*Click **here** for production status of specific part numbers.*

# MAX9644/MAX9645/ MAX9646

# nanoPower Comparators with Precision Reference in 4-Bump UCSP

## General Description

The MAX9644/MAX9645/MAX9646 are small, single comparators, ideal for a wide variety of portable electronics applications such as cell phones, media players, and notebooks that have extremely tight board space and power constraints. These comparators are offered in both a miniature 4-bump UCSP™ package with a 1mm x 1mm footprint (as small as two 0402 resistors) and a 5-pin SOT23 package.

The ICs feature an input voltage range of -0.3V to +5.5V, independent of supply voltage. These devices maintain high impedance at the inputs even when powered down ($V_{CC}$ or $V_{REF}$ = 0V). They also feature internal filtering to provide high RF immunity.

The ICs have an internal 0.2V reference. These devices feature either a push-pull or an open-drain output. They consume only 700nA (max) supply current and operate down to $V_{CC}$ = 1V over the extended -40ºC to +85ºC temperature range.

## Applications

- Cell Phones
- Portable Media Players
- Electronic Toys
- Notebook Computers
- Portable Medical Devices

## Benefits and Features

- Tiny, 1mm x 1mm x 0.6mm 4-Bump UCSP
  - Footprint = Two 0402 Resistors
  - Also Available in a 5-Pin SOT23 Package
- Ultra-Low Operating Current (700nA max)
- -0.3V to +5.5V Input Voltage Range
- Internal 0.2V Reference Trimmed to 1% Accuracy
- 15µs Propagation Delay
- -40ºC to +85ºC Extended Temperature Range

## Ordering Information

| PART | PIN-PACKAGE | TOP MARK |
|---|---|---|
| **MAX9644**EBS+G45 | 4 UCSP | +AGL |
| MAX9644EUK+ | 5 SOT23 | +AFJN |
| **MAX9645**EBS+G45 | 4 UCSP | +AGM |
| MAX9645EUK+ | 5 SOT23 | +AFJO |
| **MAX9646**EBS+G45 | 4 UCSP | +AGN |
| MAX9646EUK+ | 5 SOT23 | +AFJP |

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

*+Denotes a lead(Pb)-free/RoHS-compliant package.*

*G45 = Protective die coating.*

## Selector Guide

| PART | REFERENCE VOLTAGE (V) | INPUT | OUTPUT |
|---|---|---|---|
| MAX9644 | 0.2 | Noninverting | Open-Drain |
| MAX9645 | 0.2 | Inverting | Open-Drain |
| MAX9646 | 0.2 | Noninverting | Push-Pull |

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

*19-5803; Rev 3; 11/19*

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## Absolute Maximum Ratings

$V_{CC}$, REF, IN to GND .....-0.3V to +6V
OUT to GND (MAX9644/MAX9645).....-0.3V to +6V
OUT to GND (MAX9646 only).....-0.3V to + ($V_{CC}$ + 0.3V)
Output Short-Circuit Current Duration..... 10s
Input Current into Any Terminal.....±20mA
Continuous Power Dissipation
4-Bump UCSP (derate 3.0mW/ºC above +70ºC).....238mW
5-Pin SOT23 (derate 3.9mW/ºC above +70ºC).....312mW
Operating Temperature Range.....-40ºC to +85ºC
Junction Temperature.....+150ºC
Storage Temperature Range.....-65°C to +150ºC
Bump Temperature (soldering) Reflow.....+235ºC
Lead Temperature (soldering, 10s).....+300ºC
Soldering Temperature (reflow).....+260ºC

