# MAX3394E/MAX3395E/ MAX3396E

# ±15kV ESD-Protected, High-Drive Current, Dual-/Quad-/Octal-Level Translators with Speed-Up Circuitry

## General Description

The MAX3394E/MAX3395E/MAX3396E bidirectional level translators provide level shifting required for data transfer in a multivoltage system. Internal slew-rate enhancement circuitry features 10mA current-sink and 15mA current-source drivers to isolate capacitive loads from lower current drivers. In open-drain systems, slew-rate enhancement enables fast data rates with larger pullup resistors and increased bus load capacitance. Externally applied voltages, $V_{CC}$ and $V_L$, set the logic-high levels for the device. A logic-low signal on one I/O side of the device appears as a logic-low signal on the opposite I/O side, and vice-versa. Each I/O line is pulled up to $V_{CC}$ or $V_L$ by an internal pullup resistor, allowing the devices to be driven by either push-pull or open-drain drivers.

The MAX3394E/MAX3395E/MAX3396E feature a tri-state output mode, thermal-shutdown protection, and ±15kV Human Body Model (HBM) ESD protection on the $V_{CC}$ side for greater protection in applications that route signals externally.

The MAX3394E/MAX3395E/MAX3396E accept $V_{CC}$ voltages from +1.65V to +5.5V, and $V_L$ voltages from +1.2V to $V_{CC}$, making them ideal for data transfer between low voltage ASIC/PLDs and higher voltage systems. The MAX3394E/MAX3395E/MAX3396E operate at a guaranteed data rate of 6Mbps with push-pull drivers and 1Mbps with open-drain drivers.

The MAX3394E is a dual-level translator available in 9-bump UCSP™ and 8-pin 3mm x 3mm TDFN packages. The MAX3395E is a quad-level translator available in 12-bump UCSP, and 12-pin 4mm x 4mm TQFN packages. The MAX3396E is an octal-level translator available in 20-bump UCSP and 20-pin 5mm x 5mm TQFN packages. The MAX3394E/MAX3395E/MAX3396E operate over the extended -40°C to +85°C temperature range.

## Applications

- Multivoltage Bidirectional Level Translation
- SPI™, MICROWIRE™, and I²C Level Translation
- Open-Drain Rise-Time Speed-Up
- High-Speed Bus Fan-Out Expansion
- Cell Phones
- Telecom, Networking, Servers, RAID/SAN

*MICROWIRE is a trademark of National Semiconductor Corp.*

*SPI is a trademark of Motorola, Inc.*

*UCSP is a trademark of Maxim Integrated Products, Inc.*

## Features

- ±15kV ESD Protection on I/O $V_{CC\_}$ Lines
- Bidirectional Level Translation Without Direction Pin
- I/O $V_{L\_}$ and I/O $V_{CC\_}$ 10mA Sink-/15mA Source-Current Capability
- Slew-Rate Enhancement Circuitry Supports
- Larger Capacitive Loads or Larger External Pullup Resistors
- 6Mbps Push-Pull/1Mbps Open-Drain Guaranteed Data Rate
- Wide Supply-Voltage Range: Operation Down to +1.2V on $V_L$ and +1.65V on $V_{CC}$
- Low Supply Current in Tri-State Output Mode (3µA typ)
- Low Quiescent Current
- Thermal-Shutdown Protection
- UCSP, TDFN, and TQFN Packages

## Ordering Information

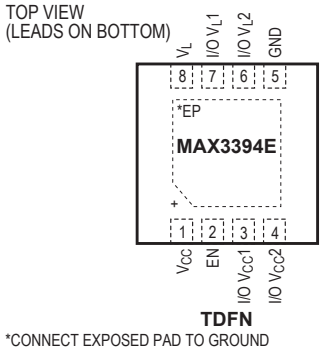
| PART | PIN-PACKAGE | PKG CODE |
|---|---|---|
| **MAX3394E**ETA+T | 8 TDFN-EP** | T833-1 |
| MAX3394EEBL+T | 9 UCSP | B9-5 |
| **MAX3395E**ETC+ | 12 TQFN-EP** | T1244-4 |
| MAX3395EEBC+T | 12 UCSP | B12-1 |
| **MAX3396E**EBP+T* | 20 UCSP | B20-1 |
| MAX3396EETP+* | 20 TQFN-EP** | T2055-4 |

***Note:*** *All devices specified over the -40°C to +85°C operating range.*

*+Denotes lead(Pb)-free/RoHS-compliant package.*
**Future product—contact factory for availability.*
***EP = Exposed paddle.*

***Selector Guide appears at end of data sheet.***

## Pin Configurations




*Pin Configurations continued at end of data sheet.*

*19-3884; Rev 3; 7/17*

## Absolute Maximum Ratings

(All voltages referenced to GND.)
$V_{CC}$ ..... -0.3V to +6V
$V_L$ ..... -0.3V to +6V
I/O $V_{CC\_}$ ..... -0.3V to $V_{CC}$ + 0.3V
I/O $V_{L\_}$ ..... -0.3V to $V_L$ + 0.3V
EN ..... -0.3V to +6V
Short-Circuit Duration I/O $V_{L\_}$, I/O $V_{CC\_}$ to GND ..... Continuous
Maximum Continuous Current ..... ±50mA
Continuous Power Dissipation ($T_A$ = +70°C)
8-Pin TDFN (derate 18.2mW/°C above +70°C) ..... 1455mW
9-Bump UCSP (derate 4.7mW/°C above +70°C) ..... 379mW
12-Pin TQFN (derate 16.9mW/°C above +70°C) ..... 1349mW
12-Bump UCSP (derate 6.5mW/°C above +70°C) ..... 519mW
20-Pin TQFN (derate 20.8mW/°C above +70°C) ..... 1667mW
20-Bump UCSP (derate 10.0mW/°C above +70°C) ..... 800mW
Operating Temperature Range ..... -40°C to +85°C
Storage Temperature Range ..... -65°C to +150°C
Junction Temperature ..... +150°C
Bump Temperature (soldering) ..... +235°C
Lead Temperature (soldering, 10s) ..... +300°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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

## Electrical Characteristics

($V_{CC}$ = +1.65V to +5.5V, $V_L$ = +1.2V to $V_{CC}$; $C_{IOVL}$ ≤ 15pF, $C_{IOVCC}$ ≤ 15pF; $T_A$ = -40°C to +85°C, unless otherwise noted. Typical values are at $T_A$ = +25°C.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **POWER SUPPLY** | | | | | | | |
| $V_L$ Supply Range | $V_L$ | | | 1.2 | | $V_{CC}$ | V |
| $V_{CC}$ Supply Range | $V_{CC}$ | | | 1.65 | | 5.50 | V |
| Supply Current from $V_{CC}$ | $I_{CC}$ | I/O lines internally pulled up | MAX3394E | | | 150 | µA |
| | | | MAX3395E | | | 300 | |
| | | | MAX3396E | | | 600 | |
| Supply Current from $V_L$ | $I_L$ | I/O lines internally pulled up | MAX3394E | | | 30 | µA |
| | | | MAX3395E | | | 30 | |
| | | | MAX3396E | | | 30 | |
| $V_{CC}$ Tri-State Supply Current | $I_{CC-3}$ | EN = GND, $T_A$ = +25°C | | | 3 | 6 | µA |
| $V_L$ Tri-State Supply Current | $I_{L-3}$ | EN = GND, $T_A$ = +25°C | | | 0.7 | 2 | µA |
| **LOGIC I/O** | | | | | | | |
| I/O $V_{L\_}$ Input-Voltage High Threshold | $V_{IHL}$ | | | 0.7 x $V_L$ | | | V |
| I/O $V_{L\_}$ Input-Voltage Low Threshold | $V_{ILL}$ | | | | | 0.3 x $V_L$ | V |
| I/O $V_{L\_}$ Internal Pullup DC Resistance | $R_L$ | EN = $V_{CC}$ or $V_L$ | | 5 | 10 | 20 | kΩ |
| I/O $V_{L\_}$ Source Current During Low-to-High Transition | $I_{IHL}$ | $V_L$ = +1.2V | | | 15 | | mA |
| I/O $V_{L\_}$ Sink Current During High-to-Low Transition | $I_{ILL}$ | $V_{CC}$ = +1.65V | | | 10 | | mA |

## Electrical Characteristics (continued)

($V_{CC}$ = +1.65V to +5.5V, $V_L$ = +1.2V to $V_{CC}$; $C_{IOVL}$ ≤ 15pF, $C_{IOVCC}$ ≤ 15pF; $T_A$ = -40°C to +85°C, unless otherwise noted. Typical values are at $T_A$ = +25°C.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| I/O $V_{L\_}$ Low-to-High Transition Threshold | $V_{L-TH}$ | $V_{CC}$ = +3.3V, $V_L$ = +1.8V | 0.3 x $V_L$ | 0.5 x $V_L$ | | V |
| I/O $V_{L\_}$ Output-Voltage Low | $V_{OLL}$ | I/O $V_{L\_}$ sink current = 5mA, $V_{ILC}$ = 0V | | | 0.25 | V |
| | | I/O $V_{L\_}$ sink current = 10mA, $V_{ILC}$ ≤ 0.4V or 0.2 x $V_L$ | | | $V_{ILC}$ + 0.4V | |
| I/O $V_{L\_}$ Tri-State Output Leakage Current | | EN = GND, $T_A$ = +25°C | -1 | | +1 | µA |
| I/O $V_{CC\_}$ Input-Voltage High Threshold | $V_{IHC}$ | (Note 2) | 0.7 x $V_{CC}$ | | | V |
| I/O $V_{CC\_}$ Input-Voltage Low Threshold | $V_{ILC}$ | (Note 2) | | | 0.3 x $V_{CC}$ | V |
| I/O $V_{CC\_}$ Internal Pullup DC Resistance | $R_{CC}$ | EN = $V_{CC}$ or $V_L$ | 5 | 10 | 20 | kΩ |
| I/O $V_{CC\_}$ Source Current During Low-to-High Transition | $I_{IHCC}$ | $V_{CC}$ = +1.65V | | 15 | | mA |
| I/O $V_{CC\_}$ Sink Current During High-to-Low Transition | $I_{ILCC}$ | $V_{CC}$ = +1.65V | | 10 | | mA |
| I/O $V_{CC\_}$ Low-to-High Transition Threshold | $V_{CC-TH}$ | $V_{CC}$ = +3.3V, $V_L$ = +1.8V | 0.3 x $V_{CC}$ | 0.5 x $V_{CC}$ | | V |
| I/O $V_{CC\_}$ Output-Voltage Low | $V_{OLC}$ | I/O $V_{CC\_}$ sink current = 5mA, $V_{ILL}$ = 0V | | | 0.25 | V |
| | | I/O $V_{CC\_}$ sink current = 10mA, $V_{ILL}$ ≤ 0.4V or 0.2 x $V_L$ | | | $V_{ILL}$ + 0.4V | |
| I/O $V_{CC\_}$ Tri-State Output Leakage Current | | EN = GND, $T_A$ = +25°C | -1 | | +1 | µA |
| EN Input-Voltage High Threshold | $V_{IHE}$ | | 0.7 x $V_L$ | | | V |
| EN Input-Voltage Low Threshold | $V_{ILE}$ | | | | 0.3 x $V_L$ | V |
| EN Pin Input Leakage Current | | $T_A$ = +25°C | -1 | | +1 | µA |
| **ESD PROTECTION** | | | | | | |
| I/O $V_{CC\_}$ ESD Protection | | $C_{VCC}$ = 1µF, Human Body Model | | ±15 | | kV |

