage during the previous conversion cycle.

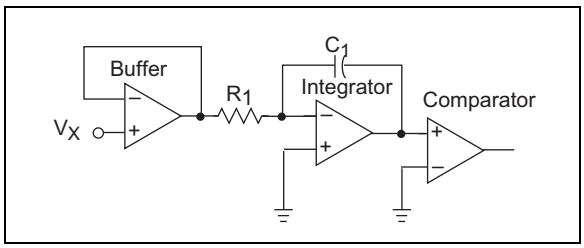


FIGURE 4-2: *Equivalent Circuit Diagrams of the Analog Section During Segment 4 of the Timing Cycle*

Segment 5 – This segment is a down-going ramp period with the reference voltage as the input to the integrator. Segment 5 of the conversion cycle has a time equal to the number of counts stored in the offset storage latches during Segment 2. As a result, the system zeros automatically.

Segment 6 – This is an extension of Segment 5. The time period for this portion is 4000 clock periods. The results of the A/D conversion cycle are determined in this portion of the conversion cycle.

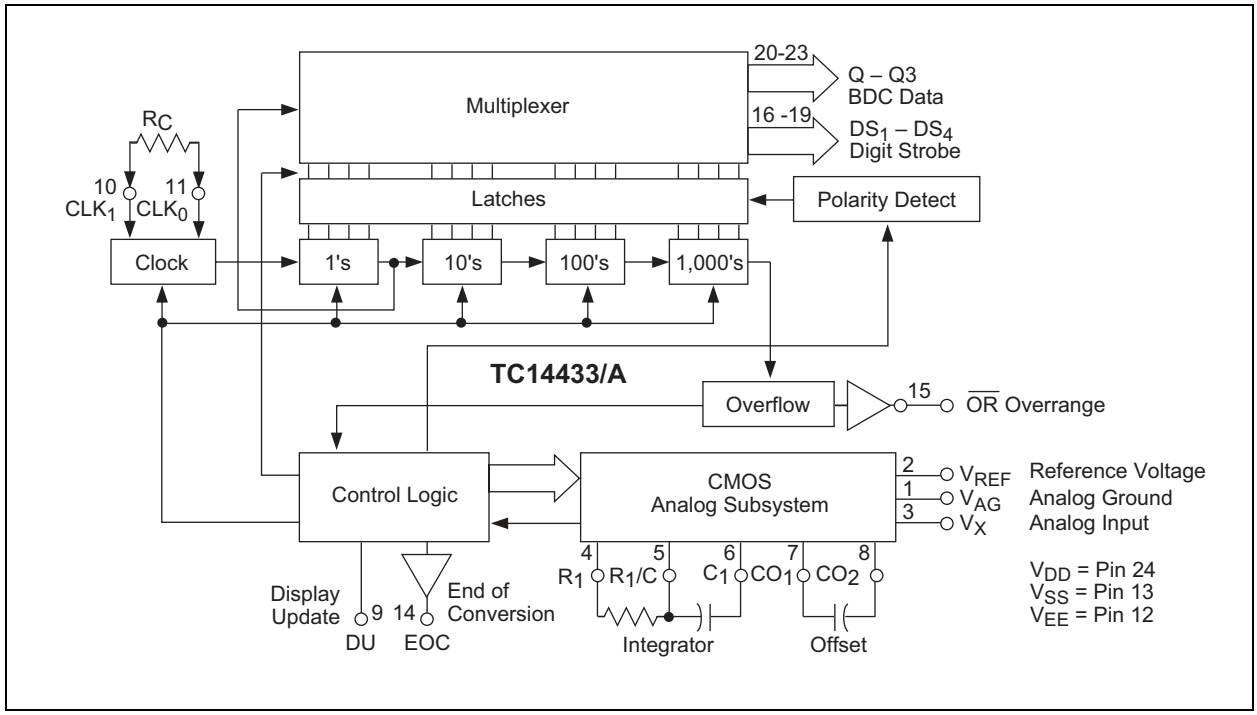


FIGURE 4-3: *Functional Block Diagram*

5.0 TYPICAL APPLICATIONS

The Typical Application circuit is an example of a 3-1/2 digit voltmeter using the TC14433 with Common-anode displays. This system requires a 2.5V reference. Full scale may be adjusted to 1.999V or 199.9 mV. Input overrange is indicated by flashing a display. This display uses LEDs with common anode digit lines. Power supply for this system is shown as a dual ±5V supply; however, the TC14433 will operate over a wide voltage range

The circuit in Figure shows a 3-1/2 digit LCD voltmeter. The 14024B provides the low frequency square wave signal drive to the LCD backplane. Dual power supplies are shown here; however, one supply may be used when V_{SS} is connected to V_{EE}. In this case, V_{AG} must be at least 2.8V above V_{EE}.