*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

($V_{CC}$ = 3.3V, $R_{PULLUP}$ = 10kΩ to $V_{PULLUP}$ = 3.3V for MAX9644/MAX9645, $T_A$ = -40°C to +85°C. Typical values at $T_A$ = +25°C, unless otherwise noted.) (Note 1)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **DC CHARACTERISTICS** | | | | | | |
| Input Voltage Range | $V_{IN}$ | Guaranteed by $I_{IN}$ test | -0.3 | | +5.5 | V |
| Input Bias Current | $I_{IN}$ | $V_{IN}$ = 0.2V to 5.5V (Note 2) | | 0.06 | 15 | nA |
| Input Leakage Current | $I_{IN\_SHDN}$ | $V_{CC}$ = 0V, $V_{IN}$ = 5.5V (Note 2) | | < 0.1 | 15 | nA |
| Output Voltage Low | $V_{OL}$ | $I_{SINK}$ = 50µA, $V_{CC}$ = 1.0V | | 0.03 | 0.2 | V |
| | | $I_{SINK}$ = 200µA, $V_{CC}$ = 1.2V | | 0.08 | 0.20 | |
| | | $I_{SINK}$ = 500µA, $V_{CC}$ = 1.8V | | 0.13 | 0.23 | |
| | | $I_{SINK}$ = 0.75mA, $V_{CC}$ = 3.3V | | 0.14 | 0.3 | |
| | | $I_{SINK}$ = 1.2mA, $V_{CC}$ = 5.5V | | 0.19 | 0.5 | |
| Output Voltage High (MAX9464 Only) | $V_{OH}$ | $I_{SOURCE}$ = 15µA, $V_{CC}$ = 1.0V | | $V_{CC}$ - 0.08V | $V_{CC}$ - 0.2V | V |
| | | $I_{SOURCE}$ = 40µA, $V_{CC}$ = 1.2V | | $V_{CC}$ - 0.08V | $V_{CC}$ - 0.20V | |
| | | $I_{SOURCE}$ = 180µA, $V_{CC}$ = 1.8V | | $V_{CC}$ - 0.15V | $V_{CC}$ - 0.23V | |
| | | $I_{SOURCE}$ = 0.3mA, $V_{CC}$ = 3.3V | | $V_{CC}$ - 0.13V | $V_{CC}$ - 0.3V | |
| | | $I_{SOURCE}$ = 0.75mA, $V_{CC}$ = 5.5V | | $V_{CC}$ - 0.24V | $V_{CC}$ - 0.5V | |
| Output Leakage Current (MAX9644/MAX9645 Only) | $I_{OUT\_LEAKAGE}$ | OUT = high, $V_{PULLUP}$ = 5.5V (Note 2) | | < 0.1 | 15 | nA |
| **AC CHARACTERISTICS** | | | | | | |
| Propagation Delay | $t_{PD}$ | $V_{OVERDRIVE}$ = ±100mV (Note 3) | | 15 | | µs |
| Fall Time | $t_F$ | $C_L$ = 10pF | | 14 | | ns |
| Rise Time | $t_R$ | $C_L$ = 10pF, MAX9646 only | | 30 | | ns |
| **REFERENCE VOLTAGE** | | | | | | |
| Input Threshold (Note 4) | $V_{REF}$ | MAX964_EBS+ | | 200 | | mV |
| | | MAX964_EUK+ | | 199 | | |

## Electrical Characteristics (continued)

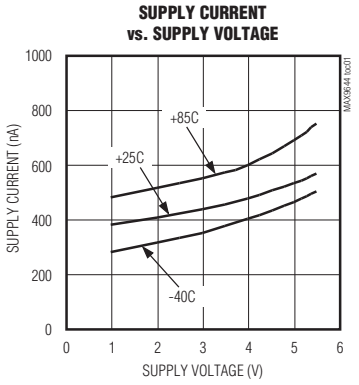
($V_{CC}$ = 3.3V, $R_{PULLUP}$ = 10kΩ to $V_{PULLUP}$ = 3.3V for MAX9644/MAX9645, $T_A$ = -40°C to +85°C. Typical values at $T_A$ = +25°C, unless otherwise noted.) (Note 1)