## Timing Characteristics

($V_{CC}$ = +1.65V to +5.5V, $V_L$ = +1.2V to $V_{CC}$; $C_{IOVL}$ ≤ 15pF, $C_{IOVCC}$ ≤ 15pF; $T_A$ = -40°C to +85°C, unless otherwise noted. Typical values are at $T_A$ = +25°C.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| I/O $V_{CC\_}$ Rise Time | $t_{RVCC}$ | Push-pull driver, Figure 1 | | | 50 | ns |
| | | Open-drain driver, internal pullup, Figure 2 | | | 500 | |
| I/O $V_{CC\_}$ Fall Time | $t_{FVCC}$ | Push-pull driver, Figure 1 | | | 50 | ns |
| | | Open-drain driver, internal pullup, Figure 2 | | | 50 | |
| I/O $V_{L\_}$ Rise Time | $t_{RVL}$ | Push-pull driver, Figure 3 | | | 50 | ns |
| | | Open-drain driver, internal pullup, Figure 4 | | | 500 | |
| I/O $V_{L\_}$ Fall Time | $t_{FVL}$ | Push-pull driver, Figure 3 | | | 50 | ns |
| | | Open-drain driver, internal pullup, Figure 4 | | | 50 | |
| Propagation Delay | $t_{I/OVL-VCC}$ | Push-pull driver, Figure 1 | | | 50 | ns |
| | | Open-drain driver, internal pullup, Figure 2 | | | 600 | |
| | $t_{I/OVCC-VL}$ | Push-pull driver, Figure 3 | | | 50 | |
| | | Open-drain driver, internal pullup, Figure 4 | | | 600 | |
| Propagation Delay After EN | $t_{EN}$ | Push-pull or open-drain driver, Figure 5 | | | 5 | µs |
| Channel-to-Channel Skew | $t_{SKEW}$ | Push-pull driver | | | 5 | ns |
| | | Open-drain driver, internal pullup | | | 100 | |
| Maximum Data Rate | | Push-pull driver, Figures 1, 3 | | | 6 | Mbps |
| | | Open-drain driver, internal pullup, Figures 2, 4 | | | 1 | |

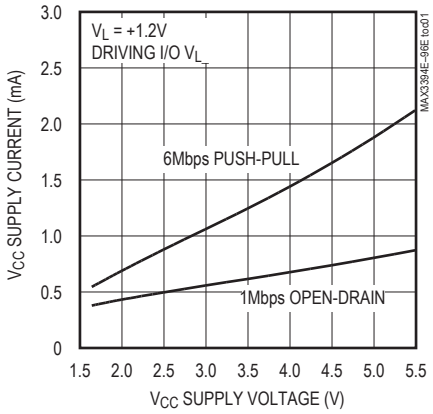
**Note 1:** All units are 100% production tested at $T_A$ = +25°C. Limits over the operating temperature range are guaranteed by design and not production tested.

**Note 2:** During a low-to-high transition, the threshold at which the I/O changes state is the lower of $V_{ILL}$ and $V_{ILC}$ since the two sides are internally connected by an internal switch while the device is in the logic-low state.

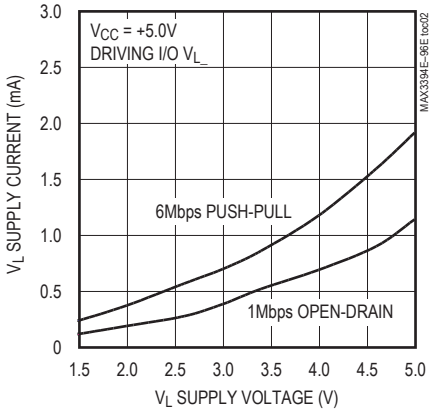
## Typical Operating Characteristics

($V_{CC}$ = +2.5V, $V_L$ = +1.8V, $C_L$ = 15pF, $T_A$ = +25°C, unless otherwise noted.)

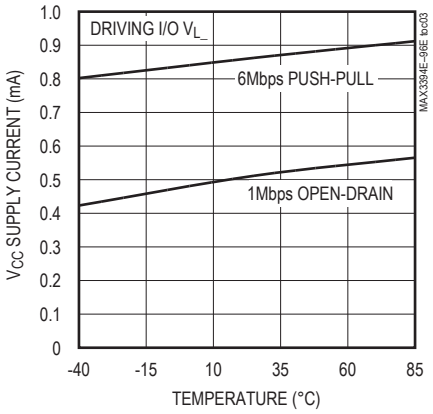
**$V_{CC}$ SUPPLY CURRENT vs. SUPPLY VOLTAGE**



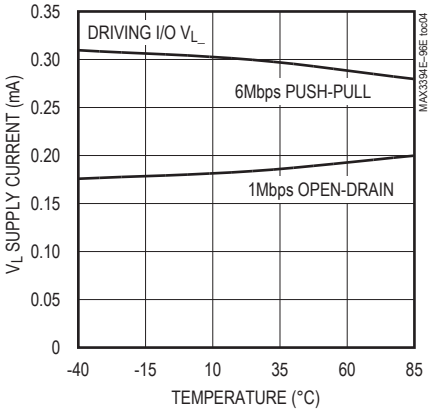

**$V_L$ SUPPLY CURRENT vs. SUPPLY VOLTAGE**



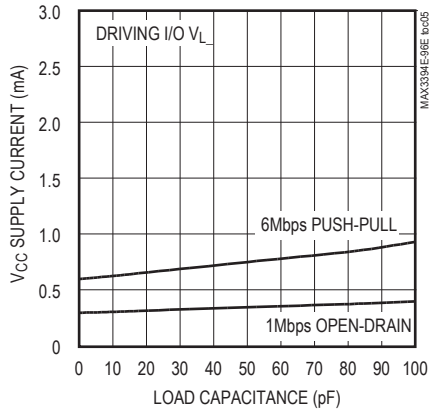

**$V_{CC}$ SUPPLY CURRENT vs. TEMPERATURE**



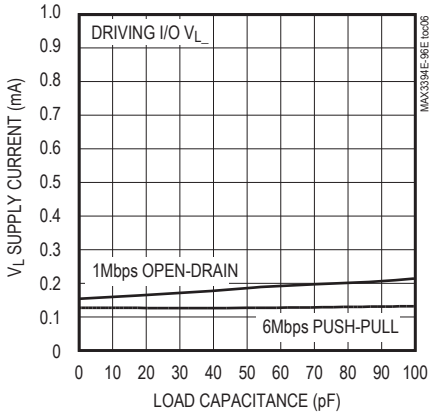

**$V_L$ SUPPLY CURRENT vs. TEMPERATURE**



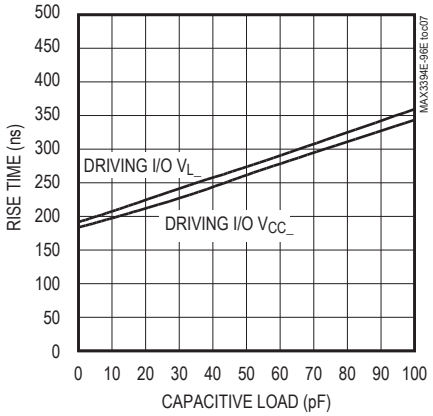

**$V_{CC}$ SUPPLY CURRENT vs. LOAD CAPACITANCE**



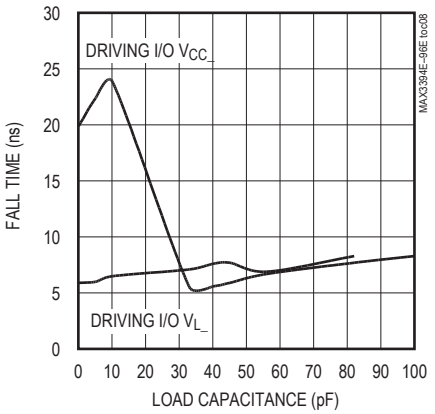

**$V_L$ SUPPLY CURRENT vs. LOAD CAPACITANCE**



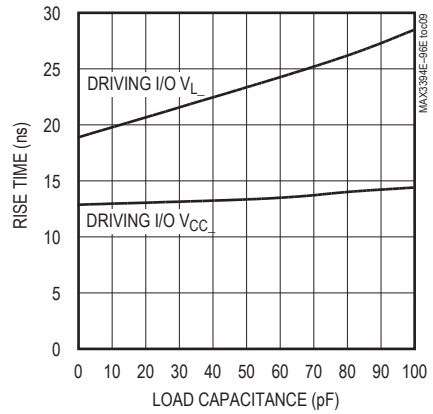

**OPEN-DRAIN RISE TIME vs. LOAD CAPACITANCE**




**OPEN-DRAIN FALL TIME vs. LOAD CAPACITANCE**



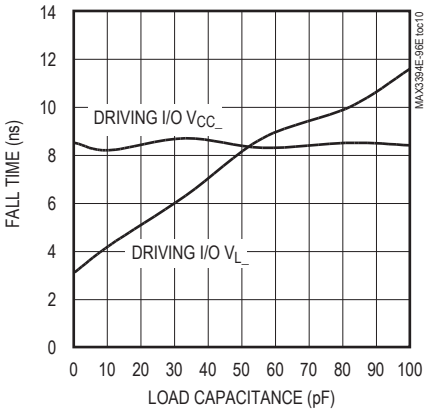

**PUSH-PULL RISE TIME vs. LOAD CAPACITANCE**



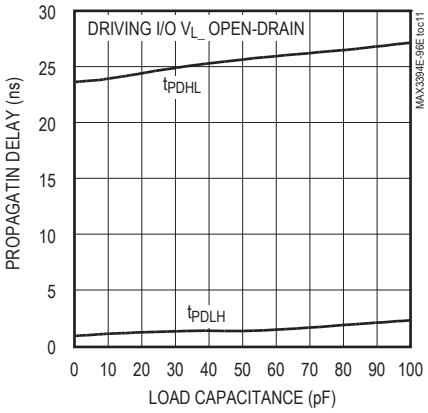
## Typical Operating Characteristics (continued)

($V_{CC}$ = +2.5V, $V_L$ = +1.8V, $C_L$ = 15pF, $T_A$ = +25°C, unless otherwise noted.)

