FAIRCHILD SEMICONDUCTOR™

August 1993
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# 74VHC161
# 4-Bit Binary Counter with Asynchronous Clear

## General Description

The VHC161 is an advanced high-speed CMOS device fabricated with silicon gate CMOS technology. It achieves the high-speed operation similar to equivalent Bipolar Schottky TTL while maintaining the CMOS low power dissipation. The VHC161 is a high-speed synchronous modulo-16 binary counter. This device is synchronously presettable for application in programmable dividers and have two types of Count Enable inputs plus a Terminal Count output for versatility in forming synchronous multistage counters. The VHC161 has an asynchronous Master Reset input that overrides all other inputs and forces the outputs LOW. An input protection circuit insures that 0V to 7V can be applied to the input pins without regard to the supply voltage. This device can be used to interface 5V to 3V systems and two supply systems such as battery backup. This circuit prevents device destruction due to mismatched supply and input voltages.

## Features

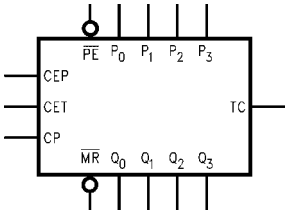
- High Speed:
  $f_{MAX}$ = 185 MHz (typ) at $T_A$ = 25°C
- Synchronous counting and loading
- High-speed synchronous expansion
- Low power dissipation:
  $I_{CC}$ = 4 μA (max) at $T_A$ = 25°C
- High noise immunity: $V_{NIH} = V_{NIL}$ = 28% $V_{CC}$ (min)
- Power down protection provided on all inputs
- Low noise: $V_{OLP}$ = 0.8V (max)
- Pin and function compatible with 74HC161

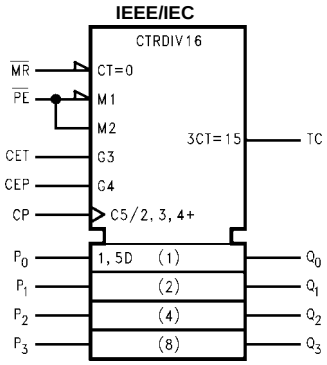
## Ordering Code:

| Order Number | Package Number | Package Description |
|---|---|---|
| 74VHC161M | M16A | 16-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150 Narrow |
| 74VHC161SJ | M16D | 16-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide |
| 74VHC161MTC | MTC16 | 16-Lead Thin Shrink Small Outline Package (TSSOP), JEDEC MO-153, 4.4mm Wide |
| 74VHC161N | N16E | 16-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide |

Surface mount packages are also available on Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

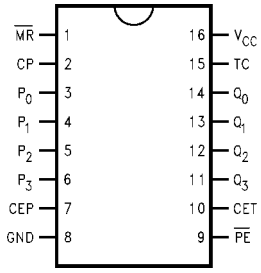
## Logic Symbols



## Connection Diagram




## Pin Descriptions

| Pin Names | Description |
|---|---|
| CEP | Count Enable Parallel Input |
| CET | Count Enable Trickle Input |
| CP | Clock Pulse Input |
| $\overline{MR}$ | Asynchronous Master Reset Input |
| $P_0$–$P_3$ | Parallel Data Inputs |
| $\overline{PE}$ | Parallel Enable Inputs |
| $Q_0$–$Q_3$ | Flip-Flop Outputs |
| TC | Terminal Count Output |

## Functional Description

The VHC161 counts in modulo-16 binary sequence. From state 15 (HHHH) it increments to state 0 (LLLL). The clock inputs of all flip-flops are driven in parallel through a clock buffer. Thus all changes of the Q outputs (except due to Master Reset of the VHC161) occur as a result of, and synchronous with, the LOW-to-HIGH transition of the CP input signal. The circuits have four fundamental modes of operation, in order of precedence: asynchronous reset, parallel load, count-up and hold. Five control inputs—Master Reset, Parallel Enable ($\overline{PE}$), Count Enable Parallel (CEP) and Count Enable Trickle (CET)—determine the mode of operation, as shown in the Mode Select Table. A LOW signal on $\overline{MR}$ overrides all other inputs and asynchronously forces all outputs LOW. A LOW signal on $\overline{PE}$ overrides counting and allows information on the Parallel Data ($P_n$) inputs to be loaded into the flip-flops on the next rising edge of CP. With $\overline{PE}$ and $\overline{MR}$ HIGH, CEP and CET permit counting when both are HIGH. Conversely, a LOW signal on either CEP or CET inhibits counting.

