

# TDC1044

## Monolithic Video A/D Converter

4-Bit, 25 Msps

### Description

The TDC1044 is a 25 Msps (Megasample per second) full-parallel analog-to-digital converter, capable of converting an analog signal with full-power frequency components up to 12.5 MHz into 4-bit digital words. Use of a sample-and-hold circuit is not necessary for operation of the TDC1044. All digital inputs and outputs are TTL compatible.

The TDC1044 consists of 15 latching comparators, encoding logic, and an output register. A single convert signal controls the conversion operation. The unit can be connected to give either true or inverted outputs in binary or offset two's complement coding.

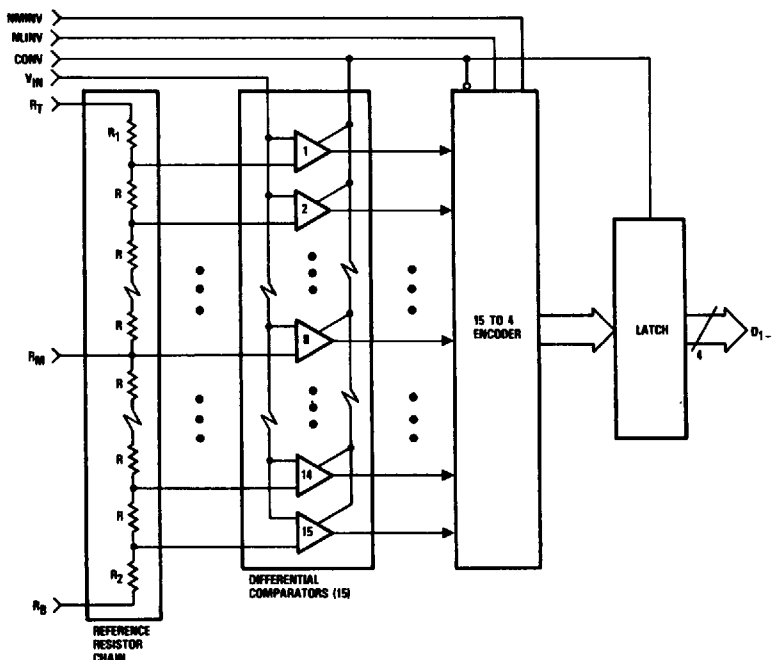
### Features

- ◆ 4-bit resolution
- ◆ 1/4 LSB non-linearity
- ◆ Sample-and-hold circuit not required
- ◆ 25 Msps conversion rate
- ◆ Selectable output format
- ◆ Available in a 16-pin DIP and a 20-lead PLCC

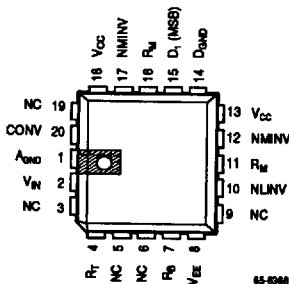
### Applications

- ◆ Video special effects
- ◆ Radar data conversion
- ◆ Medical imaging
- ◆ Medical processing