When only segments b and c of the decoder are connected to the 1/2 digit of the display, 4, 0, 7 and 3 appear as 1.

The overrange indication (Q_3 = 0 and Q_0 = 1) occurs when the count is greater than 1999; (e.g., 1.999V for a reference of 2V) The underrange indication, useful for auto-ranging circuits, occurs when the count is less than 180; (e.g., 0.180V for a reference of 2V).

Note:	If the most significant digit is connected to a display other than a "1" only, such as a full digit display, segments other than b and c must be disconnected. The BCD to 7-segment decoder must blank on BCD inputs 1010 to 1111 (see Table 5-1).

TABLE 5-1: TRUTH TABLE

Coded Condition of MSD	Q_3	Q_2	Q_1	Q_0	BDC to 7-Segment Decoding	
+0	1	1	1	0	Blank	
-0	1	0	1	0	Blank	
+0 UR	1	1	1	1	Blank	
-0 UR	1	0	1	1	Blank	
+1	0	1	0	0	4 – 1	Hook up only segments b and c to MSD
-1	0	0	0	0	0 – 1	
+1 OR	0	1	1	1	7 – 1	
-1 OR	0	0	1	1	3 – 1	

Note 1: Q_3 – 1/2 digit, low for "1", high for "0".
Q_2 – Polarity: "1" = positive, "0" = negative.
Q_0 – Out of range condition exists if Q_0 = 1. When used in conjunction with Q_3, the type of out of range condition is indicated; i.e., Q_3 = 0 → OR or Q_3 = 1 → UR.

Figure is an example of a 3-1/2 digit LED voltmeter with a minimum of external components, (only 11 additional components). In this circuit, the 14511B provides the segment drive and the 75492 or 1413 provides sink for digit current. Display is blanked during the overrange condition.