The VHC161 uses D-type edge-triggered flip-flops and changing the $\overline{PE}$, CEP and CET inputs when the CP is in either state does not cause errors, provided that the recommended setup and hold times, with respect to the rising edge of CP, are observed.

The Terminal Count (TC) output is HIGH when CET is HIGH and counter is in state 15. To implement synchronous multistage counters, the TC outputs can be used with the CEP and CET inputs in two different ways.

*Figure 1* shows the connections for simple ripple carry, in which the clock period must be longer than the CP to TC delay of the first stage, plus the cumulative CET to TC delays of the intermediate stages, plus the CET to CP setup time of the last stage. This total delay plus setup time sets the upper limit on clock frequency. For faster clock rates, the carry lookahead connections shown in *Figure 2* are recommended. In this scheme the ripple delay through the intermediate stages commences with the same clock that causes the first stage to tick over from max to min in the Up mode, or min to max in the Down mode, to start its final cycle. Since this final cycle requires 16 clocks to complete, there is plenty of time for the ripple to progress through the intermediate stages. The critical timing that limits the clock period is the CP to TC delay of the first stage plus the CEP to CP setup time of the last stage. The TC output is subject to decoding spikes due to internal race conditions and is therefore not recommended for use as a clock or asynchronous reset for flip-flops, registers or counters.