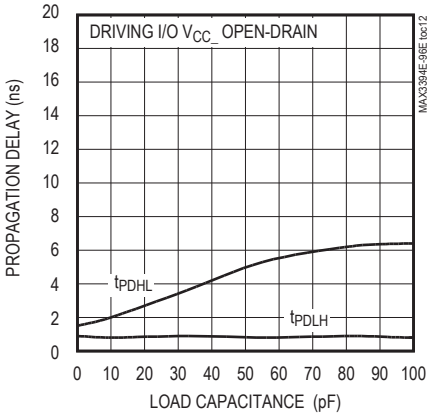
**PUSH-PULL FALL TIME vs. LOAD CAPACITANCE**



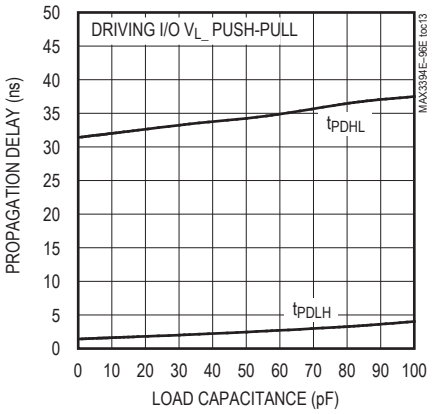

**PROPAGATION DELAY vs. LOAD CAPACITANCE**



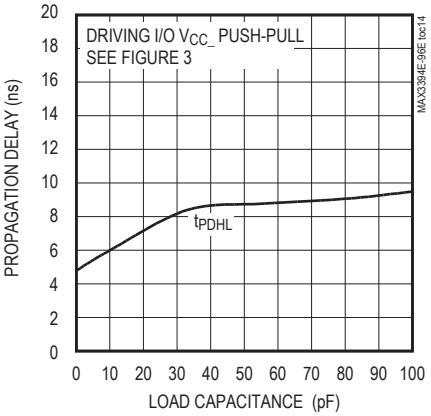

**PROPAGATION DELAY vs. LOAD CAPACITANCE**



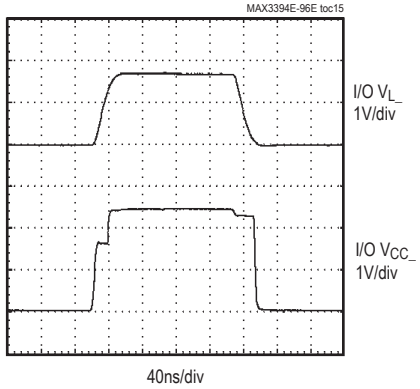

**PROPAGATION DELAY vs. LOAD CAPACITANCE**



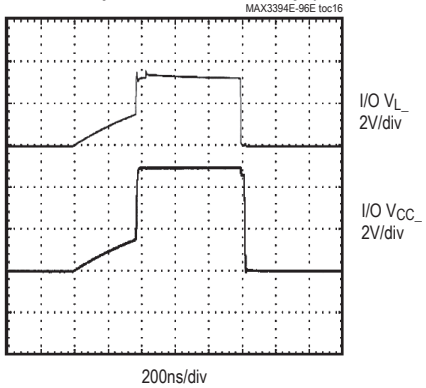

**PROPAGATION DELAY vs. LOAD CAPACITANCE**



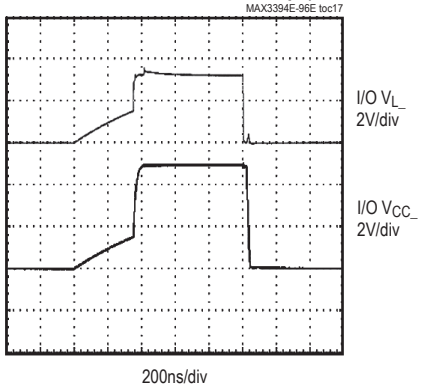

**(DRIVING I/O $V_{L\_}$, $V_{CC}$ = +2.5V, $V_L$ = +1.8V, $C_L$ = 15pF, DATA RATE = 6Mbps)**




**(DRIVING I/O $V_{L\_}$, $V_{CC}$ = +5.0V, $V_L$ = +3.3V, $C_L$ = 100pF, DATA RATE = 1Mbps)**




**(DRIVING I/O $V_{L\_}$, $V_{CC}$ = +5.0V, $V_L$ = +3.3V, $C_L$ = 400pF, EXTERNAL 4.7kΩ PULLUPS, DATA RATE = 1Mbps)**



## Pin Description

| PIN | | | | | | NAME | FUNCTION |
|---|---|---|---|---|---|---|---|
| MAX3394E | | MAX3395E | | MAX3396E | | | |
| TDFN | UCSP | TQFN | UCSP | TQFN | UCSP | | |
| 1 | A1 | 11 | B1 | 14 | D3 | $V_{CC}$ | $V_{CC}$ Supply Voltage +1.65V ≤ $V_{CC}$ ≤ +5.5V. Bypass $V_{CC}$ to GND with a 0.1µF ceramic capacitor and a 1µF or greater ceramic capacitor as close to the device as possible. |
| 2 | B1 | 6 | B3 | 4 | A4 | EN | Enable Input. Drive EN logic high for normal operation. Drive EN logic low to force all I/O lines to a high-impedance state and disconnect internal pullup resistors. |
| 3 | A2 | 10 | C1 | 18 | C1 | I/O $V_{CC}$1 | I/O 1 Referred to $V_{CC}$ |
| 4 | A3 | 9 | C2 | 16 | D1 | I/O $V_{CC}$2 | I/O 2 Referred to $V_{CC}$ |
| 5 | B3 | 5 | B4 | 13 | D4 | GND | Ground |
| 6 | C3 | 2 | A2 | 20 | A1 | I/O $V_L$2 | I/O 2 Referred to $V_L$ |
| 7 | C2 | 1 | A1 | 19 | B1 | I/O $V_L$1 | I/O 1 Referred to $V_L$ |
| 8 | C1 | 12 | B2 | 3 | A3 | $V_L$ | Logic Supply Voltage +1.2V ≤ $V_L$ ≤ $V_{CC}$. Bypass $V_L$ to GND with a 0.1µF or greater ceramic capacitor as close to the device as possible. |
| — | — | 3 | A3 | 1 | B2 | I/O $V_L$3 | I/O 3 Referred to $V_L$ |
| — | — | 4 | A4 | 2 | A2 | I/O $V_L$4 | I/O 4 Referred to $V_L$ |
| — | — | 7 | C4 | 15 | D2 | I/O $V_{CC}$4 | I/O 4 Referred to $V_{CC}$ |
| — | — | 8 | C3 | 17 | C2 | I/O $V_{CC}$3 | I/O 3 Referred to $V_{CC}$ |
| — | — | — | — | 12 | C3 | I/O $V_{CC}$5 | I/O 5 Referred to $V_{CC}$ |
| — | — | — | — | 11 | D5 | I/O $V_{CC}$6 | I/O 6 Referred to $V_{CC}$ |
| — | — | — | — | 10 | C4 | I/O $V_{CC}$7 | I/O 7 Referred to $V_{CC}$ |
| — | — | — | — | 9 | C5 | I/O $V_{CC}$8 | I/O 8 Referred to $V_{CC}$ |
| — | — | — | — | 5 | B3 | I/O $V_L$5 | I/O 5 Referred to $V_L$ |
| — | — | — | — | 6 | A5 | I/O $V_L$6 | I/O 6 Referred to $V_L$ |
| — | — | — | — | 7 | B4 | I/O $V_L$7 | I/O 7 Referred to $V_L$ |
| — | — | — | — | 8 | B5 | I/O $V_L$8 | I/O 8 Referred to $V_L$ |
| EP | — | EP | — | EP | — | EP | Exposed Pad. Connect exposed pad to GND. |

## Detailed Description

The MAX3394E/MAX3395E/MAX3396E bidirectional level translators provide level shifting required for data transfer in a multivoltage system. Internal slew-rate enhancement circuitry features 10mA current-sink and 15mA current-source drivers to isolate capacitive loads from lower current drivers. In open-drain systems, slew-rate enhancement enables fast data rates with larger pullup resistors and increased bus load capacitance. Externally applied voltages, $V_{CC}$ and $V_L$, set the logic-high levels for the device. A logic-low signal on one I/O side of the device appears as a logic-low signal on the opposite I/O side and vice-versa. Each I/O line is pulled up to $V_{CC}$ or $V_L$ by an internal pullup resistor, allowing the devices to be driven by either push-pull or open-drain drivers.

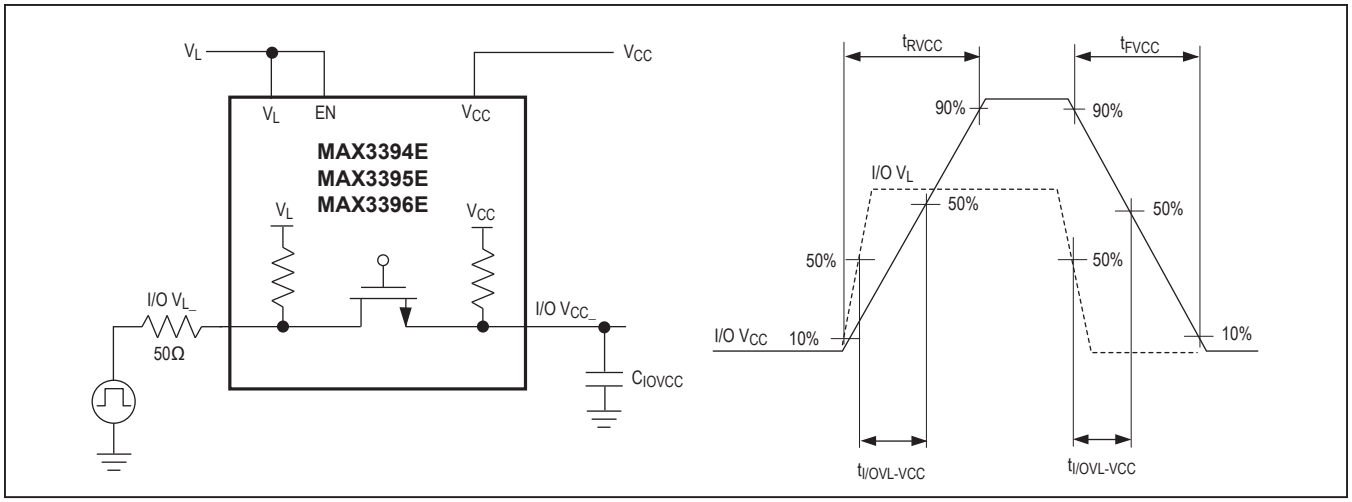



*Figure 1. Push-Pull Driving I/O $V_{L\_}$ Test Circuit and Timing*

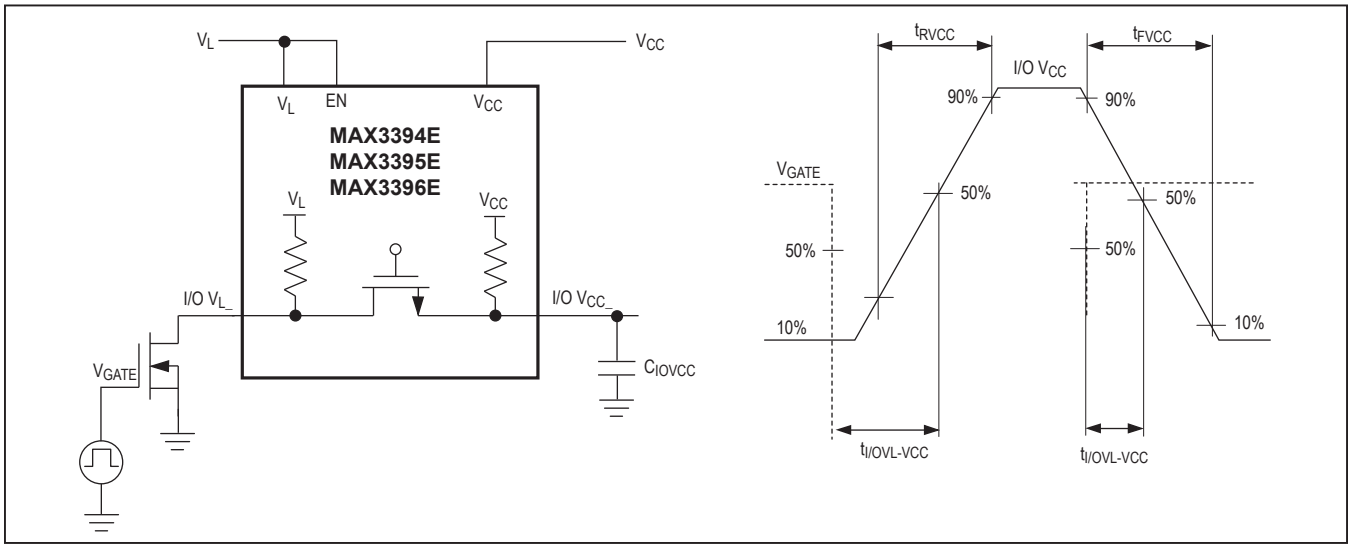



*Figure 2. Open-Drain Driving I/O $V_{L\_}$ Test Circuit and Timing*

The MAX3394E/MAX3395E/MAX3396E feature a tri-state output mode, thermal-shutdown protection, and ±15kV Human Body Model (HBM) ESD protection on the $V_{CC}$ side for greater protection in applications that route signals externally.