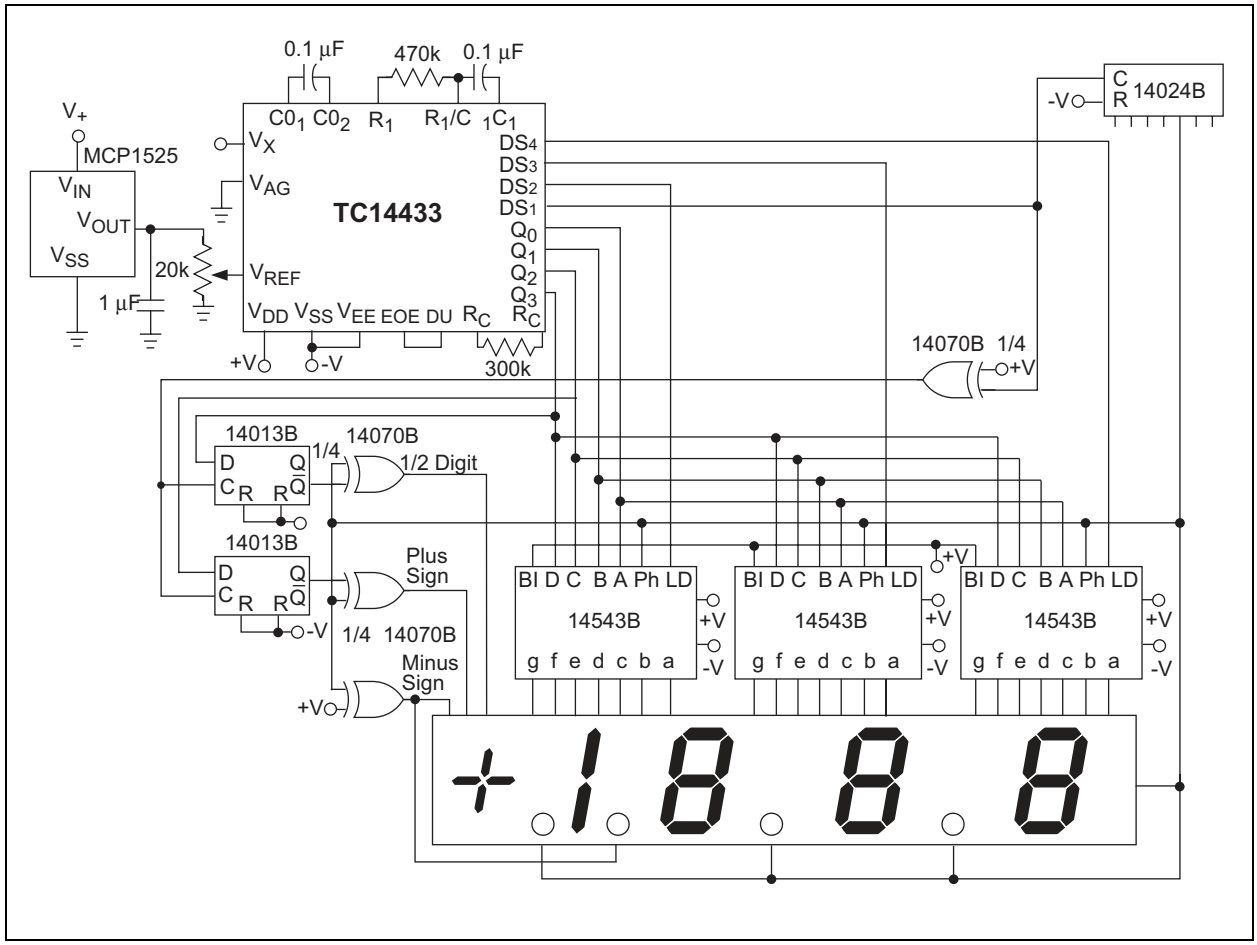