Logic Equations: Count Enable = CEP • CET • $\overline{PE}$

$TC = Q_0 \cdot Q_1 \cdot Q_2 \cdot Q_3 \cdot CET$

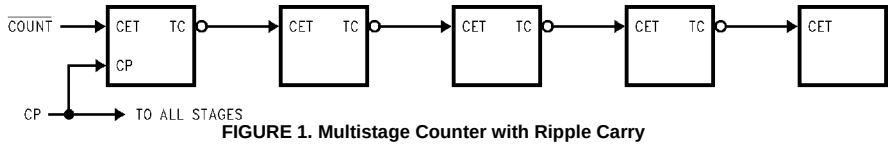



**FIGURE 1. Multistage Counter with Ripple Carry**

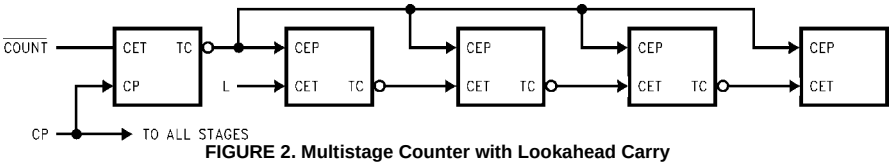


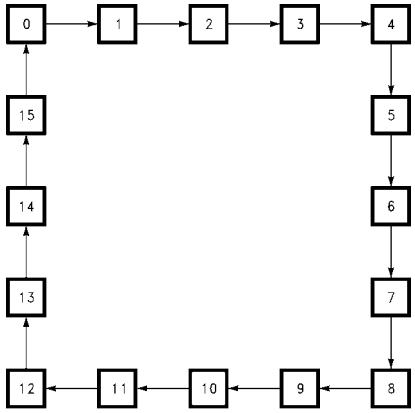

**FIGURE 2. Multistage Counter with Lookahead Carry**

## Mode Select Table

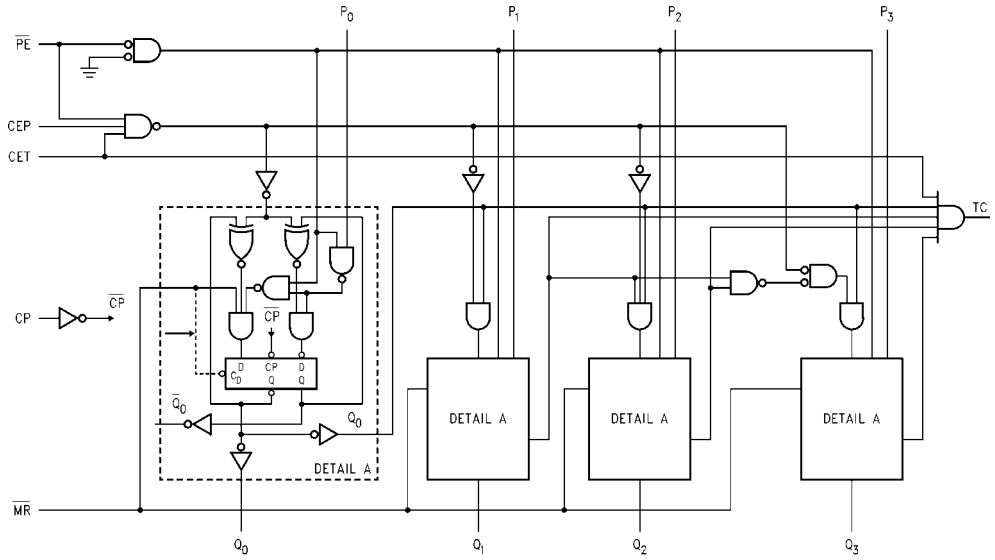
| $\overline{MR}$ | $\overline{PE}$ | CET | CEP | Action on the Rising Clock Edge (⌐) |
|---|---|---|---|---|
| L | X | X | X | Reset (Clear) |
| H | L | X | X | Load ($P_n \rightarrow Q_n$) |
| H | H | H | H | Count (Increment) |
| H | H | L | X | No Change (Hold) |
| H | H | X | L | No Change (Hold) |

H = HIGH Voltage Level
L = LOW Voltage Level
X = Immaterial

## State Diagram




## Block Diagram




Please note that this diagram is provided only for the understanding of logic operations and should not be used to estimate propagation delays.

## Absolute Maximum Ratings (Note 1)

| | |
|---|---|
| Supply Voltage ($V_{CC}$) | −0.5V to +7.0V |
| DC Input Voltage ($V_{IN}$) | −0.5V to +7.0V |
| DC Output Voltage ($V_{OUT}$) | −0.5V to $V_{CC}$ + 0.5V |
| Input Diode Current ($I_{IK}$) | −20 mA |
| Output Diode Current ($I_{OK}$) | ±20 mA |
| DC Output Current ($I_{OUT}$) | ±25 mA |
| DC $V_{CC}$/GND Current ($I_{CC}$) | ±50 mA |
| Storage Temperature ($T_{STG}$) | −65°C to +150°C |
| Lead Temperature ($T_L$) | |
| (Soldering, 10 seconds) | 260°C |

## Recommended Operating Conditions (Note 2)

| | |
|---|---|
| Supply Voltage ($V_{CC}$) | 2.0V to +5.5V |
| Input Voltage ($V_{IN}$) | 0V to +5.5V |
| Output Voltage ($V_{OUT}$) | 0V to $V_{CC}$ |
| Operating Temperature ($T_{OPR}$) | −40°C to +85°C |
| Input Rise and Fall Time ($t_r$, $t_f$) | |
| $V_{CC}$ = 3.3V ± 0.3V | 0 ~ 100 ns/V |
| $V_{CC}$ = 5.0V ± 0.5V | 0 ~ 20 ns/V |

**Note 1:** Absolute Maximum Ratings are values beyond which the device may be damaged or have its useful life impaired. The databook specifications should be met, without exception, to ensure that the system design is reliable over its power supply, temperature, and output/input loading variables. Fairchild does not recommend operation outside databook specifications.