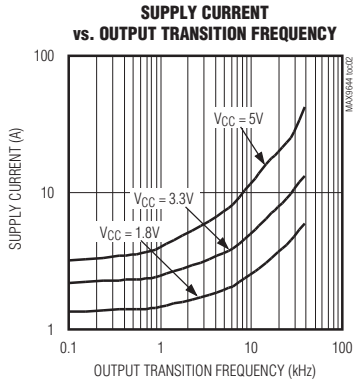
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Input Threshold Error (Note 4) | Delta-$V_{REF}$ | $T_A$ = +25°C | -1 | | +1 | % |
| | | $T_A$ = -40°C to +85°C | -3.5 | | +3.5 | |
| Input Threshold Hysteresis | $V_{HYS}$ | $T_A$ = -40°C to +85°C (Note 5) | | ±0.9 | | mV |
| REF Tempco | $V_{REF\_TEMPCO}$ | (Note 6) | | 6 | | µV/°C |
| Power-Supply Rejection Ratio | PSRR | $V_{CC}$ = 1.0V to 5.5V | 40 | 53 | | dB |
| **POWER SUPPLY** | | | | | | |
| Supply Voltage | $V_{CC}$ | Guaranteed by $V_{OL}$/$V_{OH}$ tests | 1.0 | | 5.5 | V |
| Supply Current | $I_{CC}$ | $V_{CC}$ = 1.0V | | 0.4 | 0.7 | µA |
| | | $V_{CC}$ = 5.5V | | 0.6 | 1.1 | |
| Power-Up Time | $t_{ON}$ | | | 3 | | ms |

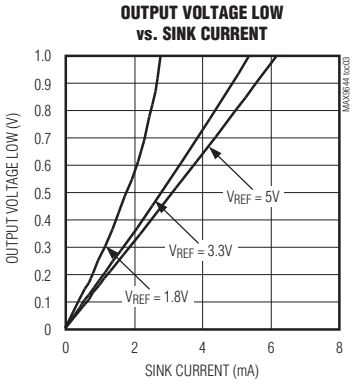
**Note 1:** All devices are 100% production tested at $T_A$ = +25°C. Temperature limits are guaranteed by design.
**Note 2:** Too small to be measured in an ATE test environment. Only gross test to catch failures is implemented.
**Note 3:** Overdrive is defined as the voltage above or below the switching points.
**Note 4:** Guaranteed by ATE and/or bench characterization over temperature. $V_{REF}$ is the average of the trip points.
**Note 5:** Hysteresis is half the input voltage difference between the two switching points.
**Note 6:** Includes reference error along with comparator offset voltage error.

## Typical Operating Characteristics

($V_{CC}$ = 3.3V, $V_{REF}$ = 1.8V, $R_{PULLUP}$ = 10kΩ to $V_{PULLUP}$ = 3.3V for MAX9644/MAX9645, $V_{GND}$ = 0V, $T_A$ = +25°C, unless otherwise noted.)



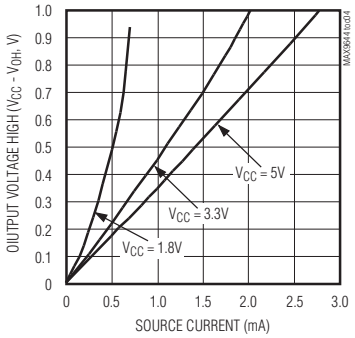



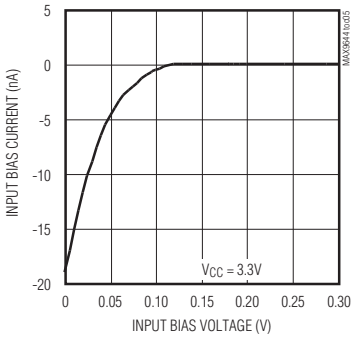
## Typical Operating Characteristics (continued)

($V_{CC}$ = 3.3V, $V_{REF}$ = 1.8V, $R_{PULLUP}$ = 10kΩ to $V_{PULLUP}$ = 3.3V for MAX9644/MAX9645, $V_{GND}$ = 0V, $T_A$ = +25°C, unless otherwise noted.)