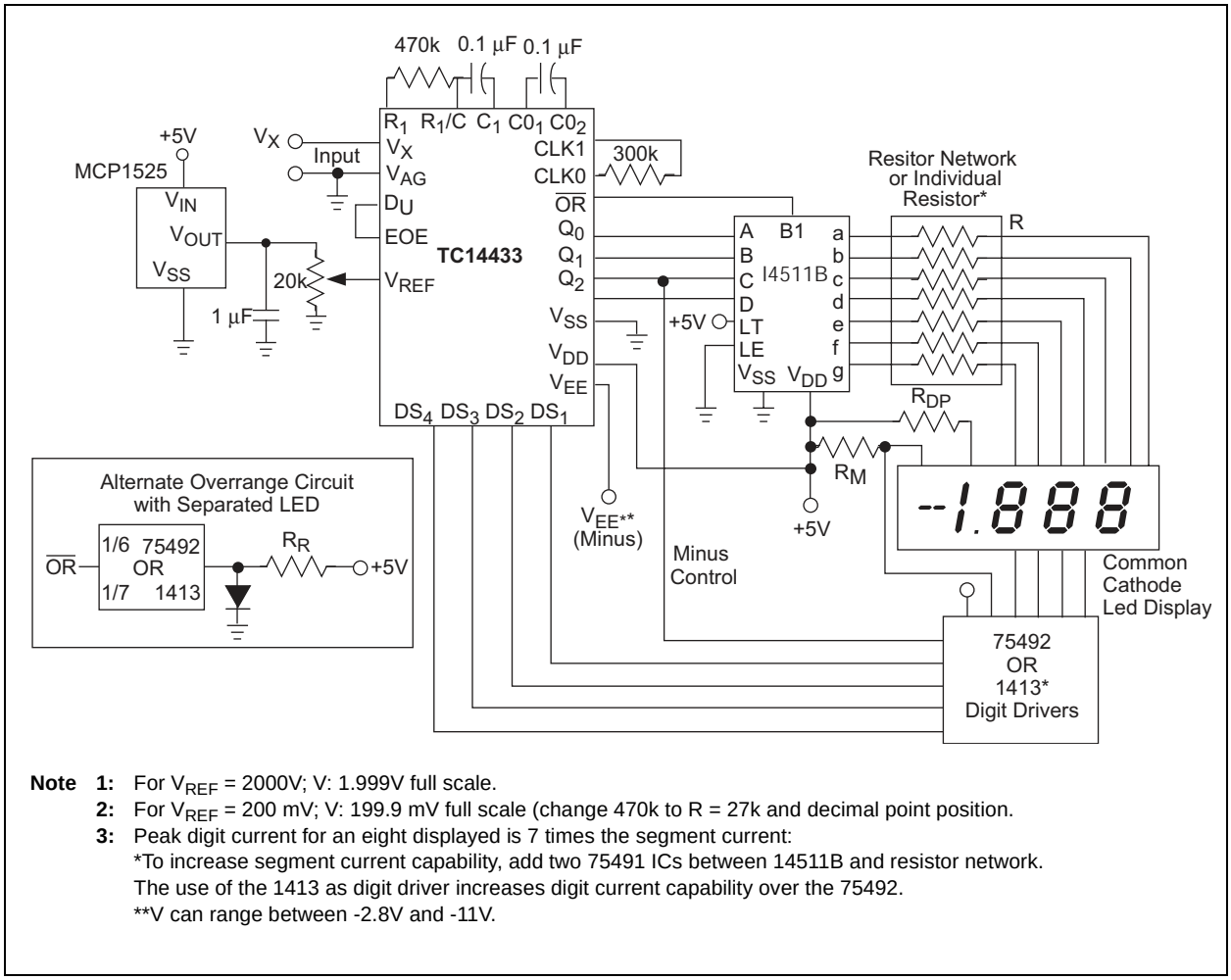