**Note 2:** Unused inputs must be held HIGH or LOW. They may not float.

## DC Electrical Characteristics

| Symbol | Parameter | $V_{CC}$ (V) | $T_A$ = 25°C | | | $T_A$ = −40°C to +85°C | | Units | Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Max | | | |
| $V_{IH}$ | HIGH Level Input Voltage | 2.0 | 1.50 | | | 1.50 | | V | | |
| | | 3.0 – 5.5 | 0.7 $V_{CC}$ | | | 0.7 $V_{CC}$ | | | | |
| $V_{IL}$ | LOW Level Input Voltage | 2.0 | | | 0.50 | | 0.50 | V | | |
| | | 3.0 – 5.5 | | | 0.3 $V_{CC}$ | | 0.3 $V_{CC}$ | | | |
| $V_{OH}$ | HIGH Level Output Voltage | 2.0 | 1.9 | 2.0 | | 1.9 | | V | $V_{IN}$ = $V_{IH}$ or $V_{IL}$ | $I_{OH}$ = −50 µA |
| | | 3.0 | 2.9 | 3.0 | | 2.9 | | | | |
| | | 4.5 | 4.4 | 4.5 | | 4.4 | | | | |
| | | 3.0 | 2.58 | | | 2.48 | | V | | $I_{OH}$ = −4 mA |
| | | 4.5 | 3.94 | | | 3.80 | | | | $I_{OH}$ = −8 mA |
| $V_{OL}$ | LOW Level Output Voltage | 2.0 | | 0.0 | 0.1 | | 0.1 | V | $V_{IN}$ = $V_{IH}$ or $V_{IL}$ | $I_{OL}$ = 50 µA |
| | | 3.0 | | 0.0 | 0.1 | | 0.1 | | | |
| | | 4.5 | | 0.0 | 0.1 | | 0.1 | | | |
| | | 3.0 | | | 0.36 | | 0.44 | V | | $I_{OL}$ = 4 mA |
| | | 4.5 | | | 0.36 | | 0.44 | | | $I_{OL}$ = 8 mA |
| $I_{IN}$ | Input Leakage Current | 0 – 5.5 | | | ±0.1 | | ±1.0 | µA | $V_{IN}$ = 5.5V or GND | |
| $I_{CC}$ | Quiescent Supply Current | 5.5 | | | 4.0 | | 40.0 | µA | $V_{IN}$ = $V_{CC}$ or GND | |

## Noise Characteristics

| Symbol | Parameter | $V_{CC}$ (V) | $T_A$ = 25°C | | Units | Conditions |
|---|---|---|---|---|---|---|
| | | | Typ | Limits | | |
| $V_{OLP}$ (Note 3) | Quiet Output Maximum Dynamic $V_{OL}$ | 5.0 | 0.4 | 0.8 | V | $C_L$ = 50 pF |
| $V_{OLV}$ (Note 3) | Quiet Output Minimum Dynamic $V_{OL}$ | 5.0 | −0.4 | −0.8 | V | $C_L$ = 50 pF |
| $V_{IHD}$ (Note 3) | Minimum HIGH Level Dynamic Input Voltage | 5.0 | | 3.5 | V | $C_L$ = 50 pF |
| $V_{ILD}$ (Note 3) | Maximum LOW Level Dynamic Input Voltage | 5.0 | | 1.5 | V | $C_L$ = 50 pF |

