

# High-Voltage, Adjustable Sequencing/Supervisory Circuits

**MAX16052/MAX16053**

## General Description

The MAX16052/MAX16053 are a family of small, low-power, high-voltage monitoring circuits with sequencing capability. These miniature devices offer very wide flexibility with an adjustable voltage threshold and an external capacitor-adjustable time delay. These devices are ideal for use in power-supply sequencing, reset sequencing, and power switching applications. Multiple devices can be cascaded for complex sequencing applications.

A high-impedance input (IN) with a 0.5V threshold allows an external resistive divider to set the monitored threshold. The output (OUT) asserts high when the input voltage rises above the 0.5V threshold and the enable input (EN) is asserted high. When the voltage at IN falls below 0.495V or when the enable input is deasserted (EN = low), the output deasserts (OUT = low). The MAX16052/MAX16053 provide a capacitor programmable delay time from when the voltage at IN rises above 0.5V to when the output is asserted.

The MAX16052 offers an active-high open-drain output while the MAX16053 offers an active-high push-pull output. Both devices operate from a 2.25V to 16V supply voltage and feature an active-high enable input. The MAX16052/MAX16053 are available in a tiny 6-pin SOT23 package and are fully specified over the automotive temperature range (-40°C to +125°C).

## Applications

- |                         |                             |
|-------------------------|-----------------------------|
| Automotive              | Computers/Servers           |
| Medical Equipment       | Critical $\mu$ P Monitoring |
| Intelligent Instruments | Set-Top Boxes               |
| Portable Equipment      | Telecom                     |

## Features

- ◆ 1.8% Accurate Adjustable Threshold Over Temperature
- ◆ Open-Drain (28V Tolerant) Output Allows Interfacing to 12V Intermediate Bus Voltage
- ◆ Operates from V<sub>CC</sub> of 2.25V to 16V
- ◆ Low Supply Current (18 $\mu$ A typ)
- ◆ Capacitor-Adjustable Delay
- ◆ Active-High Logic-Enable Input
- ◆ Fully Specified from -40°C to +125°C
- ◆ Small 6-Pin SOT23 Package

## Ordering Information

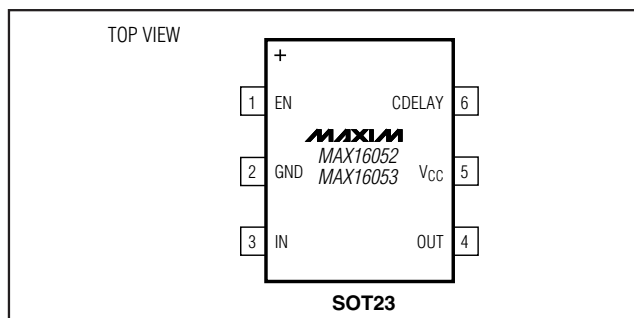
| PART          | OUTPUT     | PIN-PACKAGE | TOP MARK |
|---------------|------------|-------------|----------|
| MAX16052AUT+T | Open-Drain | 6 SOT23     | +ACLW    |
| MAX16053AUT+T | Push-Pull  | 6 SOT23     | +ACLX    |

**Note:** All devices operate over the -40°C to +125°C operating automotive temperature range.

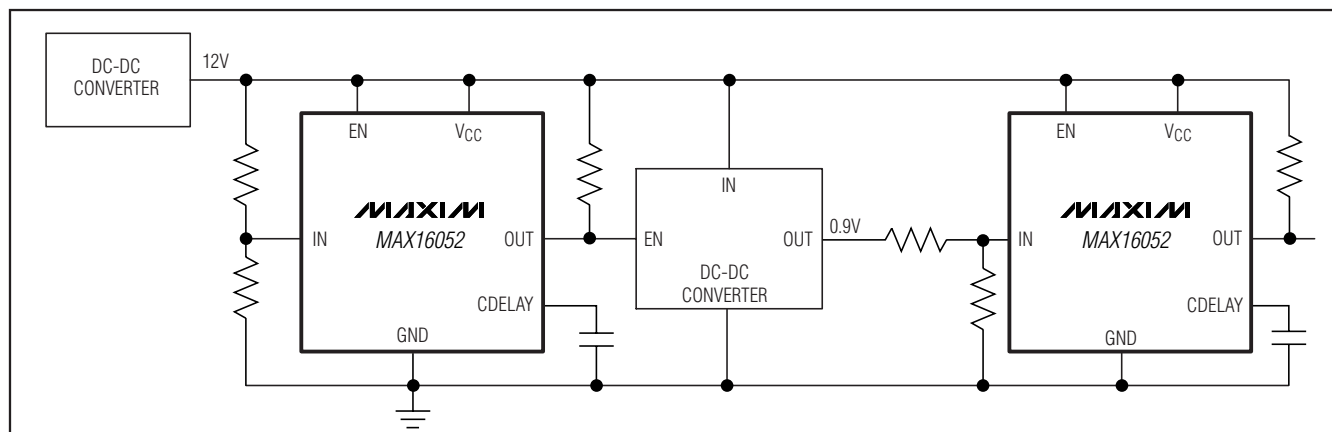
+Denotes a lead-free/RoHS-compliant package.

T = Tape and reel, offered in 2.5k increments.