FIGURE 5-1: *3-1/2 Digit Voltmeter with LCD Display*



Note 1: For V_{REF} = 2000V; V: 1.999V full scale.
2: For V_{REF} = 200 mV; V: 199.9 mV full scale (change 470k to R = 27k and decimal point position.
3: Peak digit current for an eight displayed is 7 times the segment current:
*To increase segment current capability, add two 75491 ICs between 14511B and resistor network.
The use of the 1413 as digit driver increases digit current capability over the 75492.
**V can range between -2.8V and -11V.

FIGURE 5-2: *3-1/2 Digit LED Voltmeter with Low Component Count Using Common Cathode Display*

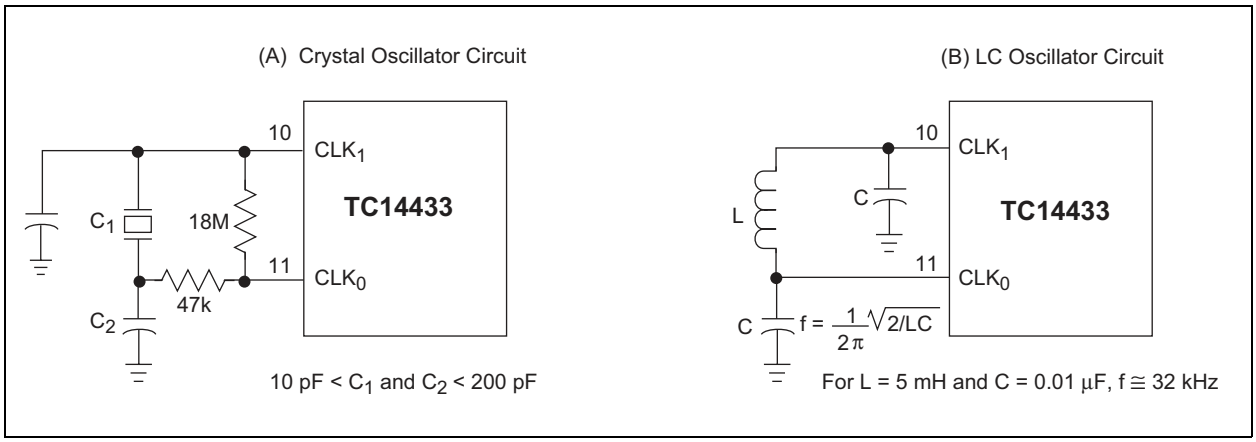


FIGURE 5-3: *Alternate Oscillator Circuits*