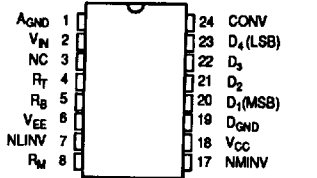
### Functional Block Diagram



### Pin Assignments



20 Lead PLCC — R4 Package



16 Pin DIP — B9 Package  
16 Pin Plastic DIP — N9 Package

### Reference

The TDC1044 converts analog signals in the range  $V_{RB} \leq V_{IN} \leq V_{RB}$  into digital form.  $V_{RB}$  (the voltage applied to  $R_B$  at the bottom of the reference resistor chain) and  $V_{RT}$  (the voltage applied to  $R_T$  at the top of the reference resistor chain) should be between  $+0.1V$  and  $-1.1V$ .  $V_{RT}$  should be more positive than  $V_{RB}$  within that range. The voltage applied across the reference resistor chain ( $V_{RT}-V_{RB}$ ) must be between  $0.4V$  and  $1.3V$ . The nominal voltages are  $V_{RT}=0.00V$  and  $V_{RB}=-1.00V$ . These voltages may be varied dynamically up to  $10MHz$ . Due to slight variation in the reference currents with clock and input signals,  $R_T$  and  $R_B$  should be low-impedance points. For circuits in which the reference is not varied, a bypass capacitor to ground is recommended. If the reference inputs are varied dynamically (as in an Automatic Gain Control circuit), a low-impedance reference source is required. A reference middle,  $R_M$ , is also provided; this may be used as an input to adjust the mid-scale point in order to improve integral linearity. This point may also be used as a tap to supply a mid-scale voltage to offset the analog input. If  $V_{RM}$  is used as an output, it must be connected to a high input impedance device which has small input current. Noise at this point may adversely affect the performance of the device.

### Functional Description

#### General Information

The TDC1044 has three functional sections: a comparator array, encoding logic, and an output register. The comparator array compares the input signal with 15 reference voltages to produce an N-of-15 code (sometimes referred to as a "thermometer" code, as all the comparators referred to voltages more positive than the input signal will be off, and those referred to voltages more negative than the input signal will be on). The encoding logic converts the N-of-15 code into binary or two's complement coding, and can invert either output code. This coding function is controlled by DC signals on pins  $NMINV$  and  $NLINV$ . The output register holds the output constant between updates.

#### Power

The TDC1044 operates from two power supply voltages,  $+5.0V$  and  $-5.2V$ . The return for  $I_{CC}$  (the current drawn from the  $+5.0V$  supply) is  $D_GND$ . The return for  $I_{EE}$  (the current drawn from the  $-5.2V$  supply) is  $A_GND$ . All power and ground pins must be connected.

#### Controls

Two function control pins,  $NMINV$  and  $NLINV$  are provided. These controls are for DC (i.e., steady state) use. They permit the output coding to be either straight binary or offset two's complement, in either true or inverted sense, according to the *Output Coding Table*. These pins are active LOW as signified by the prefix "N" in the signal name. They may be tied to  $V_{CC}$  for a logic "1" and  $D_GND$  for a logic "0."

#### Convert

The TDC1044 requires a  $CONV$  (CONV) signal. A sample is taken (the comparators are latched) within  $t_{STO}$  after a rising edge of  $CONV$ . The coded result is translated to the output latches on the next rising edge. The outputs hold the previous data a minimum time ( $t_{HQ}$ ) after the rising edge of the  $CONV$  signal. New data becomes valid after a maximum delay time,  $t_D$ .

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**Analog Input**

The TDC1044 uses latching comparators which cause the input impedance to vary slightly with the signal level. For optimal performance, the source impedance of the driving circuit must be less than 25 Ohms. The input signal will not damage the device if it remains within the range of  $V_{EE}$  to  $+0.5V$ . If the input signal is at a voltage between  $V_{RT}$  and  $V_{RB}$ , the output will be a binary code between 0 and 15 inclusive. A signal outside this range will indicate either full-scale positive or full-scale negative, depending on whether the signal is off-scale in the positive or negative direction.

**Outputs**

The outputs of the TDC1044 are TTL compatible, and capable of driving four low-power Schottky TTL (54/74 LS) unit loads. The outputs hold the previous data a minimum time ( $t_{HD}$ ) after the rising edge of the CONV signal. Data becomes valid after a maximum delay time ( $t_D$ ) after the rising edge of CONV. For optimum performance, 2.2 kOhm pull-up resistors are recommended.

**No Connects**

Pin 3 of the TDC1044 is labeled No Connect (NC), and has no connection to the chip. Connect this pin to AGND for best noise performance.