## Pin Configuration



## Typical Operating Circuit



# High-Voltage, Adjustable Sequencing/Supervisory Circuits

MAX16052/MAX16053

## ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND.)

|                                      |                                   |
|--------------------------------------|-----------------------------------|
| V <sub>CC</sub> .....                | -0.3V to +30V                     |
| OUT (push-pull, MAX16053).....       | -0.3V to (V <sub>CC</sub> + 0.3V) |
| OUT (open-drain, MAX16052).....      | -0.3V to +30V                     |
| EN, IN.....                          | -0.3V to (V <sub>CC</sub> + 0.3V) |
| CDELAY.....                          | -0.3V to +6V                      |
| Input/Output Current (all pins)..... | ±20mA                             |

Continuous Power Dissipation (T<sub>A</sub> = +70°C)

|  |                 |
|--|-----------------|
| 6-Pin SOT23 (derate 8.7mW/°C above +70°C)..... | 695.7mW         |
| Operating Temperature Range.....               | -40°C to +125°C |
| Junction Temperature.....                      | +150°C          |
| Storage Temperature Range.....                 | -65°C to +150°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<sub>CC</sub> = 2.25V to 16V, V<sub>EN</sub> = V<sub>CC</sub>, T<sub>A</sub> = T<sub>J</sub> = -40°C to +125°C, unless otherwise specified. Typical values are at V<sub>CC</sub> = 3.3V and T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                                     | SYMBOL              | CONDITIONS  | MIN                    | TYP   | MAX   | UNITS |
|---|---------------------|---|------------------------|-------|-------|-------|
| <b>SUPPLY</b>                                 |                     |   |                        |       |       |       |
| Operating Voltage Range                       | V <sub>CC</sub>     |   | 2.25                   |       | 16    | V     |
| Undervoltage Lockout                          | UVLO                | V <sub>CC</sub> falling (Note 2)                      | 1.8                    |       | 2     | V     |
| V <sub>CC</sub> Supply Current                | I <sub>CC</sub>     | MAX16052, no load                                     | V <sub>CC</sub> = 3.3V | 18    | 37    | μA    |
|   |                     |   | V <sub>CC</sub> = 12V  | 23    | 45    |       |
|   |                     | MAX16053, no load                                     | V <sub>CC</sub> = 3.3V | 22    | 47    |       |
|   |                     |   | V <sub>CC</sub> = 12V  | 29    | 57    |       |
| <b>IN</b>                                     |                     |   |                        |       |       |       |
| Threshold Voltage                             | V <sub>TH</sub>     | V <sub>IN</sub> rising, 2.25V ≤ V <sub>CC</sub> ≤ 16V | 0.491                  | 0.500 | 0.509 | V     |
| Hysteresis                                    | V <sub>HYST</sub>   | V <sub>IN</sub> falling                               |                        | 5     |       | mV    |
| Input Current                                 | I <sub>IN</sub>     | V <sub>IN</sub> = 0 or 16V                            | -40                    | +5    | +60   | nA    |
| <b>CDELAY</b>                                 |                     |   |                        |       |       |       |
| CDELAY Charge Current                         | I <sub>CD</sub>     | V <sub>CDELAY</sub> = 0V                              | 200                    | 250   | 300   | nA    |
| CDELAY Threshold                              | V <sub>TCD</sub>    | V <sub>CDELAY</sub> rising                            | 0.95                   | 1.00  | 1.05  | V     |
| CDELAY Pulldown Resistance                    | R <sub>CDELAY</sub> | V <sub>CC</sub> ≥ 2.25V, I <sub>SINK</sub> = 200μA    |                        | 15    | 60    | Ω     |
|   |                     | V <sub>CC</sub> ≥ 3.3V, I <sub>SINK</sub> = 1mA       |                        | 15    | 60    |       |
| <b>EN</b>                                     |                     |   |                        |       |       |       |
| EN Low Voltage                                | V <sub>IL</sub>     |   |                        |       | 0.5   | V     |
| EN High Voltage                               | V <sub>IH</sub>     |   | 1.4                    |       |       | V     |
| EN Leakage Current                            | I <sub>LEAK</sub>   | V <sub>EN</sub> = 0V or V <sub>CC</sub>               | -55                    | +15   | +55   | nA    |
| <b>OUT</b>                                    |                     |   |                        |       |       |       |
| OUT Low Voltage<br>(Open-Drain or Push-Pull)  | V <sub>OL</sub>     | V <sub>CC</sub> ≥ 1.2V, I <sub>SINK</sub> = 90μA      |                        |       | 0.2   | V     |
|   |                     | V <sub>CC</sub> ≥ 2.25V, I <sub>SINK</sub> = 0.5mA    |                        |       | 0.3   |       |
|   |                     | V <sub>CC</sub> > 4.5V, I <sub>SINK</sub> = 1mA       |                        |       | 0.4   |       |
| OUT High Voltage<br>(Push-Pull, MAX16053)     | V <sub>OH</sub>     | V <sub>CC</sub> ≥ 2.25V, I <sub>SOURCE</sub> = 500μA  | 0.8 × V <sub>CC</sub>  |       |       | V     |
|   |                     | V <sub>CC</sub> ≥ 4.5V, I <sub>SOURCE</sub> = 800μA   | 0.9 × V <sub>CC</sub>  |       |       |       |
| OUT Leakage Current<br>(Open-Drain, MAX16052) | I <sub>LKG</sub>    | Output not asserted low, V <sub>OUT</sub> = 28V       |                        |       | 150   | nA    |