The MAX3394E/MAX3395E/MAX3396E accept $V_{CC}$ voltages from +1.65V to +5.5V, and $V_L$ voltages from +1.2V to $V_{CC}$, making them ideal for data transfer between low-voltage ASIC/PLDs and higher voltage systems. The MAX3394E/MAX3395E/MAX3396E operate at a guaranteed data rate of 6Mbps with push-pull drivers and 1Mbps with open-drain drivers.

## Level Translation

The MAX3394E/MAX3395E/MAX3396E utilize a transmission gate architecture to provide bidirectional level translation between I/O $V_{L\_}$ and I/O $V_{CC\_}$. The transmission gate architecture is comprised of a pass-FET, gate-control logic, and slew-rate enhancement circuitry. When both I/O $V_{L\_}$ and I/O $V_{CC\_}$ are logic high, the gate-control logic disables the pass-FET, providing

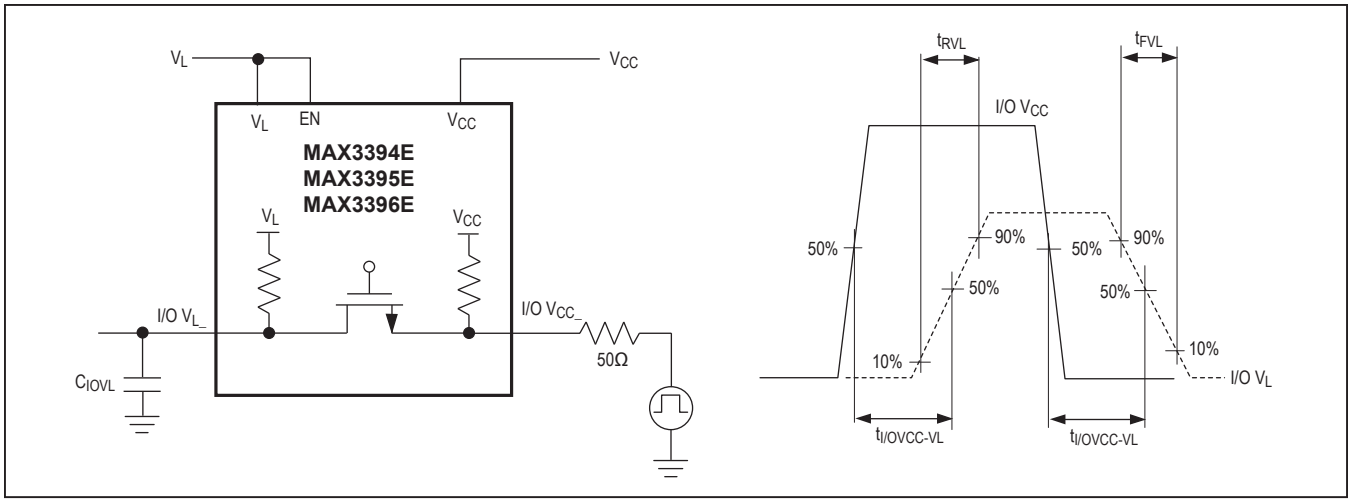



*Figure 3. Push-Pull Driving I/O $V_{CC\_}$ Test Circuit and Timing*

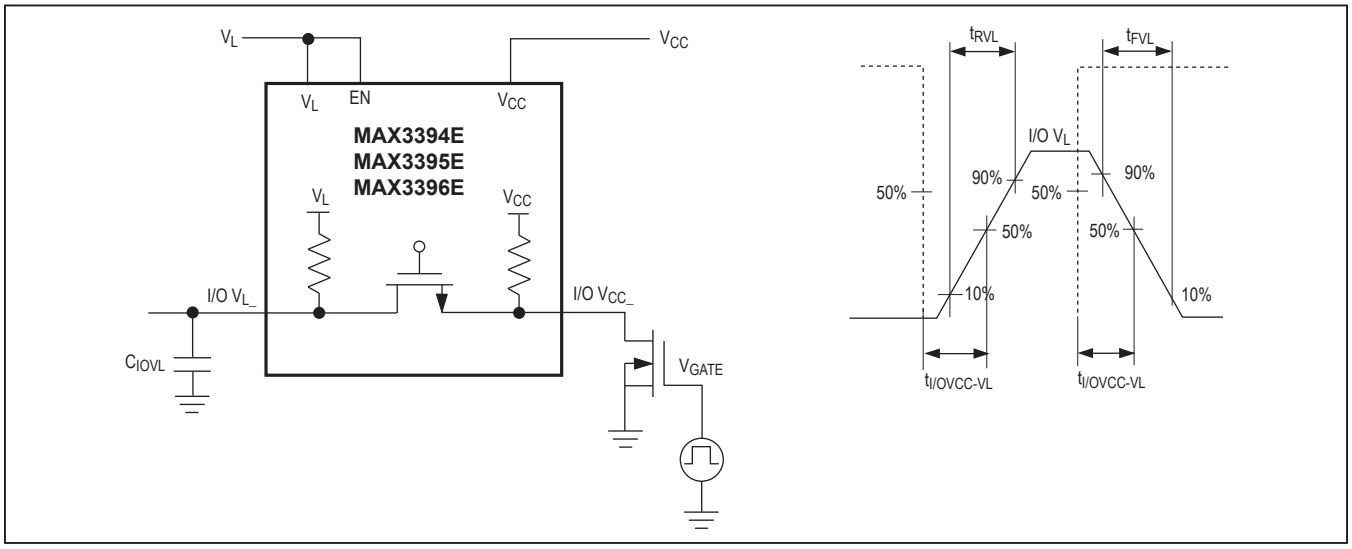



*Figure 4. Open-Drain Driving I/O $V_{CC\_}$ Test Circuit and Timing*

capacitive isolation between I/O lines. When one or both I/O lines are at a logic-low level, the gate-control logic turns the pass-FET on. When the pass-FET is active, I/O $V_{L\_}$ and I/O $V_{CC\_}$ are connected, allowing the logic-low signal to be expressed simultaneously on both I/O lines.

The MAX3394E/MAX3395E/MAX3396E have internal 10kΩ (typ) pullup resistors from I/O $V_{L\_}$ and I/O $V_{CC\_}$ to the respective supply voltages, allowing operation with open-drain drivers. Internal slew-rate enhancement circuitry accelerates logic-state transitions, maintaining a fast data rate with a higher bus load capacitance. Additionally, the 10mA current sink drivers permit the use of smaller external pullup resistors.

## Internal Slew-Rate Enhancement

Internal slew-rate enhancement circuitry accelerates logic-state changes by turning on MOSFETs $M_{P1}$ and $M_{P2}$ during low-to-high logic transitions, and MOSFETs $M_{N3}$ and $M_{N4}$ during high-to-low logic transitions (see the *Functional Diagram*). During logic-state changes, speed-up MOSFETS are triggered by I/O line voltage thresholds. MOSFETS $M_{N3}$ and $M_{N4}$ sink 10mA during high-to-low logic transitions. $M_{P1}$ and $M_{P2}$ source 15mA during low-to-high logic transitions. Slew-rate enhancement allows a fast data rate despite large capacitive bus loads, and permits larger external pullup resistors.

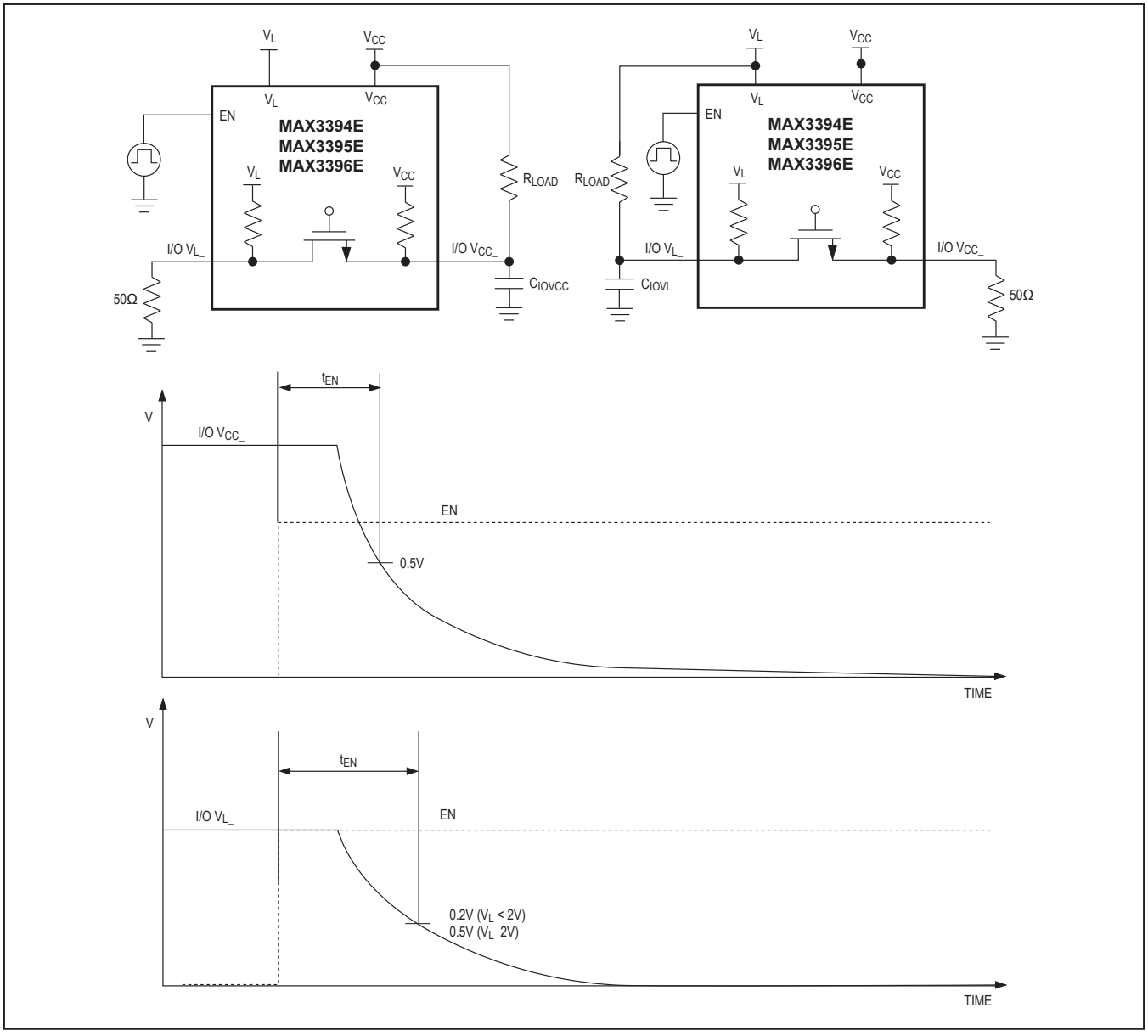



*Figure 5. Enable Test Circuit and Timing*

## Power-Supply Sequencing

The MAX3394E/MAX3395E/MAX3396E require two supply voltages. For proper operation, ensure that +1.65V ≤ $V_{CC}$ ≤ +5.5V, and +1.2V ≤ $V_L$ ≤ $V_{CC}$. There are no restrictions on power-supply sequencing. During power-up or power-down, the MAX3394E/MAX3395E/MAX3396E can withstand either the $V_L$ or the $V_{CC}$ supply floating while the other supply is applied. The device will not latch up in this state.