**Package Interconnections**

Signal Type	Signal Name	Function	Value	B9, N9 Package Pins	R4 Package Pins
Power	VCC	Positive Supply Voltage	+5.0V	10	13
	VEE	Negative Supply Voltage	-5.2V	6	8
	DGND	Digital Ground	0.0V	11	14
	AGND	Analog Ground	0.0V	1	1
Reference	RT	Reference Resistor, Top	0.0V	4	4
	RM	Reference Resistor, Middle	-0.5V	8	11
	RB	Reference Resistor, Bottom	-1.0V	5	7
Controls	NMINV	Not MSB Invert	TTL	9	12
	NLINV	Not LSB Invert	TTL	7	10
Convert	CONV	Convert	TTL	16	20
Analog Input	VIN	Analog Input Signal	0V to -1V	2	2
Outputs	D1	MSB Output	TTL	12	15
	D2		TTL	13	16
	D3		TTL	14	17
	D4	LSB Output	TTL	15	18
No Connects	NC	No Connect	AGND	3	3, 5, 6, 9, 19

Figure 1. Timing Diagram

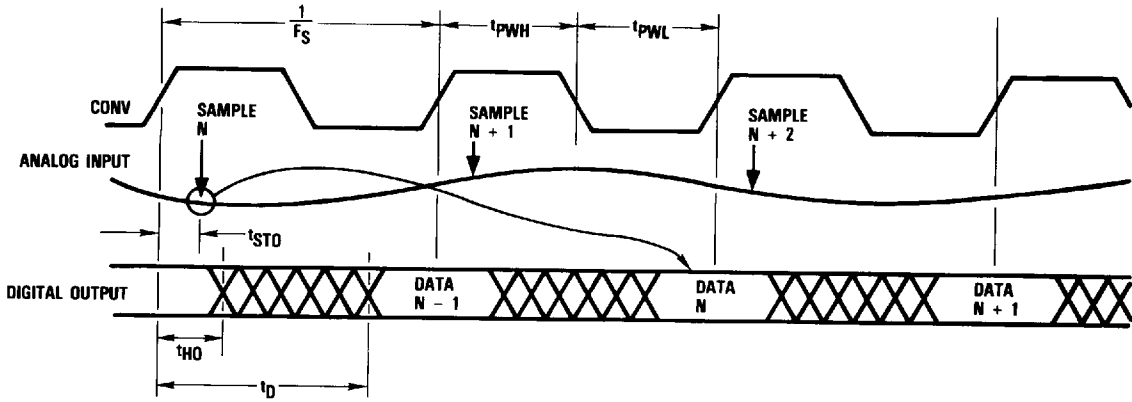


Figure 2. Simplified Analog Input Equivalent Circuit

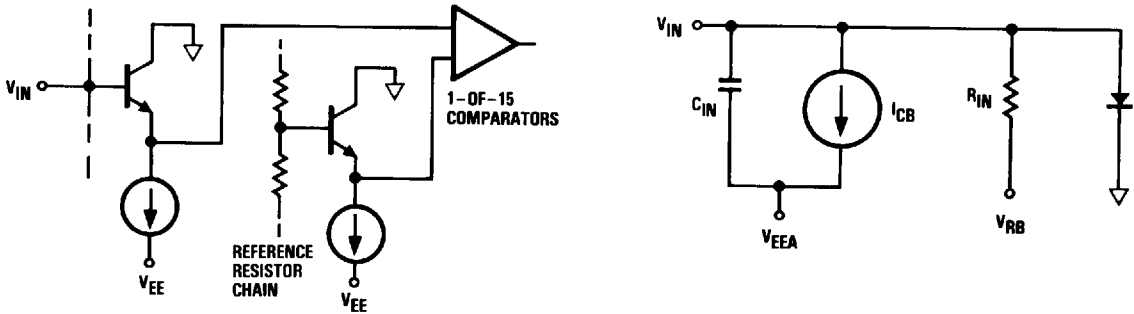


Figure 3. Digital Input Equivalent Circuit

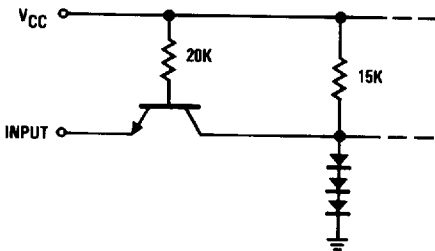
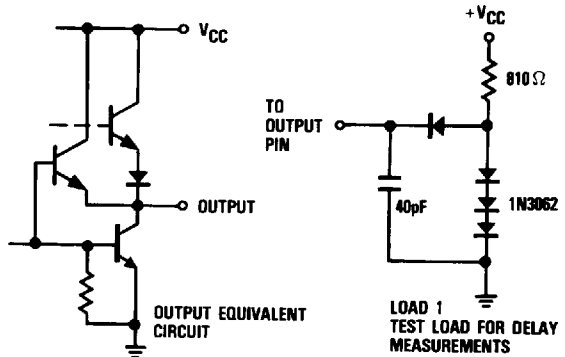


Figure 4. Output Circuits



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**Absolute maximum ratings** (beyond which the device may be damaged) <sup>1</sup>

**Supply Voltages**

V <sub>CC</sub> (measured to D <sub>GND</sub> )	-0.5 to +7.0V
V <sub>EE</sub> (measured to A <sub>GND</sub> )	+0.5 to -7.0V
A <sub>GND</sub> (measured to D <sub>GND</sub> )	-0.5 to +0.5V

**Input Voltages**

CONV, NMINV, NLINV (measured to D <sub>GND</sub> )	-0.5 to +5.5V
V <sub>IN</sub> , V <sub>RT</sub> , V <sub>RB</sub> (measured to A <sub>GND</sub> )	+0.5 to V <sub>EEV</sub>
V <sub>RT</sub> (measured to V <sub>RB</sub> )	-2.2 to +2.2V

**Output**

Applied voltage (measured to D <sub>GND</sub> )	-0.5 to +5.5V <sup>2</sup>
Applied current, externally forced	-1.0 to +6.0mA <sup>3,4</sup>