# High-Voltage, Adjustable Sequencing/Supervisory Circuits

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = 2.25V$  to  $16V$ ,  $V_{EN} = V_{CC}$ ,  $T_A = T_J = -40^{\circ}C$  to  $+125^{\circ}C$ , unless otherwise specified. Typical values are at  $V_{CC} = 3.3V$  and  $T_A = +25^{\circ}C$ .) (Note 1)

| PARAMETER                    | SYMBOL                 | CONDITIONS  |   | MIN                                | TYP | MAX     | UNITS   |
|------------------------------|------------------------|---|---|------------------------------------|-----|---------|---------|
| <b>TIMING</b>                |                        |   |   |                                    |     |         |         |
| IN to OUT Propagation Delay  | $t_{DELAY}$            | $V_{CC} = 3.3V$ ,<br>$V_{IN}$ rising,<br>$V_{IN} = V_{TH} + 25mV$ | MAX16052, 100k $\Omega$ pullup resistor, $C_{DELAY} = 0$          |                                    | 30  |         | $\mu s$ |
|                              |                        |   | MAX16053, $C_{DELAY} = 0$   |                                    | 30  |         |         |
|                              |                        |   | MAX16052, 100k $\Omega$ pullup resistor, $C_{DELAY} = 0.047\mu F$ |                                    | 190 |         | ms      |
|                              |                        |   | MAX16053, $C_{DELAY} = 0.047\mu F$                                |                                    | 190 |         |         |
|                              | $t_{DL}$               | $V_{CC} = 12V$ ,<br>$V_{IN}$ rising,<br>$V_{IN} = V_{TH} + 25mV$  | MAX16052, 100k $\Omega$ pullup resistor, $C_{DELAY} = 0$          |                                    | 30  |         | $\mu s$ |
|                              |                        |   | MAX16053, $C_{DELAY} = 0$   |                                    | 30  |         |         |
|                              | Startup Delay (Note 3) |   | $V_{CC} = 2.25V$ , $V_{IN} = 0.525V$ , $C_{DELAY} = 0$            |                                    | 0.5 |         | ms      |
|                              |                        |   | $V_{CC} = 12V$ , $V_{IN} = 12V$ , $C_{DELAY} = 0$                 |                                    | 0.5 |         |         |
| EN Minimum Input Pulse Width | $t_{MPW}$              |   |   | 1                                  |     | $\mu s$ |         |
| EN Glitch Rejection          |                        |   |   |                                    | 100 | ns      |         |
| EN to OUT Delay              | $t_{OFF}$              | From device enabled to device disabled                            | MAX16052, 100k $\Omega$ pullup resistor                           | $V_{CC} = 3.3V$                    | 250 |         | ns      |
|                              |                        |   |   | $V_{CC} = 12V$                     | 300 |         |         |
|                              |                        |   | MAX16053  | $V_{CC} = 3.3V$                    | 350 |         |         |
|                              |                        |   |   | $V_{CC} = 12V$                     | 400 |         |         |
| EN to OUT Delay              | $t_{PROP}$             | From device disabled to device enabled                            | MAX16052, 100k $\Omega$ pullup resistor, $C_{DELAY} = 0$          | $V_{CC} = 3.3V$                    | 14  |         | $\mu s$ |
|                              |                        |   |   | $V_{CC} = 12V$                     | 14  |         |         |
|                              |                        |   | MAX16053, $C_{DELAY} = 0$   | $V_{CC} = 3.3V$                    | 14  |         |         |
|                              |                        |   |   | $V_{CC} = 12V$                     | 14  |         |         |
|                              |                        |   | MAX16052, 100k $\Omega$ pullup resistor, $C_{DELAY} = 0.047\mu F$ |                                    | 190 |         | ms      |
|                              |                        |   |   | MAX16053, $C_{DELAY} = 0.047\mu F$ |     | 190     |         |

**Note 1:** All devices are production tested at  $T_A = +25^{\circ}C$ . Limits over temperature are guaranteed by design.

**Note 2:** When  $V_{CC}$  falls below the UVLO threshold, the outputs deassert (OUT goes low). When  $V_{CC}$  falls below 1.2V, the output state cannot be determined.