**Note 3:** Parameter guaranteed by design.

## AC Electrical Characteristics

| Symbol | Parameter | $V_{CC}$ (V) | $T_A = 25°C$ | | | $T_A = -40°$ to $+85°C$ | | Units | Conditions |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Max | | |
| $t_{PLH}$ $t_{PHL}$ | Propagation Delay Time (CP–$Q_n$) | 3.3 ± 0.3 | | 8.3 | 12.8 | 1.0 | 15.0 | ns | $C_L$ = 15 pF |
| | | | | 10.8 | 16.3 | 1.0 | 18.5 | | $C_L$ = 50 pF |
| | | 5.0 ± 0.5 | | 4.9 | 8.1 | 1.0 | 9.5 | ns | $C_L$ = 15 pF |
| | | | | 6.4 | 10.1 | 1.0 | 11.5 | | $C_L$ = 50 pF |
| $t_{PLH}$ $t_{PHL}$ | Propagation Delay Time (CP–TC, Count) | 3.3 ± 0.3 | | 8.7 | 13.6 | 1.0 | 16.0 | ns | $C_L$ = 15 pF |
| | | | | 11.2 | 17.1 | 1.0 | 19.5 | | $C_L$ = 50 pF |
| | | 5.0 ± 0.5 | | 4.9 | 8.1 | 1.0 | 9.5 | ns | $C_L$ = 15 pF |
| | | | | 6.4 | 10.1 | 1.0 | 11.5 | | $C_L$ = 50 pF |
| $t_{PLH}$ $t_{PHL}$ | Propagation Delay Time (CP–TC, Load) | 3.3 ± 0.3 | | 11.0 | 17.2 | 1.0 | 20.0 | ns | $C_L$ = 15 pF |
| | | | | 13.5 | 20.7 | 1.0 | 23.5 | | $C_L$ = 50 pF |
| | | 5.0 ± 0.5 | | 6.2 | 10.3 | 1.0 | 12.0 | ns | $C_L$ = 15 pF |
| | | | | 7.7 | 12.3 | 1.0 | 14.0 | | $C_L$ = 50 pF |
| $t_{PLH}$ $t_{PHL}$ | Propagation Delay Time (CET–TC) | 3.3 ± 0.3 | | 7.5 | 12.3 | 1.0 | 14.5 | ns | $C_L$ = 15 pF |
| | | | | 10.5 | 15.8 | 1.0 | 18.0 | | $C_L$ = 50 pF |
| | | 5.0 ± 0.5 | | 4.9 | 8.1 | 1.0 | 9.5 | ns | $C_L$ = 15 pF |
| | | | | 6.4 | 10.1 | 1.0 | 11.5 | | $C_L$ = 50 pF |
| $t_{PHL}$ | Propagation Delay Time ($\overline{MR}$ –$Q_n$) | 3.3 ± 0.3 | | 8.9 | 13.6 | 1.0 | 16.0 | ns | $C_L$ = 15 pF |
| | | | | 11.2 | 17.1 | 1.0 | 19.5 | | $C_L$ = 50 pF |
| | | 5.0 ± 0.5 | | 5.5 | 9.0 | 1.0 | 10.5 | ns | $C_L$ = 15 pF |
| | | | | 7.0 | 11.0 | 1.0 | 12.5 | | $C_L$ = 50 pF |
| $t_{PHL}$ | Propagation Delay Time ($\overline{MR}$ –TC) | 3.3 ± 0.3 | | 8.4 | 13.2 | 1.0 | 15.5 | ns | $C_L$ = 15 pF |
| | | | | 10.9 | 16.7 | 1.0 | 19.0 | | $C_L$ = 50 pF |
| | | 5.0 ± 0.5 | | 5.0 | 8.6 | 1.0 | 10.0 | ns | $C_L$ = 15 pF |
| | | | | 6.5 | 10.6 | 1.0 | 12.0 | | $C_L$ = 50 pF |
| $f_{MAX}$ | Maximum Clock Frequency | 3.3 ± 0.3 | 80 | 130 | | 70 | | MHz | $C_L$ = 15 pF |
| | | | 55 | 85 | | 50 | | | $C_L$ = 50 pF |
| | | 5.0 ± 0.5 | 135 | 185 | | 115 | | MHz | $C_L$ = 15 pF |
| | | | 95 | 125 | | 85 | | | $C_L$ = 50 pF |
| $C_{IN}$ | Input Capacitance | | | 4 | 10 | | 10 | pF | $V_{CC}$ = Open |
| $C_{PD}$ | Power Dissipation Capacitance | | | 23 | | | | pF | (Note 4) |

**Note 4:** $C_{PD}$ is defined as the value of the internal equivalent capacitance which is calculated from the operating current consumption without load. Average operating current can be obtained by the equation: $I_{CC}$ (opr) = $C_{PD}$ * $V_{CC}$ * $f_{IN}$ + $I_{CC}$.