### Tri-State Output Mode

Connect EN to $V_L$ or $V_{CC}$ for normal operation. Drive EN low to force the MAX3394E/MAX3395E/MAX3396E to a tri-state output mode. In tri-state output mode, all I/O lines are driven to a high-impedance state, and the pass-FET is disabled to prevent current flow between I/O lines. Tri-state output mode disables the internal pullup resistors on I/O $V_{L\_}$ and I/O $V_{CC\_}$, and reduces supply current to 3µA typ ($V_{CC}$) and 0.7µA typ ($V_L$).

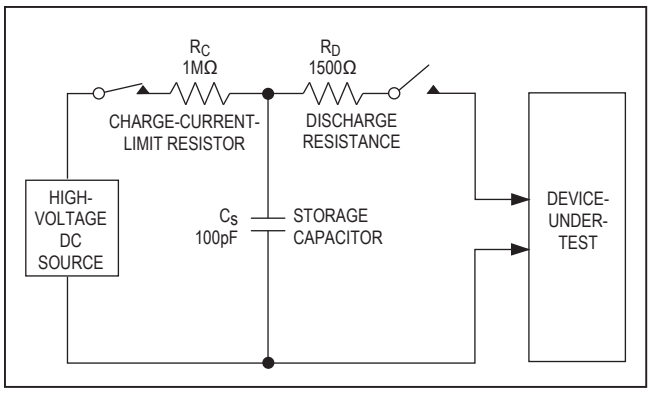



*Figure 6a. Human Body ESD Test Model*

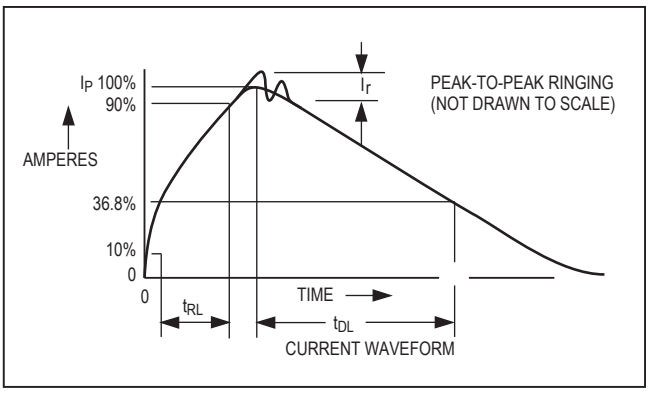



*Figure 6b. HBM Discharge Current Waveform*

The high-impedance state of the I/O lines during tri-state output mode facilitates use in multidrop networks. In tri-state output mode, do not exceed ($V_L$ + 0.3V) on I/O $V_L$_ or ($V_{CC}$ + 0.3V) on I/O $V_{CC}$_.

### Thermal-Shutdown Protection

The MAX3394E/MAX3395E/MAX3396E are protected from thermal damage resulting from short-circuit faults. In the event of a short-circuit fault, when the junction temperature ($T_J$) reaches +125°C, a thermal sensor forces the device into the tri-state output mode. When $T_J$ drops below +115°C, normal operation resumes.

### ±15kV ESD Protection

As with all Maxim devices, ESD-protection structures are incorporated on all pins to protect against ESD encountered during handling and assembly. The I/O $V_{CC}$_ lines are further protected by advanced ESD structures to guard these pins from damage caused by ESD of up to ±15kV. Protection structures prevent damage caused by ESD events in normal operation, tri-state output mode, and when the device is unpowered. After arresting an ESD event, MAX3394E/MAX3395E/MAX3396E continue to function without latching up, whereas competing devices can enter a latched-up state and must be power cycled to restore functionality.

Several ESD testing standards exist for gauging the robustness of ESD structures. The ESD protection of the MAX3394E/MAX3395E/MAX3396E is characterized for the human body model (HBM). Figure 6a shows the model used to simulate an ESD event resulting from contact with the human body. The model consists of a 100pF storage capacitor that is charged to a high voltage then discharged through a 1.5kΩ resistor. Figure 6b shows the current waveform when the storage capacitor is discharged into a low impedance.

To ensure full ±15kV ESD protection, bypass $V_{CC}$ to ground with a 0.1µF ceramic capacitor and an additional 1µF ceramic capacitor as close to the device as possible.

### ESD Test Conditions

ESD performance depends on a variety of conditions. Contact Maxim for a reliability report documenting test setup, methodology, and results.

## Applications Information

### Power-Supply Decoupling

Bypass $V_L$ and $V_{CC}$ to ground with 0.1µF ceramic capacitors. To ensure full ±15kV ESD protection, bypass $V_{CC}$ to ground with an additional 1µF or greater ceramic capacitor. Place all capacitors as close to the device as possible.

### Open-Drain Mode vs. Push-Pull Mode

The MAX3394E/MAX3395E/MAX3396E are compatible with push-pull (active) and open-drain drivers. For push-pull operation, maximum data rate is guaranteed to 6Mbps. For open-drain applications, the MAX3394E/MAX3395E/MAX3396E include internal pullup resistors and slew-rate enhancement circuitry, providing a maximum data rate of 1Mbps. External pullup resistors can be added to increase data rate when the bus is loaded by high capacitance. (See the *Use of External Pullup Resistors* section.)

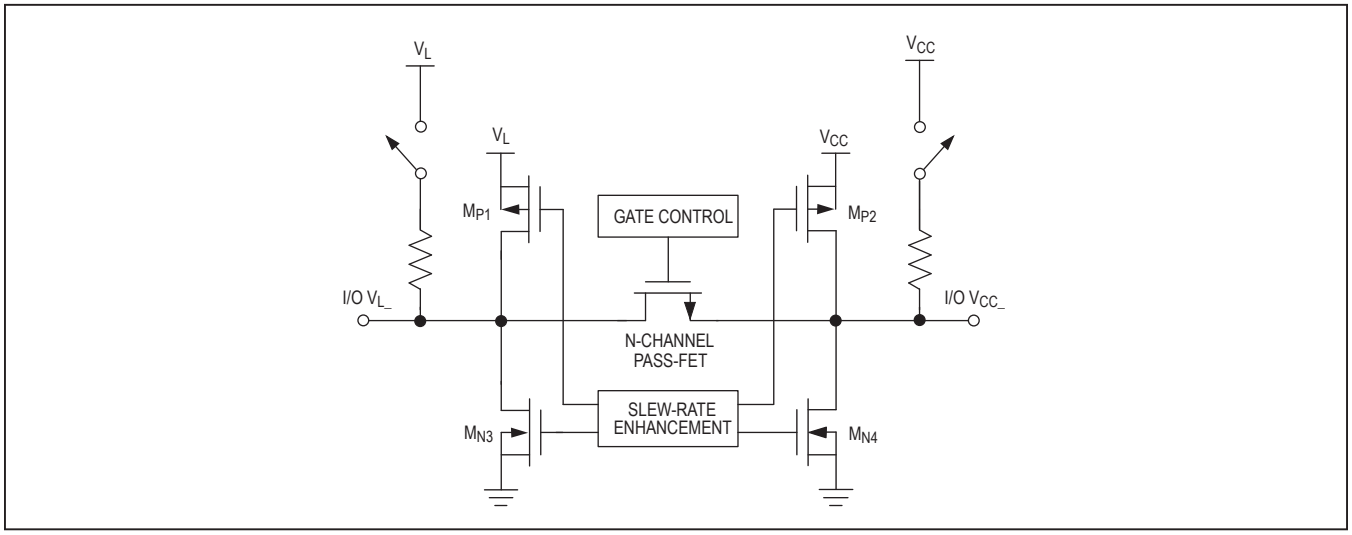
#### Serial-Interface Level Translation

The MAX3395E provides level translation on four I/O lines, making it an ideal device for multivoltage $I^2C$, MICROWIRE, and SPI serial interfaces.

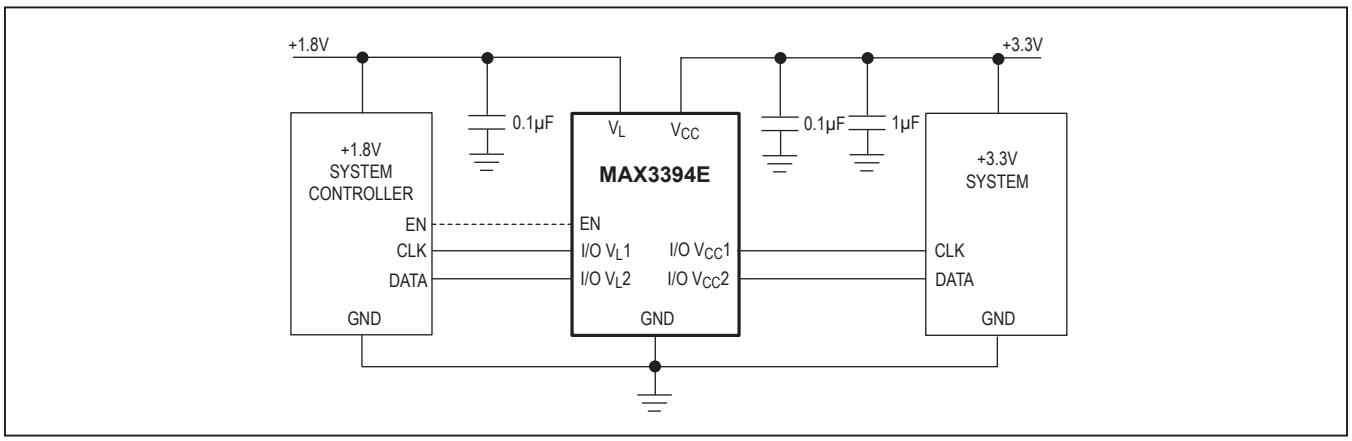
### Use of External Pullup Resistors

The MAX3394E/MAX3395E/MAX3396E include internal 10kΩ pullup resistors. During a low-to-high logic transition, the internal pullup resistors charge the bus capaci-

## Functional Diagram




## Typical Operating Circuit




tance with a characteristic RC charging waveform. When the low-to-high transition threshold ($V_{CC-TH}$ or $V_{LTH}$) is reached, the rise time accelerators switch on, sourcing 15mA to fully charge the bus capacitance. External pullup resistors reduce the time needed to reach the low-to-high transition threshold, thereby increasing the data rate. In the logic-low state however, external pullup resistors increase the DC current through the internal pass-FET, increasing the output voltage of the device.

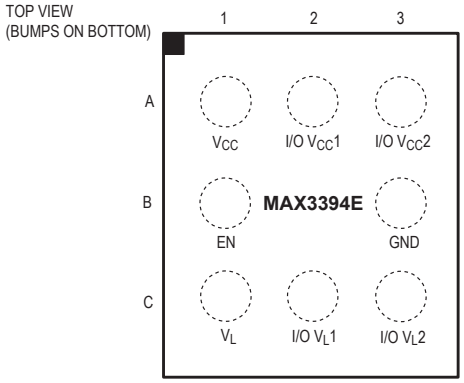
### Smart-Card Interface

The MAX3395E provides level translation for Class A, B, and C smart cards. When supply voltage $V_{CC}$ is interrupted due to the disconnection of a smart card, the device does not latch up. Normal operation resumes upon restoration of the $V_{CC}$ supply voltage. The MAX3395E provides bidirectional level translation on four I/O lines, making it well suited for buffering and translating 4-wire serial interfaces.