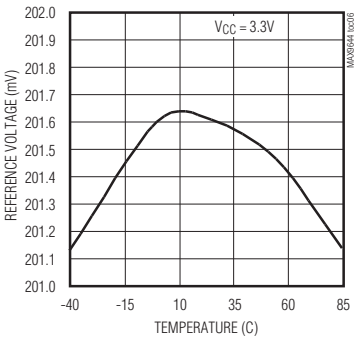
**OUTPUT VOLTAGE HIGH vs. SOURCE CURRENT (MAX9646)**



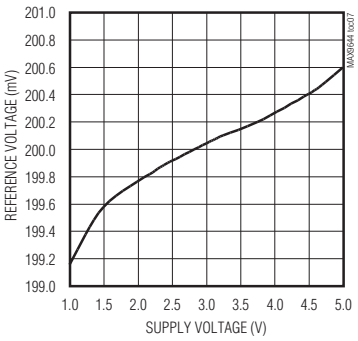

**INPUT BIAS CURRENT vs. INPUT BIAS VOLTAGE**



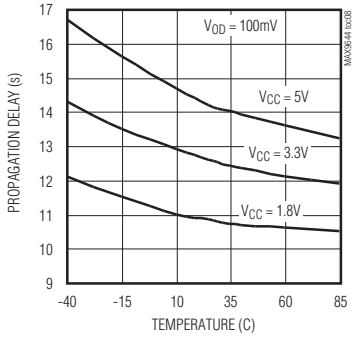

**REFERENCE VOLTAGE vs. TEMPERATURE**



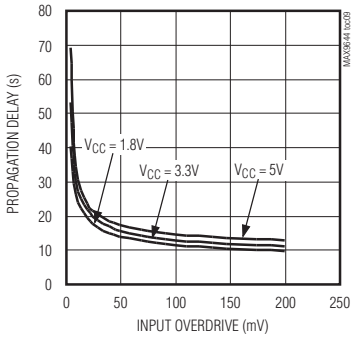

**REFERENCE VOLTAGE vs. SUPPLY VOLTAGE**




**PROPAGATION DELAY vs. TEMPERATURE**



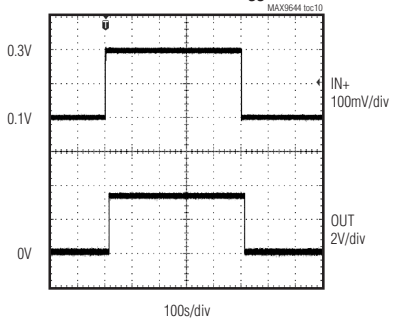

**PROPAGATION DELAY vs. INPUT OVERDRIVE**



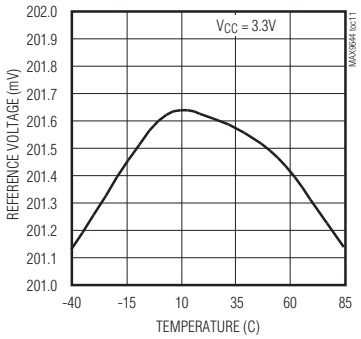
## Typical Operating Characteristics (continued)

($V_{CC}$ = 3.3V, $V_{REF}$ = 1.8V, $R_{PULLUP}$ = 10kΩ to $V_{PULLUP}$ = 3.3V for MAX9644/MAX9645, $V_{GND}$ = 0V, $T_A$ = +25°C, unless otherwise noted.)

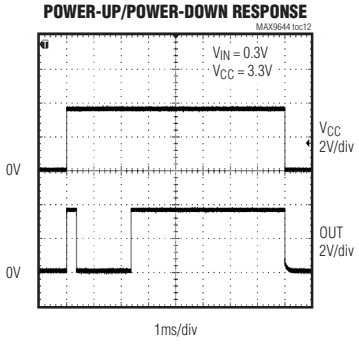
**PROPAGATION DELAY AT $V_{CC}$ = 3.3V**