**Note 3:** During the initial power-up,  $V_{CC}$  must exceed 2.25V for at least 0.5ms before OUT can go high.

**MAX16052/MAX16053**

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**MAX16052/MAX16053**

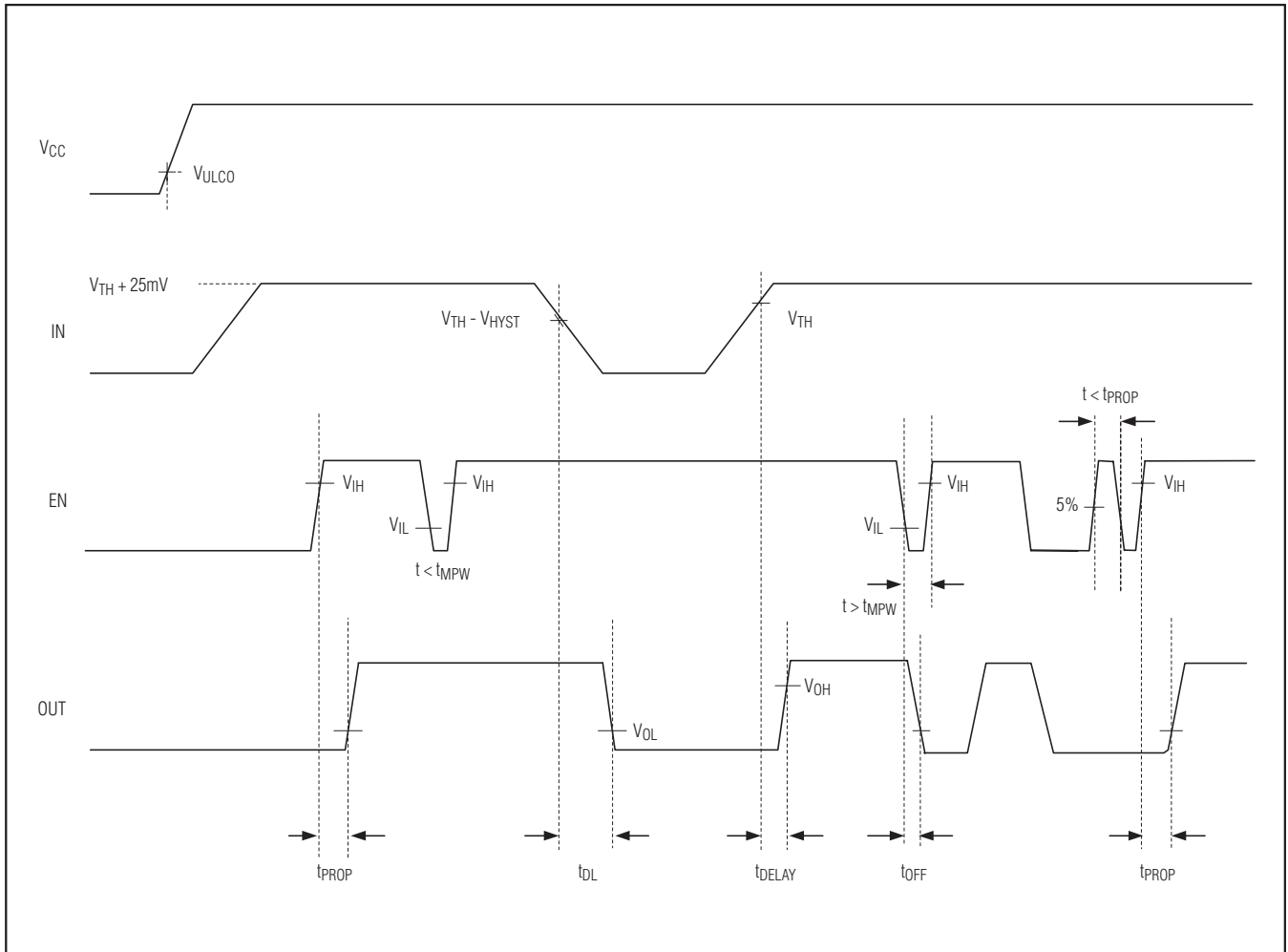


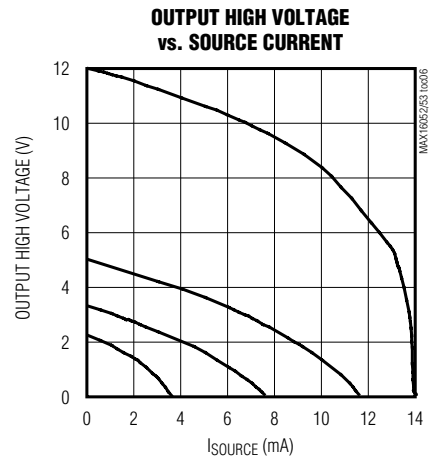
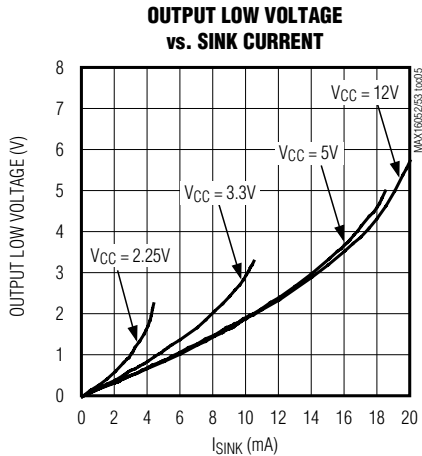
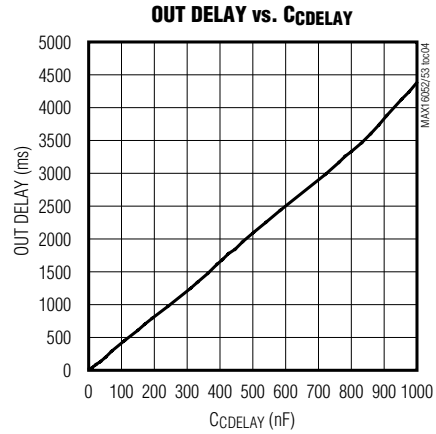
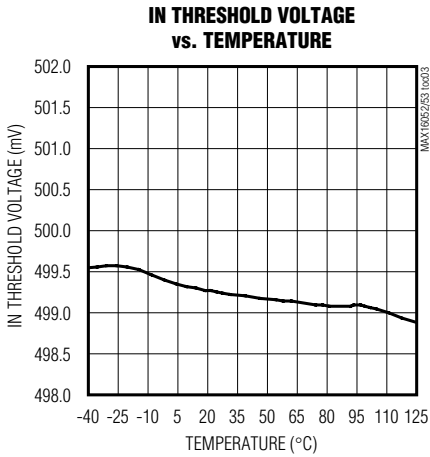
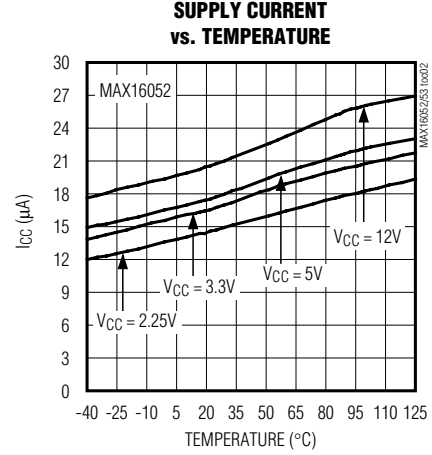
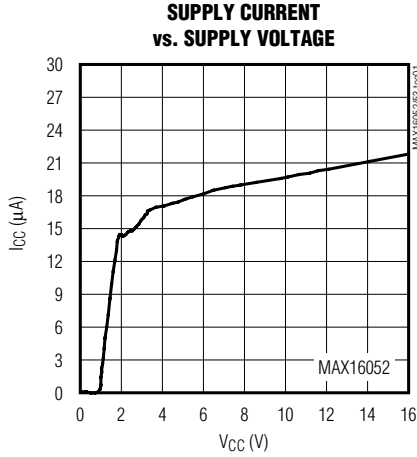