Short circuit duration (single output in high state to ground)	1 sec

**Temperature**

Operating, ambient	-55 to +125°C
junction	+150°C
Lead, soldering (10 seconds)	+300°C
Storage	-65 to +150°C

Notes:

1. Absolute maximum ratings are limiting values applied individually while all other parameters are within specified operating conditions. Functional operation under any of these conditions is NOT implied.
2. Applied voltage must be current limited to specified range.
3. Forcing voltage must be limited to specified range.
4. Current is specified as positive when flowing into the device.

**Operating conditions**

Parameter		Temperature Range						Units
		Standard			Extended			
		Min	Nom	Max	Min	Nom	Max	
V <sub>CC</sub>	Positive Supply Voltage (Measured to D <sub>GND</sub> )	4.75	5.0	5.25	4.5	5.0	5.5	V
V <sub>EE</sub>	Negative Supply Voltage (Measured to A <sub>GND</sub> )	-4.9	-5.2	-5.5	-4.9	-5.2	-5.5	V
V <sub>AGND</sub>	Analog Ground Voltage (Measured to D <sub>GND</sub> )	-0.1	0.0	0.1	-0.1	0.0	0.1	V
t <sub>PWL</sub>	CONV Pulse Width, LOW	17			17			ns
t <sub>PWH</sub>	CONV Pulse Width, HIGH	17			17			ns
V <sub>IL</sub>	Input Voltage, Logic LOW			0.8			0.8	V
V <sub>IH</sub>	Input Voltage, Logic HIGH	2.0			2.0			V
I <sub>OL</sub>	Output Current, Logic LOW			4.0			2.0	mA
I <sub>OH</sub>	Output Current, Logic HIGH			-400			-400	μA
V <sub>RT</sub>	Most Positive Reference	-1.9	0.0	0.1	-1.9	0.0	0.1	V
V <sub>RB</sub>	Most Negative Reference	-2.1	-1.0	-0.1	-2.1	-1.0	-0.1	V
V <sub>RT-V<sub>RB</sub></sub>	Reference Differential	0.2	1.0	2.0	0.2	1.0	2.0	V
V <sub>IN</sub>	Input Voltage	V <sub>RB</sub>		V <sub>RT</sub>	V <sub>RB</sub>		V <sub>RT</sub>	V
T <sub>A</sub>	Ambient Temperature, Still Air	0		70				°C
T <sub>C</sub>	Case Temperature				-55		125	°C