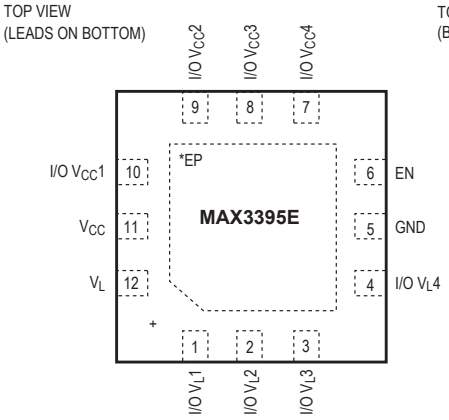
## UCSP Applications Information

For the latest application details on UCSP construction, dimensions, tape carrier information, PCB techniques, bump-pad layout, and recommended reflow temperature profiles, as well as the latest information on reliability testing results, go to Maxim's web site at **www.maximintegrated.com/ucsp** to find the Application Note 1891: *Wafer-Level Packaging (WLP) and Its Applications*.

## Pin Configurations (continued)

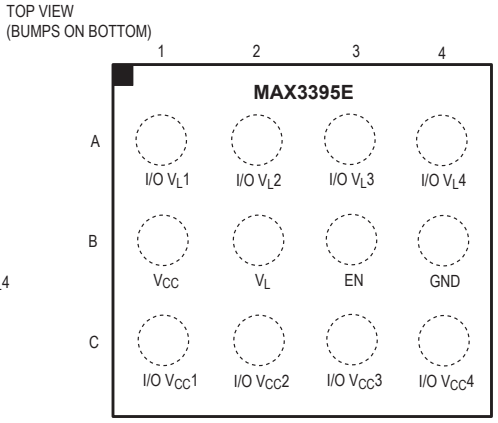



UCSP

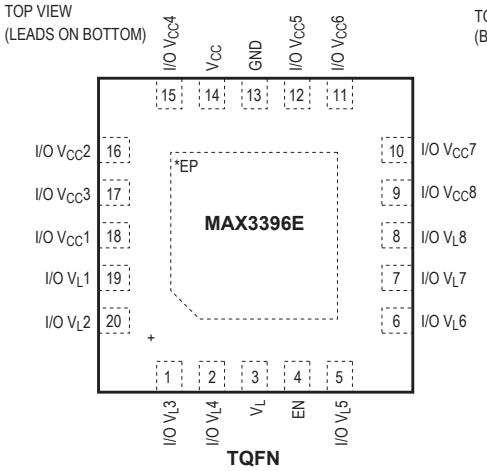



TQFN

*CONNECT EXPOSED PAD TO GROUND

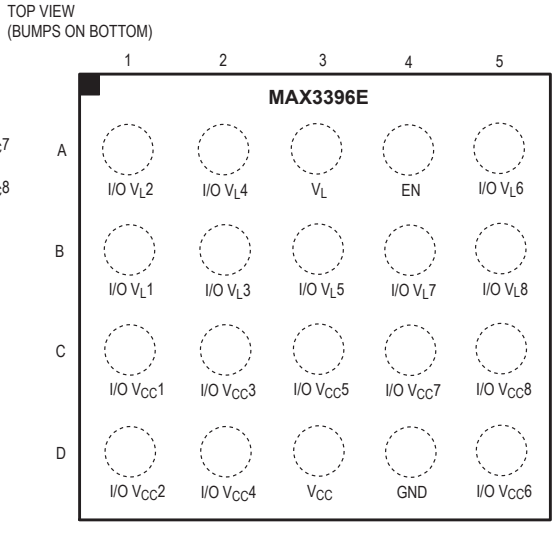



UCSP




TQFN

*CONNECT EXPOSED PAD TO GROUND




UCSP

## Selector Guide

| PART | NUMBER OF TRANSLATORS | TOP MARK |
|---|---|---|
| MAX3394EETA+T | 2 | APE |
| MAX3394EEBL+T | 2 | AEZ |
| MAX3395EETC+ | 4 | AAFZ |
| MAX3395EEBC+T | 4 | ACO |
| MAX3396EEBP+T | 8 | — |
| MAX3396EETP+ | 8 | — |

***Note:*** *All devices specified over the -40°C to +85°C operating range.*
*+Denotes lead(Pb)-free/RoHS-compliant package.*

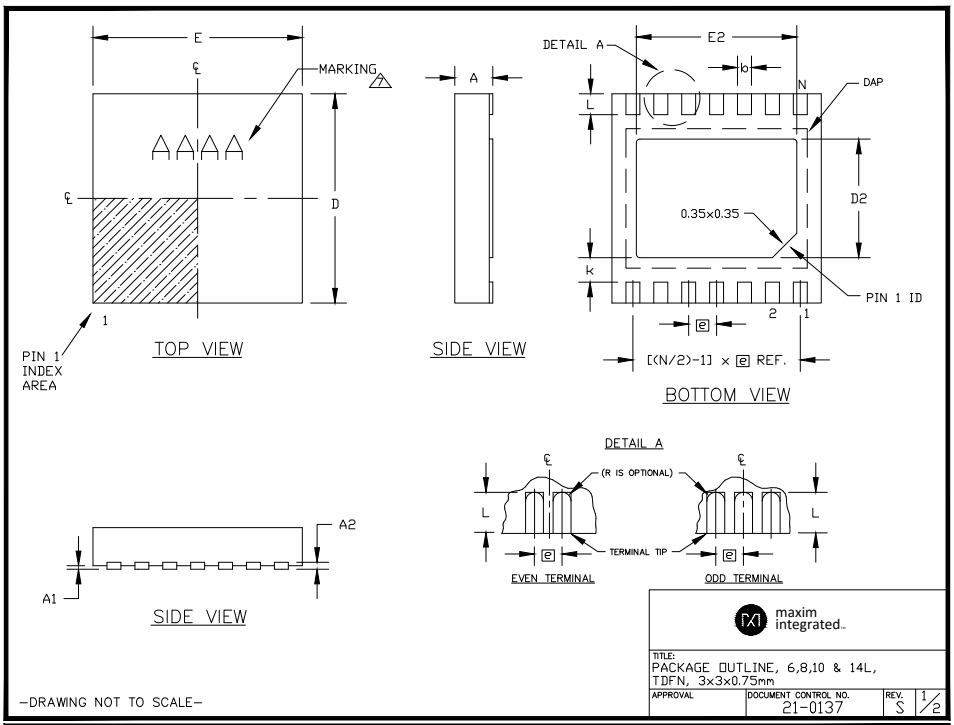
## Chip Information

PROCESS: BiCMOS

CONNECT EXPOSED PAD TO GND.

## Package Information

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.




| COMMON DIMENSIONS | | | |
|---|---|---|---|
| SYMBOL | MIN | NOM | MAX |
| A | 0.70 | 0.75 | 0.80 |
| D | 2.90 | 3.00 | 3.10 |
| E | 2.90 | 3.00 | 3.10 |
| A1 | 0.00 | 0.025 | 0.05 |
| L | 0.20 | 0.30 | 0.40 |
| k | 0.25 MIN. | | |
| A2 | 0.20 REF. | | |

| PACKAGE VARIATIONS | | | | | | | |
|---|---|---|---|---|---|---|---|
| PKG. CODE | N | D2 | E2 | e | JEDEC SPEC | b | [(N/2)-1] x e |
| T633-2 | 6 | 1.50±0.10 | 2.30±0.10 | 0.95 BSC | MO229 / WEEA | 0.40±0.05 | 1.90 REF |
| T633-2C | 6 | 1.50±0.10 | 2.30±0.10 | 0.95 BSC | MO229 / WEEA | 0.40±0.05 | 1.90 REF |
| T633MK-1 | 6 | 1.50±0.10 | 2.30±0.10 | 0.95 BSC | MO229 / WEEA | 0.40±0.05 | 1.90 REF |
| T833-1F | 8 | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC | 0.30±0.05 | 1.95 REF |
| T833-2 | 8 | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC | 0.30±0.05 | 1.95 REF |
| T833-2C | 8 | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC | 0.30±0.05 | 1.95 REF |
| T833-3 | 8 | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC | 0.30±0.05 | 1.95 REF |
| T833-3C | 8 | 1.50±0.10 | 2.30±0.10 | 0.65 BSC | MO229 / WEEC | 0.30±0.05 | 1.95 REF |
| T1033-1 | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF |
| T1033-1C | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF |
| T1033MK-1 | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF |
| T1033-2 | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF |
| T1033-4 | 10 | 1.50±0.10 | 2.30±0.10 | 0.50 BSC | MO229 / WEED-3 | 0.25±0.05 | 2.00 REF |
| T1433-1 | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | ---- | 0.20±0.05 | 2.40 REF |
| T1433-2 | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | ---- | 0.20±0.05 | 2.40 REF |
| T1433-2C | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | ---- | 0.20±0.05 | 2.40 REF |
| T1433-3F | 14 | 1.70±0.10 | 2.30±0.10 | 0.40 BSC | ---- | 0.20±0.05 | 2.40 REF |

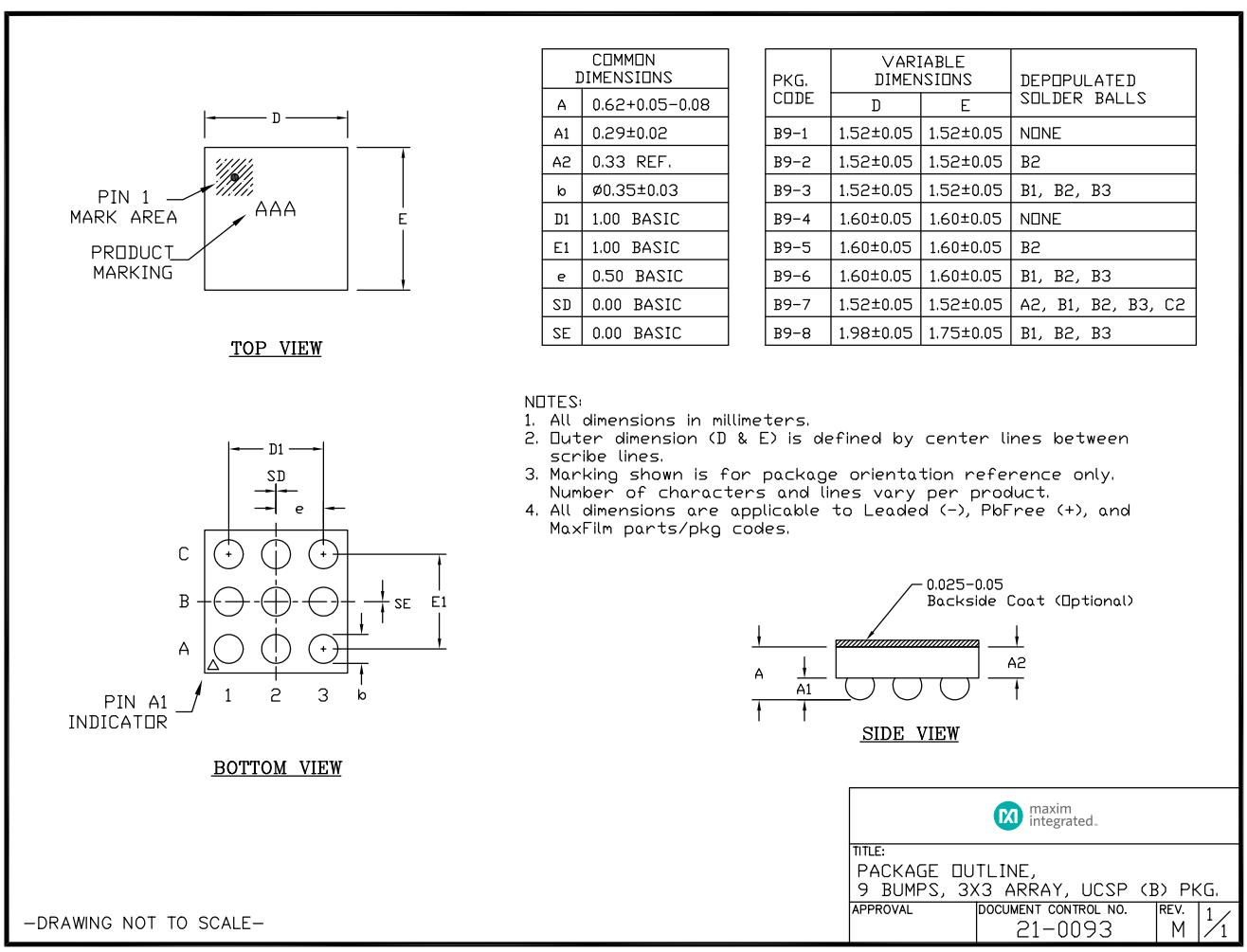
NOTES:
1. ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
2. WARPAGE SHALL NOT EXCEED 0.10 mm.
3. PACKAGE LENGTH/PACKAGE WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC(S).
4. DRAWING CONFORMS TO JEDEC MO229, EXCEPT DIMENSIONS "D2" AND "E2", AND T1433-1 & T1433-2."
5. N" IS THE TOTAL NUMBER OF LEADS.
6. NUMBER OF LEADS SHOWN ARE FOR REFERENCE ONLY.
7. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
8. MATERIAL MUST BE COMPLIANT WITH MAXIM SPECIFICATION 10-0131 FOR SUBSTANCE CONTENT, MUST BE Eu ROHS COMPLIANT WITHOUT EXEMPTION AND PB-FREE.
9. ALL DIMENSIONS APPLY TO BOTH LEADED (-) AND PbFREE (+) PKG. CODES.