Figure 1. MAX16052/MAX16053 Timing Diagram (C<sub>DELAY</sub> = 0)

# High-Voltage, Adjustable Sequencing/Supervisory Circuits

## Typical Operating Characteristics

( $V_{CC} = 3.3V$  and  $T_A = +25^\circ C$ , unless otherwise noted.)

MAX16052/MAX16053

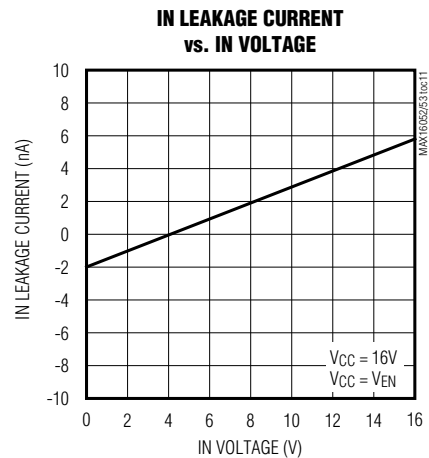
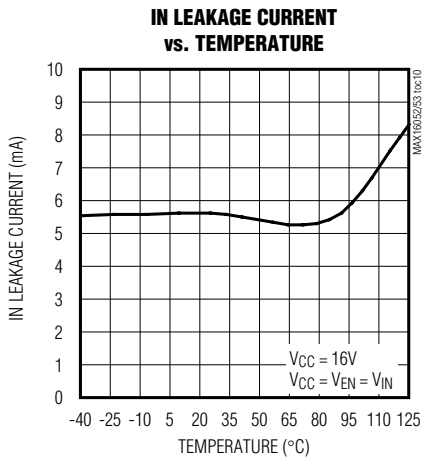
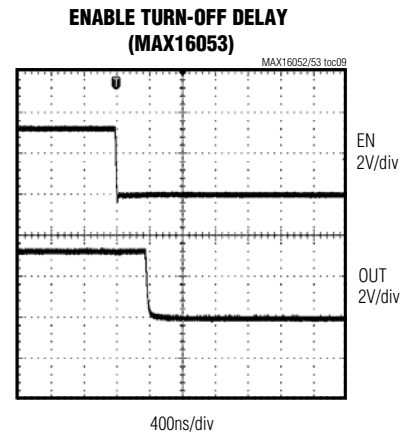
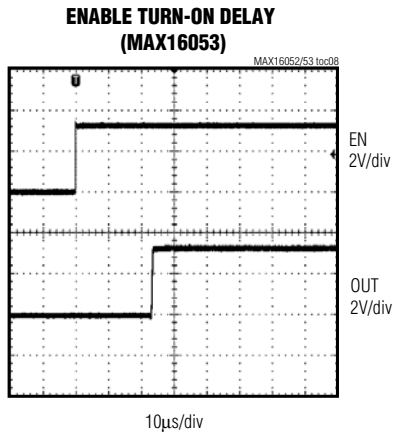
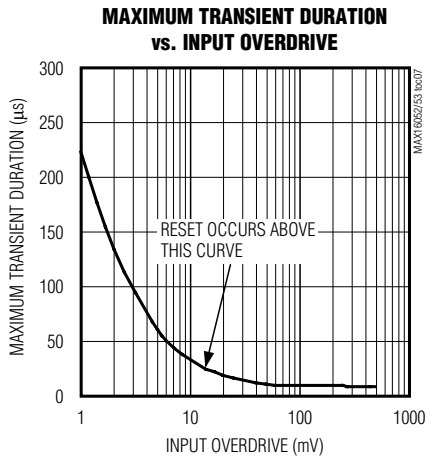