When the outputs drive a capacitive load, total current consumption is the sum of $C_{PD}$, and $\Delta I_{CC}$ which is obtained from the following formula:

$$\Delta I_{CC} = F_{CP} \bullet V_{CC} \left( \frac{C_{Q0}}{2} + \frac{C_{Q1}}{4} + \frac{C_{Q2}}{8} + \frac{C_{Q3}}{16} + \frac{C_{TC}}{16} \right)$$

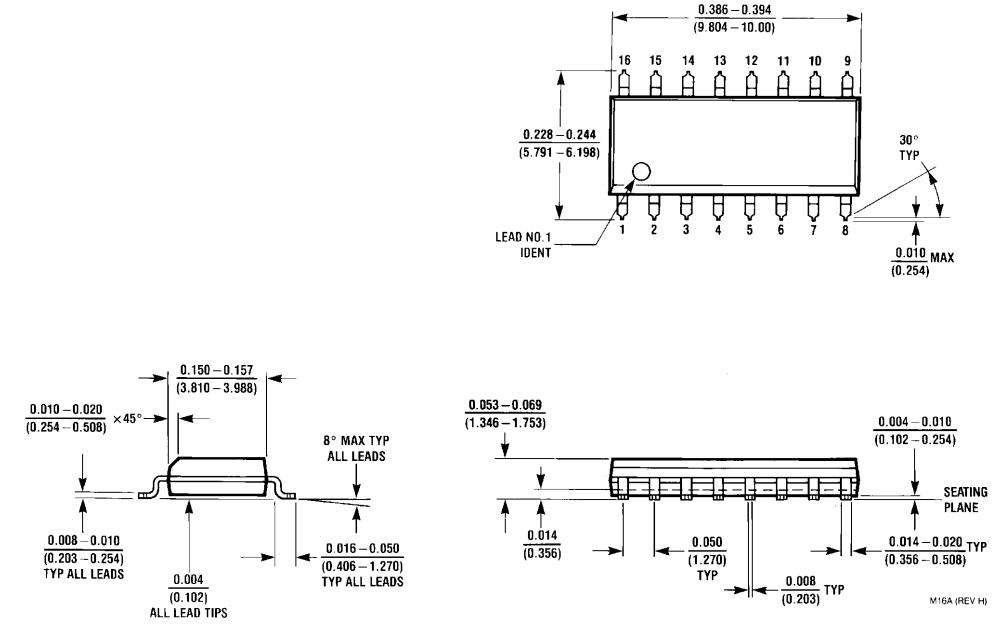
$C_{Q0}$–$C_{Q3}$ and $C_{TC}$ are the capacitances at Q0–Q3 and TC, respectively. $F_{CP}$ is the input frequency of the CP.