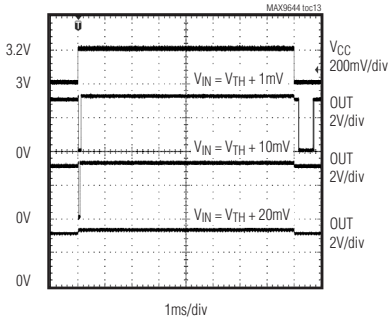

**REFERENCE VOLTAGE vs. TEMPERATURE**



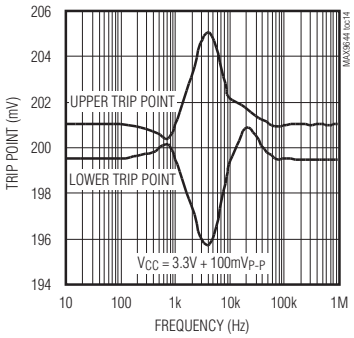

**POWER-UP/POWER-DOWN RESPONSE**



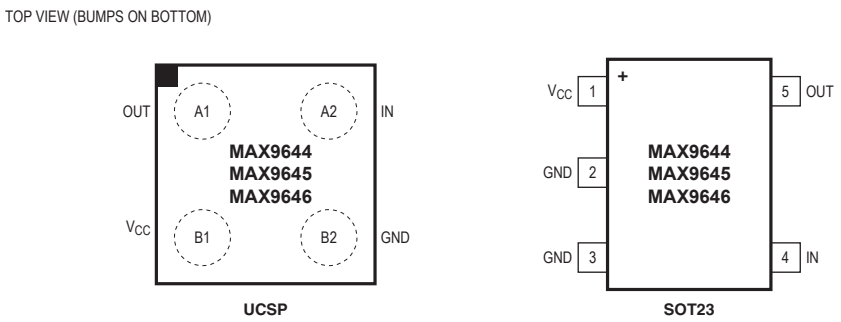

**OUTPUT RESPONSE TO SUPPLY VOLTAGE TRANSIENT**




**POWER-SUPPLY REJECTION FOR NO FALSE TRIGGERING**



## Pin Configuration




## Pin Description

| PIN | | NAME | FUNCTION |
|---|---|---|---|
| UCSP | SOT23 | | |
| A1 | 5 | OUT | Comparator Output. The MAX9644/MAX9645 have open-drain outputs. The MAX9646 has a push-pull output. |
| A2 | 4 | IN | Comparator Input. The MAX9644/MAX9646 have noninverting inputs. The MAX9645 has inverting inputs. |
| B1 | 1 | $V_{CC}$ | Power-Supply Voltage. Bypass to ground with a 0.1µF bypass capacitor. |
| B2 | 2, 3 | GND | Ground |

## Detailed Description

The MAX9644/MAX9645/MAX9646 are extremely small comparators ideal for compact, low-current, and low-voltage applications.

The ICs consume only 400nA (typ). The low-voltage operating capability of the operating current makes these devices extremely attractive to long-life battery-operated devices—these applications can now use a single digital power-supply rail to power the new generation of microcontrollers (which can be down to 0.9V). All parts are available in a tiny 4-bump UCSP, which is only 0.6mm tall and occupies a 1mm x 1mm footprint and a 5-pin SOT23.

### Input Stage Circuitry

Noninverting inputs are available on the MAX9644/MAX9646 and inverting inputs are available on the MAX9645.

The MAX9644/MAX9645/MAX9646 incorporate an innovative input stage architecture that allows their input voltage to exceed $V_{CC}$ by several volts (limited only by the *Absolute Maximum Ratings*). This is unlike traditional comparators that have an input ESD diode clamp between the input and $V_{CC}$, limiting this maximum overvoltage to about 0.3V. The ICs architecture maintains a high input impedance to input signals even when the device power-supply voltage is completely turned off ($V_{CC}$ or REF taken to 0V). This greatly benefits flexible power-saving schemes to be easily implemented in advanced battery-operated devices. On-chip filtering provides immunity from any RF noise being picked up by input traces. These devices feature an internal temperature-compensated, low-power 0.2V reference voltage

### Output Stage Structure

The MAX9644/MAX9645 have open-drain outputs that allow them to interface to logic circuitry running from supply voltages other than the one supplied to the part. These devices require an external pullup resistor or current source for proper operation. Many microcontroller digital inputs ports can be readily programmed to include these.