# High-Voltage, Adjustable Sequencing/Supervisory Circuits

MAX16052/MAX16053

## Typical Operating Characteristics

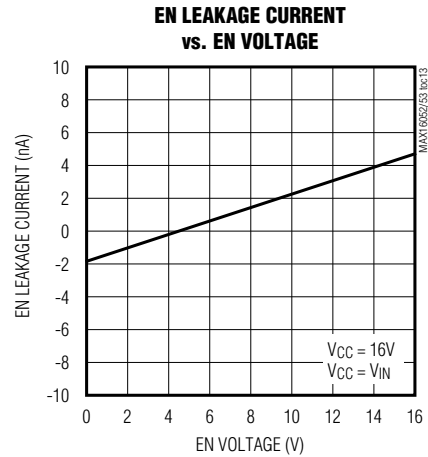
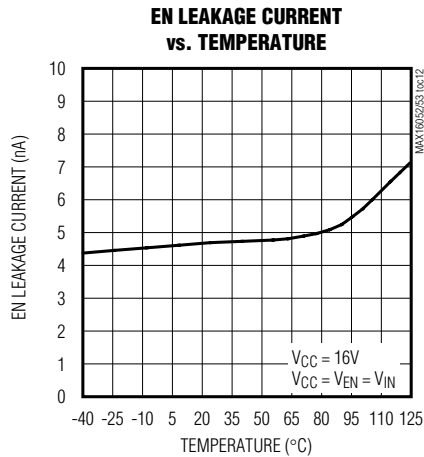
( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)



# High-Voltage, Adjustable Sequencing/Supervisory Circuits

## Typical Operating Characteristics (continued)

( $V_{CC} = 3.3V$  and  $T_A = +25^\circ C$ , unless otherwise noted.)



**MAX16052/MAX16053**

## Pin Description

| PIN | NAME     | FUNCTION   |
|-----|----------|--|
| 1   | EN       | Active-High Logic-Enable Input. Drive EN low to immediately deassert the output to its false state (OUT = low) independent of $V_{IN}$ . With $V_{IN}$ above $V_{TH}$ , drive EN high to assert the output to its true state (OUT = high) after the adjustable delay period. Connect EN to $V_{CC}$ , if not used.   |
| 2   | GND      | Ground   |
| 3   | IN       | High-Impedance Monitor Input. Connect IN to an external resistive divider to set the desired monitor threshold. The output changes state when $V_{IN}$ rises above 0.5V and when $V_{IN}$ falls below 0.495V.  |
| 4   | OUT      | Active-High Sequencer/Monitor Output. Open-drain (MAX16052) or push-pull (MAX16053). OUT is asserted to its true state (OUT = high) when $V_{IN}$ is above $V_{TH}$ and the enable input is in its true state (EN = high) after the capacitor-adjusted delay period. OUT is deasserted to its false state (OUT = low) immediately after $V_{IN}$ drops below 0.495V or the enable input is in its false state (EN = low). The MAX16052 open-drain output requires an external pullup resistor. |
| 5   | $V_{CC}$ | Supply Voltage Input. Connect a 2.25V to 16V supply to $V_{CC}$ to power the device. For noisy systems, bypass with a 0.1 $\mu$ F ceramic capacitor to GND.  |
| 6   | CDELAY   | Capacitor-Adjustable Delay Input. Connect an external capacitor ( $C_{CDELAY}$ ) from CDELAY to GND to set the IN-to-OUT and EN-to-OUT delay period. For $V_{IN}$ rising, $t_{DELAY} = (C_{CDELAY} \times 4.0 \times 10^6) + 30\mu s$ . For EN rising, $t_{PROP} = (C_{CDELAY} \times 4.0 \times 10^6) + 14\mu s$ .  |