## AC Operating Requirements

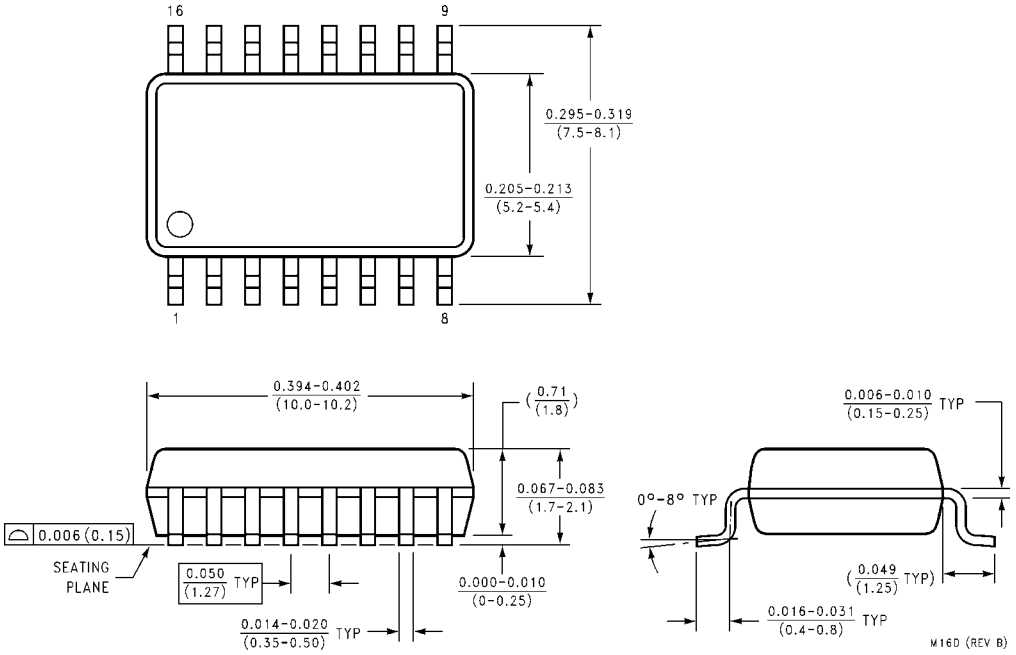
| Symbol | Parameter | $V_{CC}$ (Note 5) (V) | $T_A = 25°C$ | $T_A = -40°C$ to $+85°C$ | | Units |
|---|---|---|---|---|---|---|
| | | | Typ | Guaranteed Minimum | | |
| $t_S$ | Minimum Setup Time | 3.3 | | 5.5 | 6.5 | ns |
| | ($P_n$–CP) | 5.0 | | 4.5 | 4.5 | |
| $t_S$ | Minimum Setup Time | 3.3 | | 8.0 | 9.5 | ns |
| | ($\overline{PE}$ –CP) | 5.0 | | 5.0 | 6.0 | |
| $t_S$ | Minimum Setup Time | 3.3 | | 7.5 | 9.0 | ns |
| | (CEP or CET–CP) | 5.0 | | 5.0 | 6.0 | |
| $t_H$ | Minimum Hold Time | 3.3 | | 1.0 | 1.0 | ns |
| | ($P_n$–CP) | 5.0 | | 1.0 | 1.0 | |
| $t_H$ | Minimum Hold Time | 3.3 | | 1.0 | 1.0 | ns |
| | ($\overline{PE}$ –CP) | 5.0 | | 1.0 | 1.0 | |
| $t_H$ | Minimum Hold Time | 3.3 | | 1.0 | 1.0 | ns |
| | (CEP or CET–CP) | 5.0 | | 1.0 | 1.0 | |
| $t_W(L)$ | Minimum Pulse Width | 3.3 | | 5.0 | 5.0 | ns |
| $t_W(H)$ | CP (Count) | 5.0 | | 5.0 | 5.0 | |
| $t_W(L)$ | Minimum Pulse Width | 3.3 | | 5.0 | 5.0 | ns |
| | ($\overline{MR}$) | 5.0 | | 5.0 | 5.0 | |
| $t_{REC}$ | Minimum Removal | 3.3 | | 2.5 | 2.5 | ns |
| | Time | 5.0 | | 1.5 | 1.5 | |