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Electrical characteristics within specified operating conditions

Parameter	Test Conditions	Temperature Range				Units
		Standard		Extended		
		Min	Max	Min	Max	
$I_{CC}$ Positive Supply Current	$V_{CC} - MAX, static^1$		15		20	mA
$I_{EE}$ Negative Supply Current	$V_{EE} - MAX, static^1$ $T_A - 0^\circ C \text{ to } 70^\circ C$ $T_A - 70^\circ C$ $T_C - -55^\circ C \text{ to } 125^\circ C$ $T_C - -125^\circ C$		-50			mA
			-40			mA
					-65	mA
					-35	mA
$I_{REF}$ Reference Current	$V_{RT}, V_{RB} - NOM$		2		2	mA
$R_{REF}$ Total Reference Resistance		500		500		Dhms
$R_{IN}$ Input Equivalent Resistance	$V_{RT}, V_{RB} - NOM, V_{IN} - V_{RB}$	300		100		kOhms
$C_{IN}$ Input Capacitance			25		25	pF
$I_{CB}$ Input Constant Bias Current	$V_{EE} - MAX$		25		50	$\mu A$
$I_{IL}$ Input Current, Logic LOW	$V_{CC} - MAX, V_I - 0.5V \text{ CONV}$ $NMINV, NLINEV$		-0.4		-0.6	mA
			-0.6		-0.8	mA
$I_{IH}$ Input Current, Logic HIGH	$V_{CC} - MAX, V_I - 2.4V$		50		50	$\mu A$
$I_I$ Input Current, Max Input Voltage	$V_{CC} - MAX, V_I - 5.5V$		1.0		1.0	mA
$V_{OL}$ Output Voltage, Logic LOW	$V_{CC} - MIN, I_{OL} - MAX$		0.5		0.5	V
$V_{OH}$ Output Voltage, Logic HIGH	$V_{CC} - MIN, I_{OH} - MAX$	2.4		2.4		V
$I_{OS}$ Short Circuit Output Current	$V_{CC} - MAX, \text{One pin to ground, one second duration, Output HIGH.}$		-30		-30	mA
$C_I$ Digital Input Capacitance	$T_A - 25^\circ C, F - 1MHz$		15		15	pF

Note:

1. Worst case: all digital inputs and outputs LOW.

### Switching characteristics within specified operating conditions

Parameter	Test Conditions	Temperature Range				Units
		Standard		Extended		
		Min	Max	Min	Max	
$F_S$ Maximum Conversion Rate	$V_{CC} - MIN, V_{EE} - MIN$	25		25		MSPS
$t_{STD}$ Sampling Time Offset	$V_{CC} - MIN, V_{EE} - MIN$		10		15	ns
$t_D$ Digital Output Delay	$V_{CC} - MIN, V_{EE} - MIN, \text{Load 1}$		30		35	ns
$t_{HO}$ Digital Output Hold Time	$V_{CC} - MAX, V_{EE} - MAX, \text{Load 1}$	5		5		ns

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System performance characteristics within specified operating conditions