-DRAWING NOT TO SCALE-

maxim integrated
TITLE:
PACKAGE OUTLINE, 6,8,10 & 14L,
TDFN, 3x3x0.75mm
APPROVAL
DOCUMENT CONTROL NO.
21-0137
REV.
S
2/2

## Package Information (continued)

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.



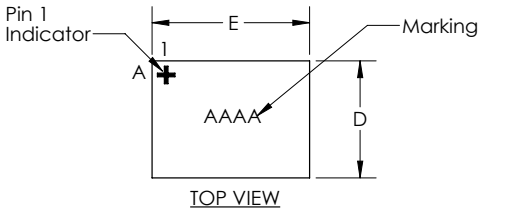

| COMMON DIMENSIONS | |
|---|---|
| A | 0.62±0.05-0.08 |
| A1 | 0.29±0.02 |
| A2 | 0.33 REF. |
| b | ø0.35±0.03 |
| D1 | 1.00 BASIC |
| E1 | 1.00 BASIC |
| e | 0.50 BASIC |
| SD | 0.00 BASIC |
| SE | 0.00 BASIC |

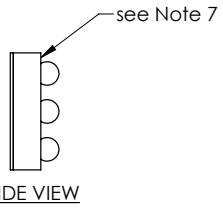
| PKG. CODE | VARIABLE DIMENSIONS | | DEPOPULATED SOLDER BALLS |
|---|---|---|---|
| | D | E | |
| B9-1 | 1.52±0.05 | 1.52±0.05 | NONE |
| B9-2 | 1.52±0.05 | 1.52±0.05 | B2 |
| B9-3 | 1.52±0.05 | 1.52±0.05 | B1, B2, B3 |
| B9-4 | 1.60±0.05 | 1.60±0.05 | NONE |
| B9-5 | 1.60±0.05 | 1.60±0.05 | B2 |
| B9-6 | 1.60±0.05 | 1.60±0.05 | B1, B2, B3 |
| B9-7 | 1.52±0.05 | 1.52±0.05 | A2, B1, B2, B3, C2 |
| B9-8 | 1.98±0.05 | 1.75±0.05 | B1, B2, B3 |

NOTES:
1. All dimensions in millimeters.
2. Outer dimension (D & E) is defined by center lines between scribe lines.
3. Marking shown is for package orientation reference only. Number of characters and lines vary per product.
4. All dimensions are applicable to Leaded (-), PbFree (+), and MaxFilm parts/pkg codes.

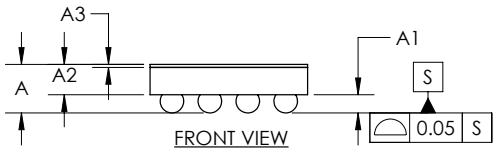
## Package Information (continued)

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

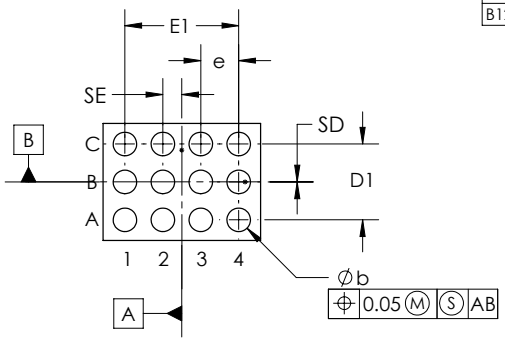



| COMMON DIMENSIONS | | |
|---|---|---|
| A | 0.64 | ±0.05 |
| A1 | 0.24 | ±0.03 |
| A2 | 0.40 | REF |
| A3 | 0.040 | BASIC |
| b | ∅0.31 | ±0.03 |
| D1 | 1.00 | BASIC |
| E1 | 1.50 | BASIC |
| e | 0.50 | BASIC |
| SD | 0.00 | BASIC |
| SE | 0.25 | BASIC |
| DEPOPULATED BUMPS: see table on left | | |




| PKG. CODE | VARIABLE DIMENSIONS | | DEPOPULATED SOLDER BALLS |
|---|---|---|---|
| | D | E | |
| B12-1 | 1.54±0.05 | 2.02±0.05 | NONE |
| B12-2 | 1.54±0.05 | 2.02±0.05 | B3 |
| B12-3 | 1.54±0.05 | 2.12±0.05 | NONE |
| B12-4 | 1.54±0.05 | 2.02±0.05 | B2, B3 |
| B12-6 | 1.64±0.05 | 2.12±0.05 | B3 |
| B12-7 | 1.54±0.05 | 2.02±0.05 | B1, B3 |
| B12-8 | 1.54±0.05 | 2.02±0.05 | B2 |
| B12-9 | 1.54±0.05 | 2.12±0.05 | B2, B3 |
| B12-10 | 1.54±0.05 | 2.02±0.05 | B1, B2, B3, B4 |
| B12-11 | 1.54±0.05 | 2.02±0.05 | A2, C3 |




NOTES:
1. Terminal pitch is defined by terminal center to center value.
2. Outer dimension is defined by center lines between scribe lines.
3. All dimensions in millimeter.
4. Marking shown is for package orientation reference only.
5. Tolerance is ± 0.02 unless specified otherwise.
6. All dimensions apply to PbFree (+) package codes only.
7. Front - side finish can be either Black or Clear.

maxim integrated™

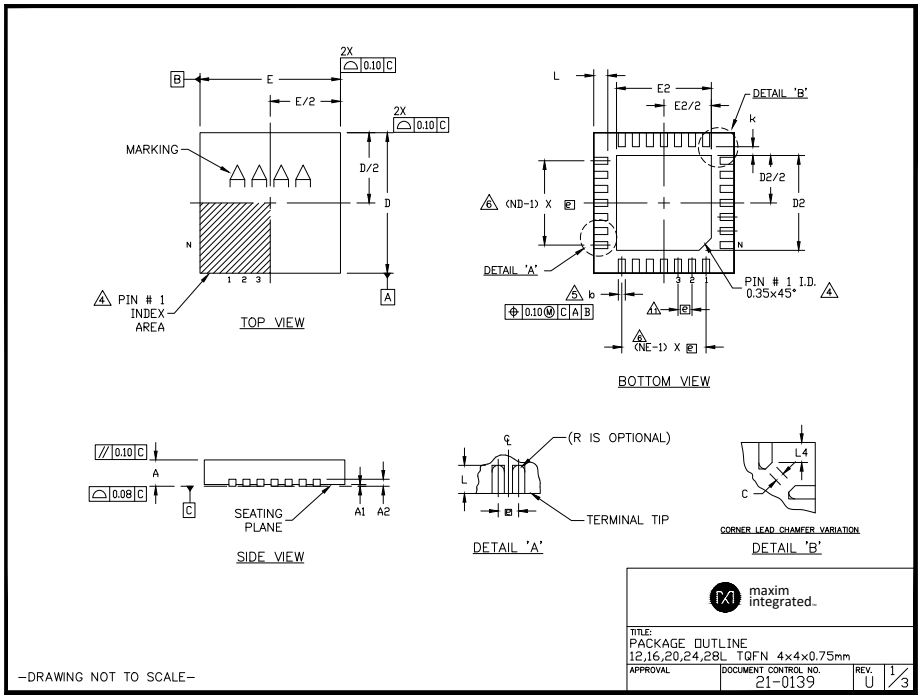
TITLE: PACKAGE OUTLINE 12 BUMPS
WLP PKG. 0.5 mm PITCH,

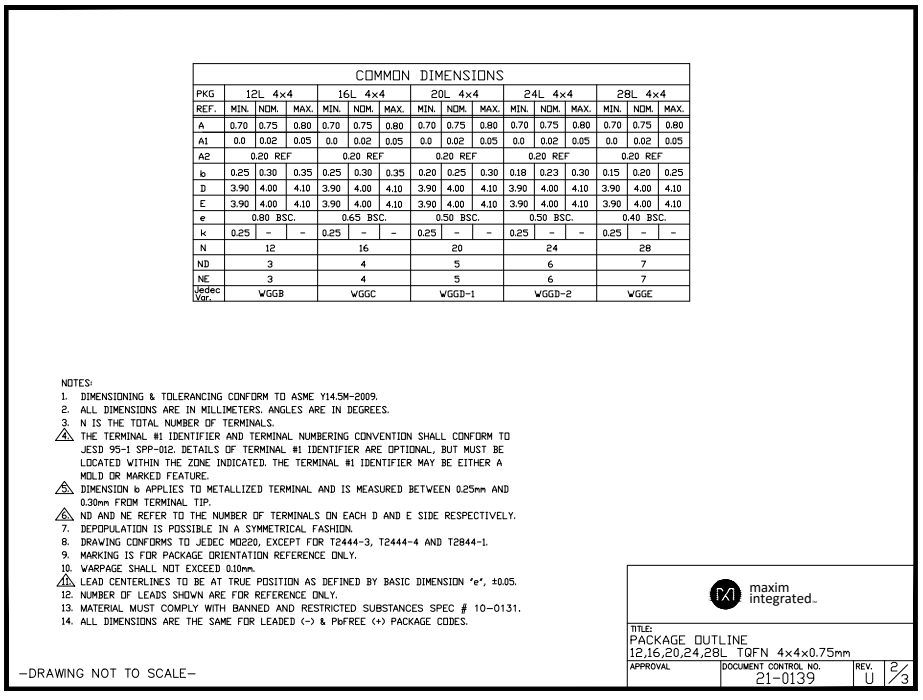
| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0104 | I | 1/1 |

- DRAWING NOT TO SCALE -

## Package Information (continued)

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.