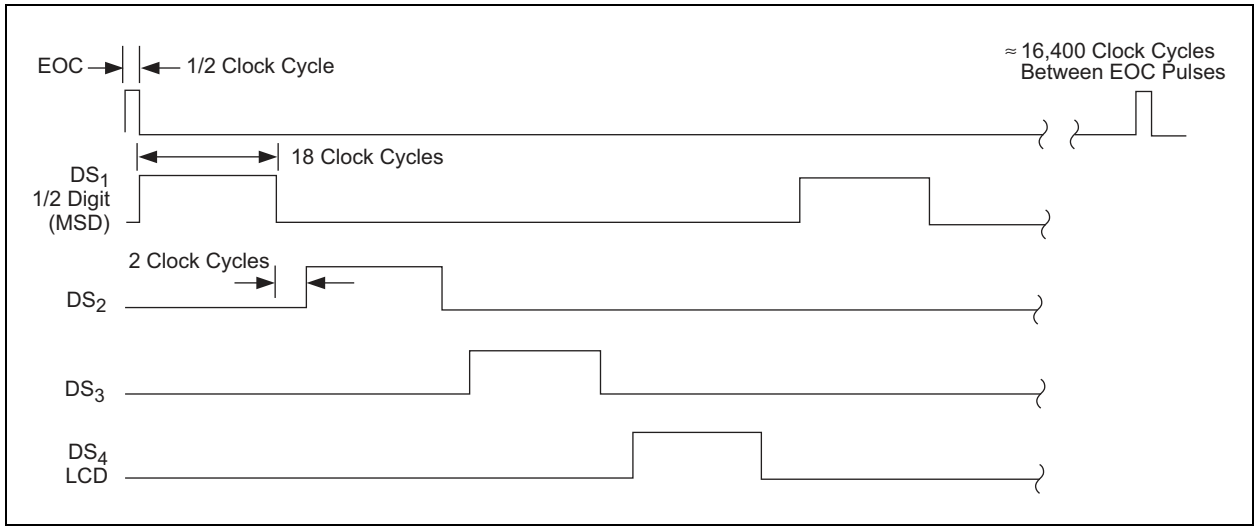


FIGURE 5-4: *Digit Select Timing Diagram*

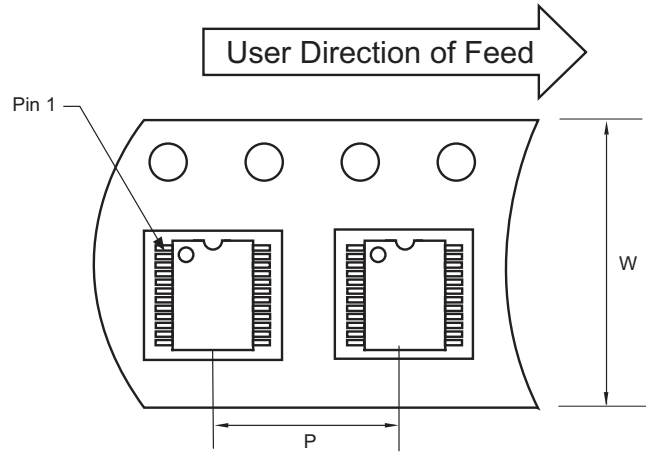
6.0 PACKAGING INFORMATION

6.1 Package Marking Information

Package marking data not available at this time.

6.2 Taping Form

Component Taping Orientation for 24-Pin SOIC (Wide) Devices

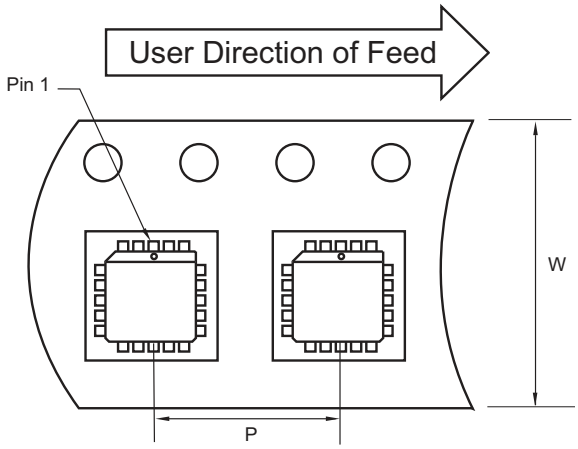


Standard Reel Component Orientation
for 713 Suffix Device

Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
24-Pin SOIC (W)	24 mm	12 mm	1000	13 in

Component Taping Orientation for 28-Pin PLCC Devices



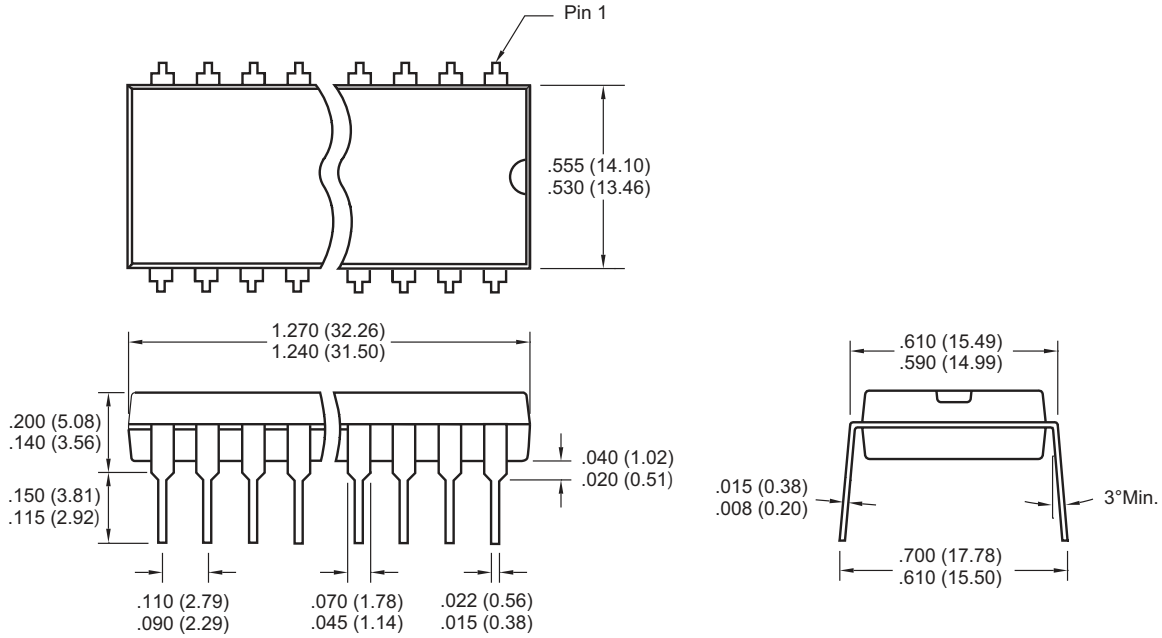
Standard Reel Component Orientation
for 713 Suffix Device

Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
28-Pin PLCC	24 mm	16 mm	750	13 in

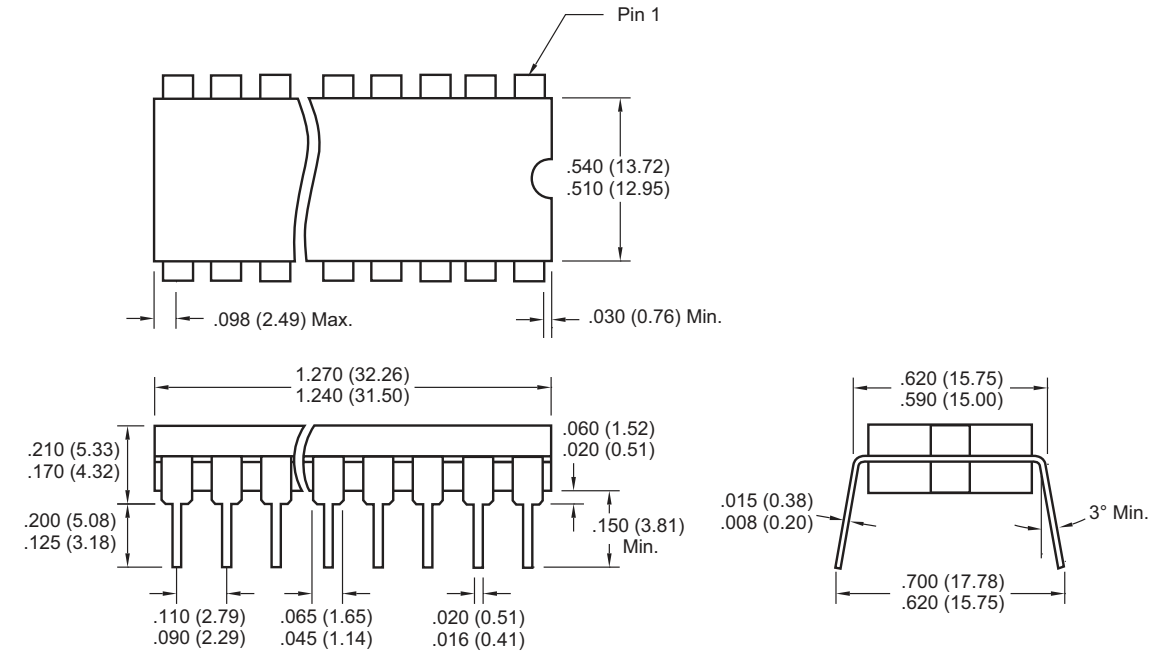
6.3 Package Dimensions

24-Pin PDIP (Wide)



Dimensions: inches (mm)