# High-Voltage, Adjustable Sequencing/Supervisory Circuits

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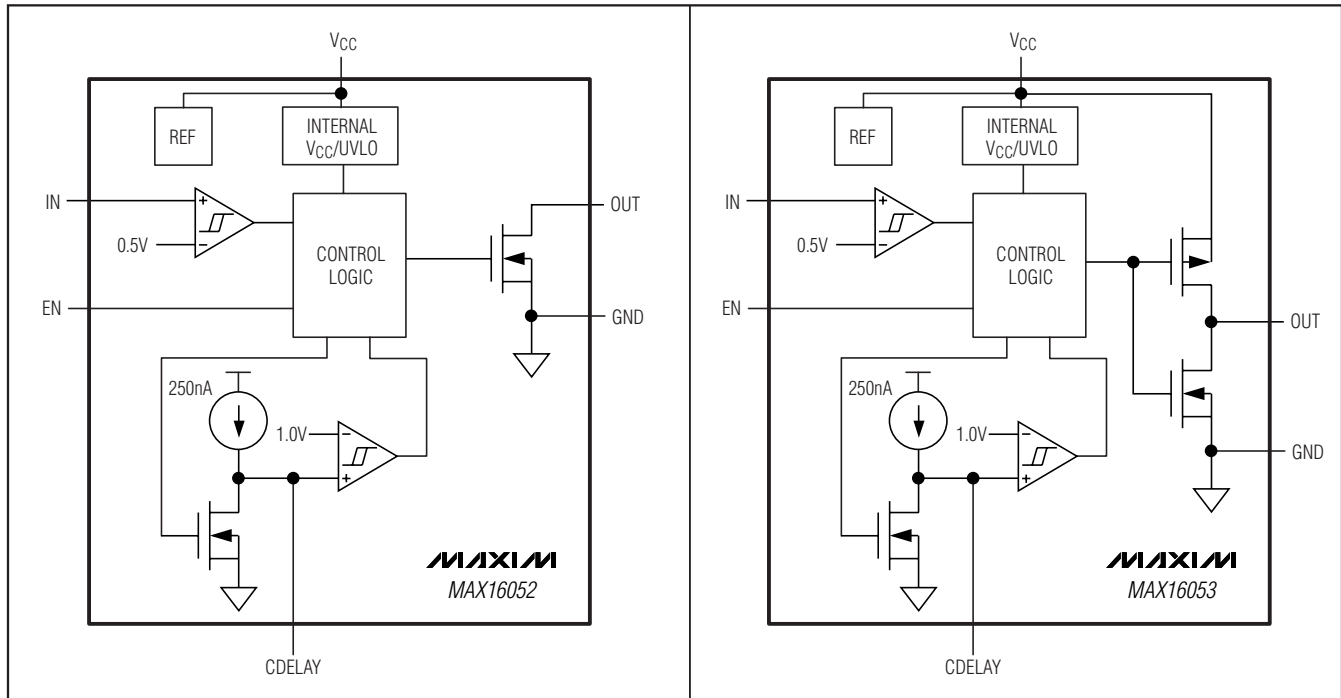


Figure 2. Simplified Functional Diagram

## Detailed Description

The MAX16052/MAX16053 family of high-voltage, sequencing/supervisory circuits provide adjustable voltage monitoring for inputs down to 0.5V. These devices are ideal for use in power-supply sequencing, reset sequencing, and power-switching applications. Multiple devices can be cascaded for complex sequencing applications.

The MAX16052/MAX16053 perform voltage monitoring using a high-impedance input (IN) with an internally fixed 0.5V threshold. When the voltage at IN falls below 0.5V or when the enable input is deasserted (EN = low) OUT goes low. When  $V_{IN}$  rises above 0.5V and the enable input is asserted (EN = high), OUT goes high after a capacitor-adjustable time delay.

With  $V_{IN}$  above 0.5V, the enable input can be used to turn on or off the output. Table 1 details the output state depending on the various input and enable conditions.

Table 1. MAX16052/MAX16053

| IN                | EN   | OUT                             |
|-------------------|------|---------------------------------|
| $V_{IN} < V_{TH}$ | Low  | Low                             |
| $V_{IN} < V_{TH}$ | High | Low                             |
| $V_{IN} > V_{TH}$ | Low  | Low                             |
| $V_{IN} > V_{TH}$ | High | OUT = High Impedance (MAX16052) |
|                   |      | OUT = $V_{CC}$ (MAX16053)       |

## Supply Input ( $V_{CC}$ )

The device operates with a  $V_{CC}$  supply voltage from 2.25V to 16V. In order to maintain a 1.8% accurate threshold at IN,  $V_{CC}$  must be above 2.25V. When  $V_{CC}$  falls below the UVLO threshold, the output deasserts low. When  $V_{CC}$  falls below 1.2V, the output state is not guaranteed. For noisy systems, connect a 0.1 $\mu$ F ceramic capacitor from  $V_{CC}$  to GND as close to the device as possible.



# High-Voltage, Adjustable Sequencing/Supervisory Circuits

## Monitor Input (IN)

Connect the center point of a resistive divider to IN to monitor external voltages (see R1 and R2 of Figure 4). IN has a rising threshold of  $V_{TH} = 0.5V$  and a falling threshold of  $0.495V$  (5mV hysteresis). When  $V_{IN}$  rises above  $V_{TH}$  and EN is high, OUT goes high after the adjustable  $t_{DELAY}$  period. When  $V_{IN}$  falls below  $0.495V$ , OUT goes low after a  $18\mu s$  delay. IN has a maximum input current of  $60nA$ , so large value resistors are permitted without adding significant error to the resistive divider.

## Adjustable Delay (CDELAY)

When  $V_{IN}$  rises above  $V_{TH}$  with EN high, the internal  $250nA$  current source begins charging an external capacitor connected from CDELAY to GND. When the voltage at CDELAY reaches  $1V$ , the output asserts (OUT goes high). When the output asserts, CDELAY is immediately discharged. Adjust the delay ( $t_{DELAY}$ ) from when  $V_{IN}$  rises above  $V_{TH}$  (with EN high) to OUT going high according to the equation:

$$t_{DELAY} = C_{CDELAY} \times (4 \times 10^6 \Omega) + (30\mu s)$$

where  $t_{DELAY}$  is in seconds and  $C_{CDELAY}$  is in Farads.