Parameter	Test Conditions	Temperature Range				Units
		Standard		Extended		
		Min	Max	Min	Max	
$E_{LI}$ Linearity Error Integral, Independent	$V_{RB} - NOM$		1.6		1.6	%
$E_{LD}$ Linearity Error Differential			1.6		1.6	%
CS Code Size	$V_{RT}, V_{RB} - NOM$	75	125	75	125	% Nominal
$E_{OT}$ Offset Error Top	$V_{IN} - V_{RT}$		+30		+30	mV
$E_{OB}$ Offset Error Bottom	$V_{IN} - V_{RB}$		+40		+40	mV
$T_{CO}$ Offset Error Temperature Coefficient			±20		±20	μV/°C
BW Bandwidth, Full Power Input		12.5		12.5		MHz
$t_{TR}$ Transient Response, Full Scale			10		10	ns
EAP Aperture Error			30		30	ps

Output Coding Table<sup>1</sup>

Range	Binary		Offset Two's Complement	
	True	Inverted	True	Inverted
-1.00V FS	NMINV - 1 NLINV - 1	0 0	0 1	1 0
0.000V	0000	1111	1000	0111
-0.067V	0001	1110	1001	0110
-0.133V	0010	1101	1010	0101
-0.200V	0011	1100	1011	0100
-0.267V	0100	1011	1100	0011
-0.333V	0101	1010	1101	0010
-0.400V	0110	1001	1110	0001
-0.467V	0111	1000	1111	0000
-0.533V	1000	0111	0000	1111
-0.600V	1001	0110	0001	1110
-0.667V	1010	0101	0010	1101
-0.733V	1011	0100	0011	1100
-0.800V	1100	0011	0100	1011
-0.867V	1101	0010	0101	1010
-0.933V	1110	0001	0110	1001
-1.000V	1111	0000	0111	1000

Note:

1. Input voltages are at code centers.

### Calibration

To calibrate the TDC1044, adjust  $V_{RT}$  and  $V_{RB}$  to set the 1st and 15th thresholds to the desired voltages. Assuming a 0V to -1V desired range, continuously strobe the converter with -0.0033V (1/2 LSB from 0.000V) on the analog input, and adjust  $V_{RT}$  for output toggling between codes 0000 and 0001. Then apply -0.967V (1/2 LSB from -1.000V) and adjust  $V_{RB}$  for toggling between codes 1110 and 1111. Instead of adjusting  $V_{RT}$ ,  $R_T$  can be connected to analog ground and the 0V end of the range calibrated with an amplifier offset control.  $R_B$  is a convenient point for gain adjustment that is not in the analog signal path.

### Typical Interface Circuit

The TDC1044 does not require a special input buffer amplifier to drive the analog input because of its low input capacitance. A terminated low-impedance transmission line (<100 Ohms) connected to the  $V_{IN}$  terminal of the device is sufficient if the input voltage levels match those of the A/D converter.

However, many driver circuits lack sufficient offset control, drive current, or gain stability. The *Typical Interface Circuit* in *Figure 5* shows a simple amplifier and voltage reference circuit that may be used with the device. U2 is a wide-band operational amplifier with a

gain factor of -1. A small value resistor, R12, serves to isolate the small input capacitance of the A/D converter from the amplifier output and insure frequency stability. The pulse and frequency response of the amplifier are optimized by variable capacitor C12. The reference voltage for the TDC1044 is generated by amplifier U3. System gain is adjusted by varying R9 which controls the reference voltage level to the A/D converter.