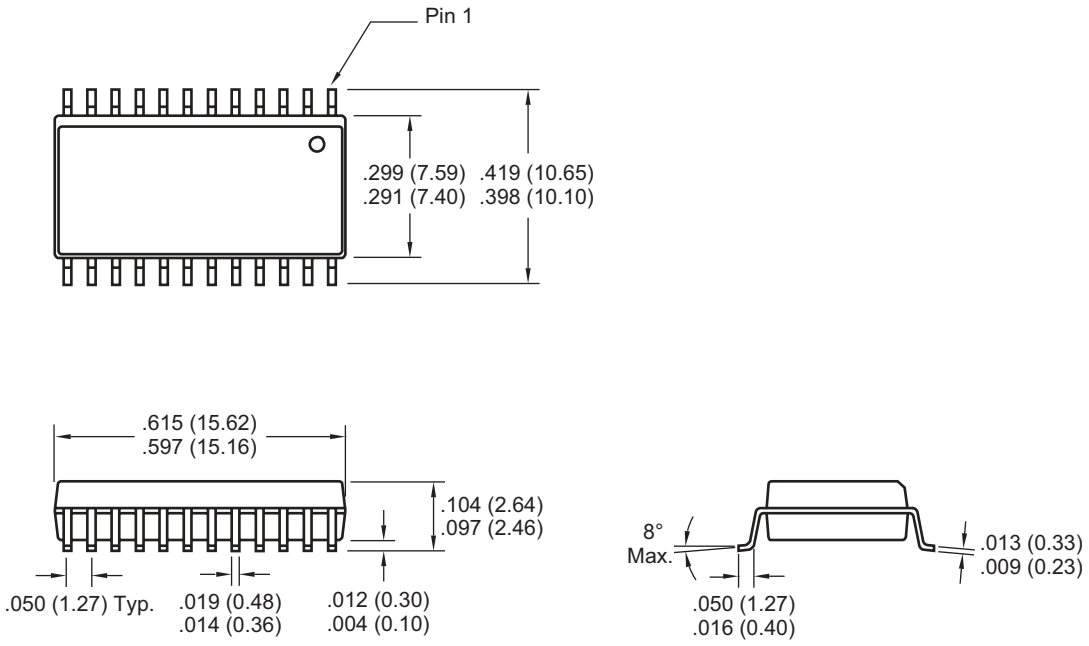
24-Pin CERDIP (Wide)



Dimensions: inches (mm)

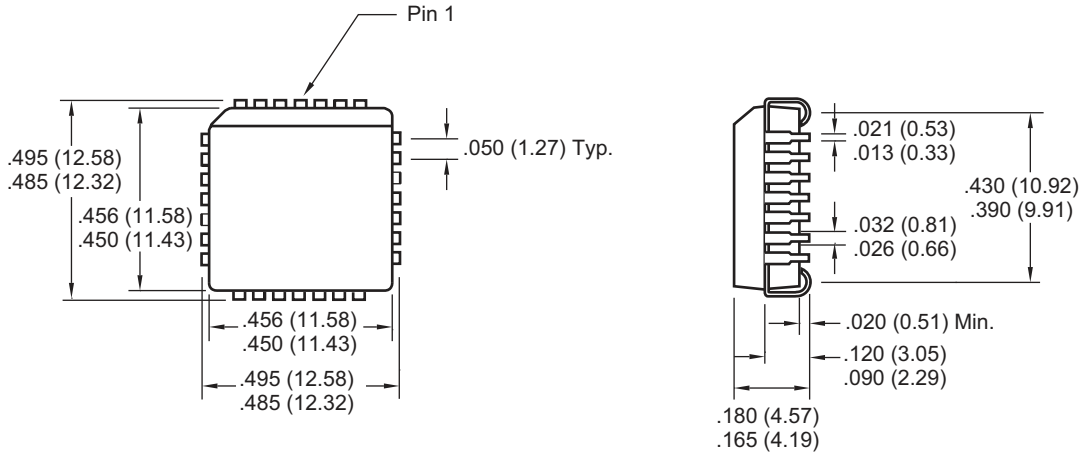
Package Dimensions (Continued)

24-Pin SOIC (Wide)



Dimensions: inches (mm)

28-Pin PLCC



Dimensions: inches (mm)

SALES AND SUPPORT

Data Sheets
Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

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3. The Microchip Worldwide Site (www.microchip.com)

Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

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CERTIFIED BY DNV
ISO/TS 16949:2002

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