The MAX9646 has a push-pull output stage that can both sink and source current, eliminating the need for an external pullup resistor. In this case, the MAX9646 uses the microcontroller's power supply as $V_{CC}$

## Applications Information

### Bypassing REF/$V_{CC}$

Place a 0.1µF capacitor between REF or $V_{CC}$ and GND as close as possible to the device. During a switching event, all comparators draw a current spike from their power-supply rails. This current spike is minimized by the use of an internal break-before-make design.

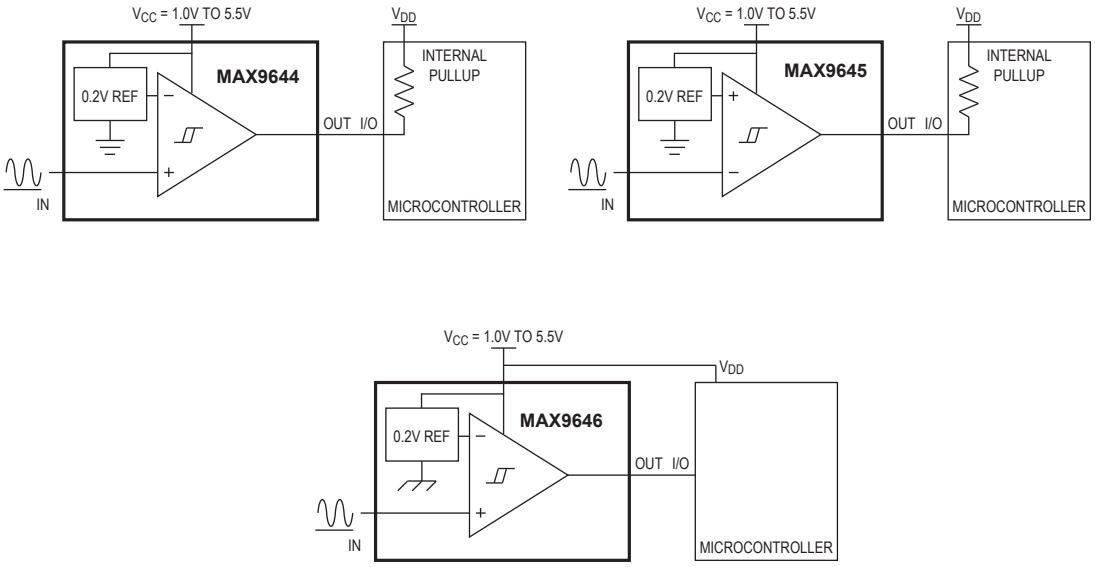
### Hysteresis Operation

The ICs feature internal hysteresis for noise immunity and glitch-free operation. If additional hysteresis is needed, an external positive feedback network can be easily implemented on the MAX9644 and MAX9646 noninverting input devices. Additional external hysteresis is not possible on the MAX9645 because the noninverting input of the comparator is not externally accessible.

Table 1. How Devices Behave Under Various Input Voltage Conditions

| PART | INPUT VOLTAGE CONDITIONS | ACTION AT OUTPUT |
|---|---|---|
| MAX9644 | $V_{IN}$ > 0.2V | External pullup resistor pulls output high. |
| | $V_{IN}$ < 0.2V | Output asserts low. |
| MAX9645 | $V_{IN}$ > 0.2V | Output asserts low. |
| | $V_{IN}$ < 0.2V | External pullup resistor pulls output high. |
| MAX9646 | $V_{IN}$ > 0.2V | Output asserts high. |
| | $V_{IN}$ < 0.2V | Output asserts low. |

## Typical Operating Circuits




## Chip Information

PROCESS: BiCMOS

## 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.

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO. | LAND PATTERN NO. |
|---|---|---|---|
| 4 UCSP | B4+1 | **21-0789** | Refer to **Application Note 1891** |
| 5 SOT23 | U5+2 | **21-0057** | **90-0174** |

## Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|---|---|---|---|
| 0 | 3/14 | Initial release | — |
| 1 | 10/11 | Updated *Features* section | 1 |
| 2 | 3/17 | Updated title to include “nanoPower” | 1–11 |
| 3 | 11/19 | Updated *Absolute Maximum Ratings* and *Package Information* | 2, 8 |