**Note 5:** $V_{CC}$ is 3.3 ± 0.3V or 5.0 ± 0.5V

## Physical Dimensions inches (millimeters) unless otherwise noted

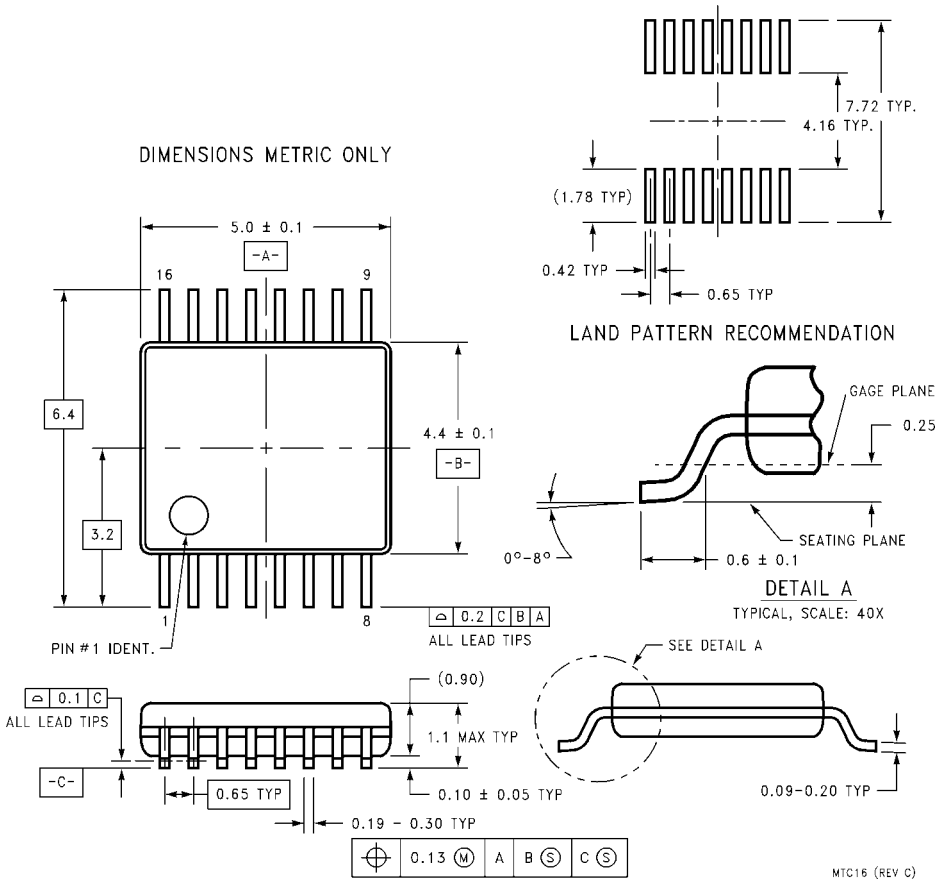



**16-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150 Narrow**
**Package Number M16A**



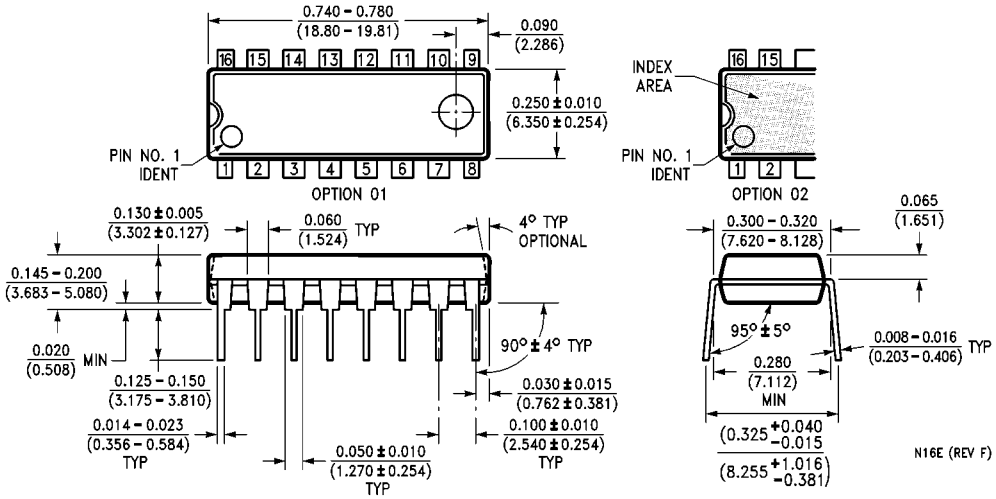

**16-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide**
**Package Number M16D**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)




**16-Lead Thin Shrink Small Outline Package (TSSOP), JEDEC MO-153, 4.4mm Wide**
**Package Number MTC16**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)




**16-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide**
**Package Number N16E**