Input voltage range and input impedance for the circuit are determined by resistors R1 and R2. Formulas for calculating values for these input resistors are:

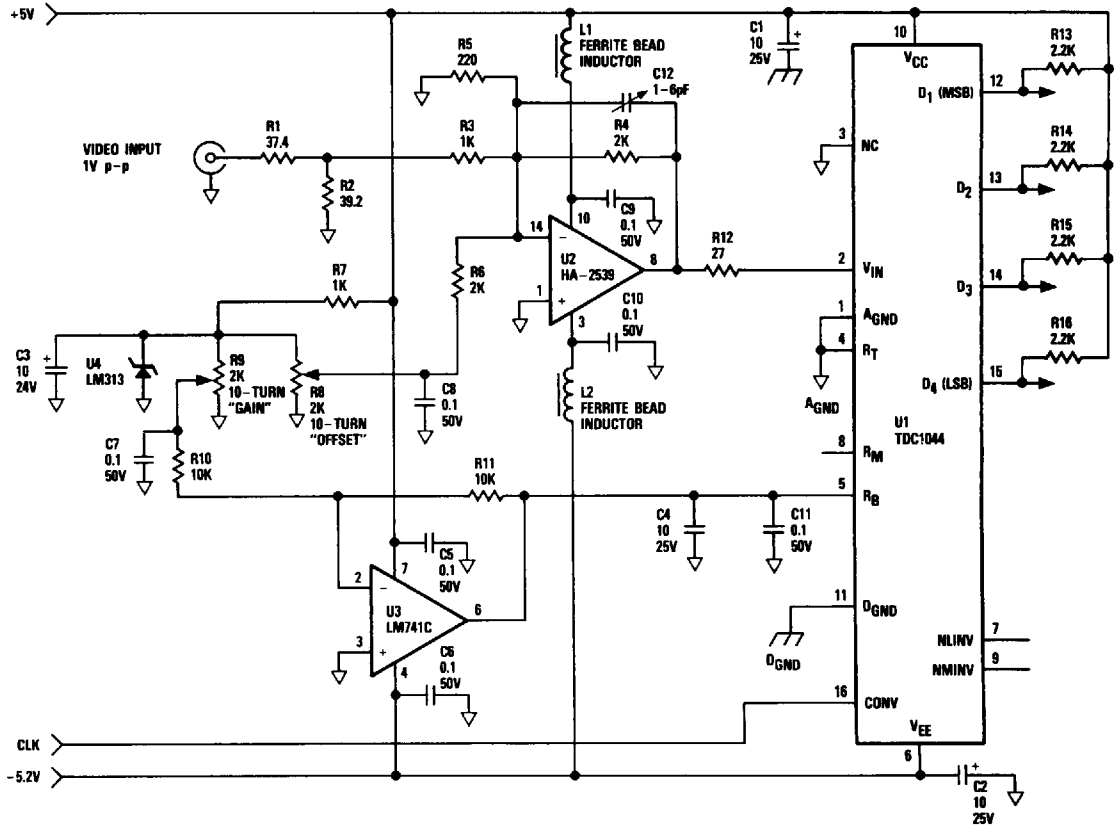
$$R1 = \frac{1}{\left(\frac{2VR}{Z_{IN}}\right) - \frac{1}{1000}}$$

and

$$R2 = Z_{IN} - \left(\frac{1000 R1}{1000 + R1}\right)$$

where VR is the input voltage range of the circuit,  $Z_{IN}$  is the input impedance of the circuit, and the constant 1000 comes from the value of R3. As shown, the circuit is set up for 1Vp-p 75 Ohm video input.

Figure 5. Typical Interface Circuit



Ordering Information

Product Number	Temperature Range	Screening	Package	Package Marking
TDC1044B9C	STD - T <sub>A</sub> = 0°C to 70°C	Commercial	16-Pin DIP	1044B9C
TDC1044B9V	EXT - T <sub>C</sub> = -55°C to 125°C	MIL-STD-883	16-Pin DIP	1044B9V
TDC1044N9C	STD - T <sub>A</sub> = 0°C to 70°C	Commercial	16-Pin Plastic DIP	1044N9C
TDC1044R4C	STD - T <sub>A</sub> = 0°C to 70°C	Commercial	20-Lead PLCC	1044R4C

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