## Package Information (continued)

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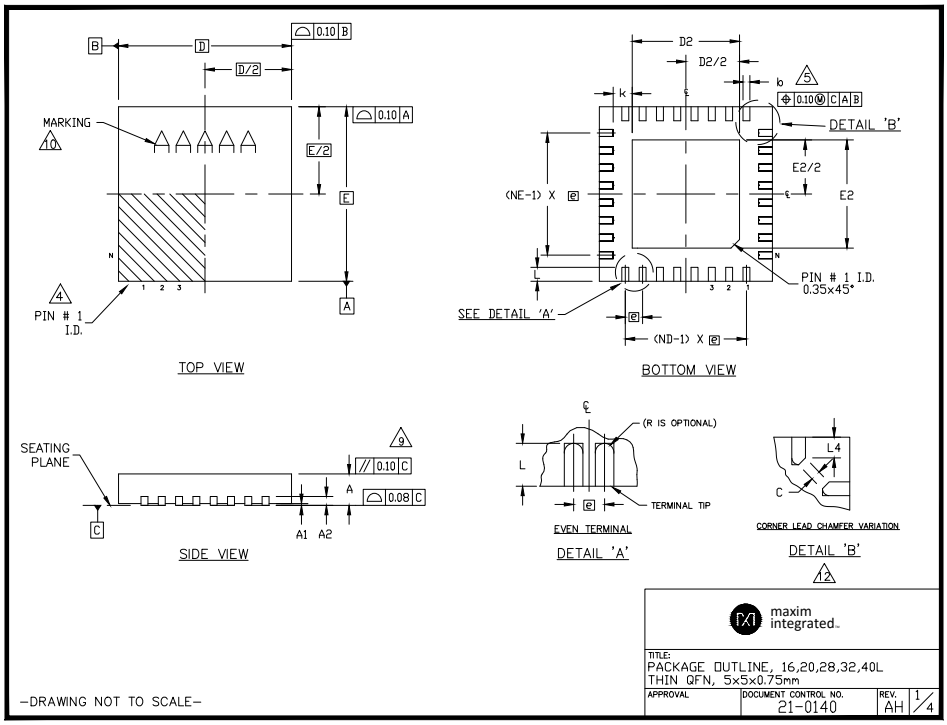
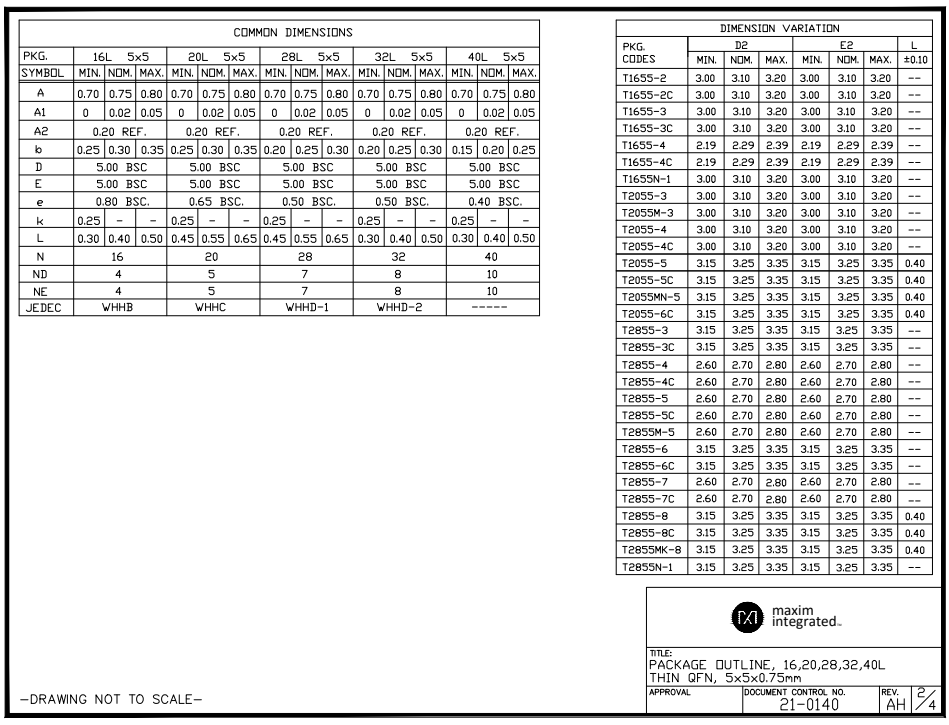



COMMON DIMENSIONS

| PKG. | 16L 5x5 | | | 20L 5x5 | | | 28L 5x5 | | | 32L 5x5 | | | 40L 5x5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SYMBOL | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. |
| A | 0.70 | 0.75 | 0.80 | 0.70 | 0.75 | 0.80 | 0.70 | 0.75 | 0.80 | 0.70 | 0.75 | 0.80 | 0.70 | 0.75 | 0.80 |
| A1 | 0 | 0.02 | 0.05 | 0 | 0.02 | 0.05 | 0 | 0.02 | 0.05 | 0 | 0.02 | 0.05 | 0 | 0.02 | 0.05 |
| A2 | 0.20 REF. | | | 0.20 REF. | | | 0.20 REF. | | | 0.20 REF. | | | 0.20 REF. | | |
| b | 0.25 | 0.30 | 0.35 | 0.25 | 0.30 | 0.35 | 0.20 | 0.25 | 0.30 | 0.20 | 0.25 | 0.30 | 0.15 | 0.20 | 0.25 |
| D | 5.00 BSC | | | 5.00 BSC | | | 5.00 BSC | | | 5.00 BSC | | | 5.00 BSC | | |
| E | 5.00 BSC | | | 5.00 BSC | | | 5.00 BSC | | | 5.00 BSC | | | 5.00 BSC | | |
| e | 0.80 BSC. | | | 0.65 BSC. | | | 0.50 BSC. | | | 0.50 BSC. | | | 0.40 BSC. | | |
| k | 0.25 | – | – | 0.25 | – | – | 0.25 | – | – | 0.25 | – | – | 0.25 | – | – |
| L | 0.30 | 0.40 | 0.50 | 0.45 | 0.55 | 0.65 | 0.45 | 0.55 | 0.65 | 0.30 | 0.40 | 0.50 | 0.30 | 0.40 | 0.50 |
| N | 16 | | | 20 | | | 28 | | | 32 | | | 40 | | |
| ND | 4 | | | 5 | | | 7 | | | 8 | | | 10 | | |
| NE | 4 | | | 5 | | | 7 | | | 8 | | | 10 | | |
| JEDEC | WHHB | | | WHHC | | | WHHD-1 | | | WHHD-2 | | | ----- | | |

DIMENSION VARIATION

| PKG. CODES | D2 | | | E2 | | | L |
|---|---|---|---|---|---|---|---|
| | MIN. | NOM. | MAX. | MIN. | NOM. | MAX. | ±0.10 |
| T1655-2 | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 | -- |
| T1655-2C | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 | -- |
| T1655-3 | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 | -- |
| T1655-3C | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 | -- |
| T1655-4 | 2.19 | 2.29 | 2.39 | 2.19 | 2.29 | 2.39 | -- |
| T1655-4C | 2.19 | 2.29 | 2.39 | 2.19 | 2.29 | 2.39 | -- |
| T1655N-1 | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 | -- |
| T2055-3 | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 | -- |
| T2055M-3 | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 | -- |
| T2055-4 | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 | -- |
| T2055-4C | 3.00 | 3.10 | 3.20 | 3.00 | 3.10 | 3.20 | -- |
| T2055-5 | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | 0.40 |
| T2055-5C | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | 0.40 |
| T2055MN-5 | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | 0.40 |
| T2055-6C | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | 0.40 |
| T2855-3 | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | -- |
| T2855-3C | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | -- |
| T2855-4 | 2.60 | 2.70 | 2.80 | 2.60 | 2.70 | 2.80 | -- |
| T2855-4C | 2.60 | 2.70 | 2.80 | 2.60 | 2.70 | 2.80 | -- |
| T2855-5 | 2.60 | 2.70 | 2.80 | 2.60 | 2.70 | 2.80 | -- |
| T2855-5C | 2.60 | 2.70 | 2.80 | 2.60 | 2.70 | 2.80 | -- |
| T2855M-5 | 2.60 | 2.70 | 2.80 | 2.60 | 2.70 | 2.80 | -- |
| T2855-6 | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | -- |
| T2855-6C | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | -- |
| T2855-7 | 2.60 | 2.70 | 2.80 | 2.60 | 2.70 | 2.80 | -- |
| T2855-7C | 2.60 | 2.70 | 2.80 | 2.60 | 2.70 | 2.80 | -- |
| T2855-8 | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | 0.40 |
| T2855-8C | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | 0.40 |
| T2855MK-8 | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | 0.40 |
| T2855N-1 | 3.15 | 3.25 | 3.35 | 3.15 | 3.25 | 3.35 | -- |



## Package Information (continued)

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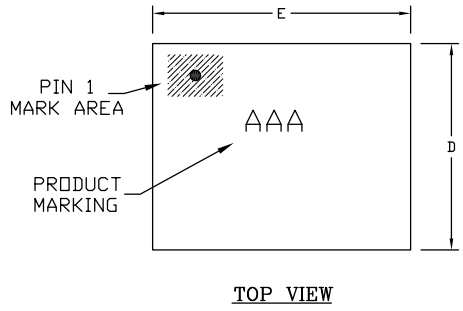
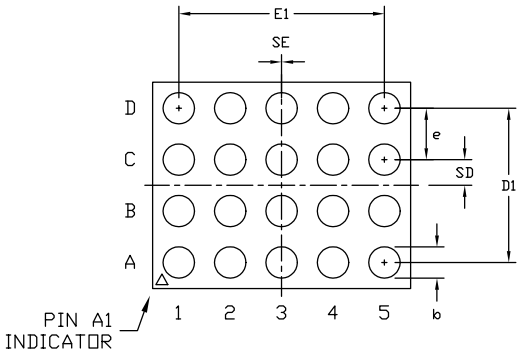



TOP VIEW

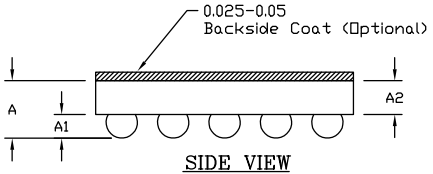
| COMMON DIMENSIONS | |
|---|---|
| A | 0.62±0.05-0.08 |
| A1 | 0.29±0.02 |
| A2 | 0.33 REF. |
| b | ø0.35±0.03 |
| D1 | 1.50 BASIC |
| E1 | 2.00 BASIC |
| e | 0.50 BASIC |
| SD | 0.25 BASIC |
| SE | 0.00 BASIC |

| PKG. CODE | VARIABLE DIMENSIONS | | DEPOPULATED SOLDER BALLS |
|---|---|---|---|
| | D | E | |
| B20-1 | 2.03±0.08 | 2.54±0.08 | NONE |
| B20-2 | 2.03±0.08 | 2.54±0.08 | B2, B3, B4 |
| B20-4 | 2.03±0.08 | 2.54±0.08 | B2, B3, B4, C2, C4 |
| B20-5 | 2.03±0.08 | 2.54±0.08 | B2, B3, B4, C2, C3, C4 |
| B20-6 | 2.16±0.08 | 2.54±0.08 | B2, B3, B4 |
| B20-7 | 2.03±0.08 | 2.54±0.08 | B3, C3 |
| B20-8 | 2.03±0.08 | 2.54±0.08 | B2, B4, C2, C4 |

NOTES:
1. All dimensions in millimeters.
2. Outer dimension (D & E) is defined by center lines between scribe lines.
3. Marking shown is for package orientation reference only. Number of characters and lines vary per product.
4. All dimensions are applicable to Leaded (-), PbFree (+), and MaxFilm parts/pkg codes.




BOTTOM VIEW




SIDE VIEW

MAXIM

TITLE:
PACKAGE OUTLINE,
20 BUMPS, 5X4 ARRAY, UCSP (B) PKG.

| APPROVAL | DOCUMENT CONTROL NO. | REV. | |
|---|---|---|---|
| | 21-0095 | K | 1/1 |

-DRAWING NOT TO SCALE-

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|---|---|---|---|
| 3 | 7/17 | Updated *Electrical Characteristics* table | 2–3 |

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