## Enable Input (EN)

The MAX16052/MAX16053 offer an active-high enable input (EN). With  $V_{IN}$  above  $V_{TH}$ , drive EN high to force OUT high after the capacitor-adjustable delay time. The EN-to-OUT delay time ( $t_{PROP}$ ) can be calculated from when EN goes above the EN threshold using the equation:

$$t_{PROP} = C_{CDELAY} \times (4 \times 10^6 \Omega) + (14\mu s)$$

where  $t_{PROP}$  is in seconds and  $C_{CDELAY}$  is in Farads. Drive EN low to force OUT low within  $300ns$  for the MAX16052 and within  $400ns$  for the MAX16053.

## Output (OUT)

The MAX16052 offers an active-high, open-drain output while the MAX16053 offers an active-high push-pull output. The push-pull output is referenced to  $V_{CC}$ . The open-drain output requires a pullup resistor and can be pulled up to  $28V$ .

## Applications Information

### Input Threshold

The MAX16052/MAX16053 monitor the voltage on IN with an external resistive divider (Figure 4). R1 and R2 can have very high values to minimize current consumption due to low IN leakage currents ( $60nA$  max). Set R2 to some conveniently high value ( $200k\Omega$  for  $\pm 1\%$

additional variation in threshold, for example) and calculate R1 based on the desired monitored voltage using the following formula:

$$R1 = R2 \times \left[ \frac{V_{MONITOR}}{V_{TH}} - 1 \right]$$

where  $V_{MONITOR}$  is the desired monitored voltage and  $V_{TH}$  is the reset input threshold ( $0.5V$ ).

### Pullup Resistor Values (MAX16052 Only)

The exact value of the pullup resistor for the open-drain output is not critical, but some consideration should be made to ensure the proper logic levels when the device is sinking current. For example, if  $V_{CC} = 2.25V$  and the pullup voltage is  $28V$ , keep the sink current less than  $0.5mA$  as shown in the *Electrical Characteristics* table. As a result, the pullup resistor should be greater than  $56k\Omega$ . For a  $12V$  pullup, the resistor should be larger than  $24k\Omega$ . Note that the ability to sink current is dependent on the  $V_{CC}$  supply voltage.

### Ensuring a Valid OUT Down to $V_{CC} = 0V$ (Push-Pull OUT)

In applications in which OUT must be valid down to  $V_{CC} = 0V$ , add a pulldown resistor between OUT and GND for the push-pull output (MAX16053). The resistor sinks any stray leakage currents, holding OUT low (Figure 3). The value of the pulldown resistor is not critical;  $100k\Omega$  is large enough not to load OUT and small enough to pull OUT to ground. The external pulldown cannot be used with the open-drain OUT output.

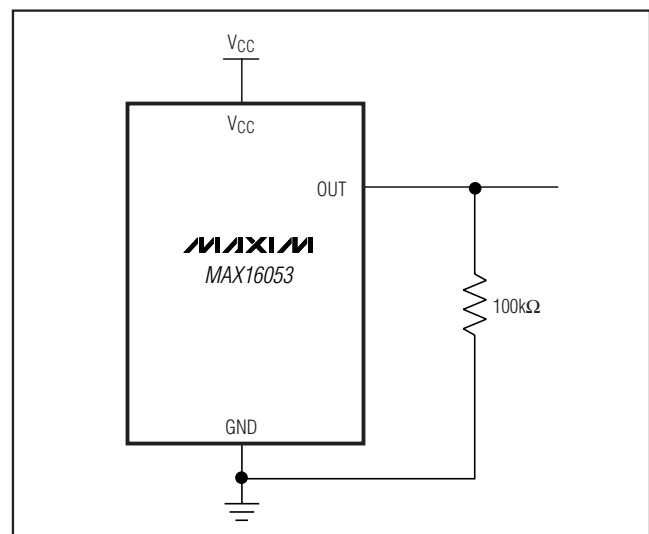


Figure 3. Ensuring OUT Valid to  $V_{CC} = 0V$

# High-Voltage, Adjustable Sequencing/Supervisory Circuits

MAX16052/MAX16053

## Typical Application Circuits

Figures 4–6 show typical applications for the MAX16052/MAX16053. Figure 4 shows the MAX16052 used with a p-channel MOSFET in an overvoltage protection circuit. Figure 5 shows the MAX16053 in a low-voltage sequencing application using an n-channel MOSFET. Figure 6 shows the MAX16053 used in a multiple output sequencing application.

### Using an n-Channel Device for Sequencing

In higher power applications, using an n-channel device reduces the loss across the MOSFET as it offers

a lower drain-to-source on-resistance. However, an n-channel MOSFET requires a sufficient  $V_{GS}$  voltage to fully enhance it for a low  $R_{DS\_ON}$ . The application shown in Figure 5 shows the MAX16053 in a switch sequencing application using an n-channel MOSFET.

Similarly, if a higher voltage is present in the system, the open-drain version can be used in the same manner.

### Power-Supply Bypassing

In noisy applications, bypass  $V_{CC}$  to ground with a  $0.1\mu\text{F}$  capacitor as close to the device as possible. The additional capacitor improves transient immunity. For fast-rising  $V_{CC}$  transients, additional capacitors may be required.

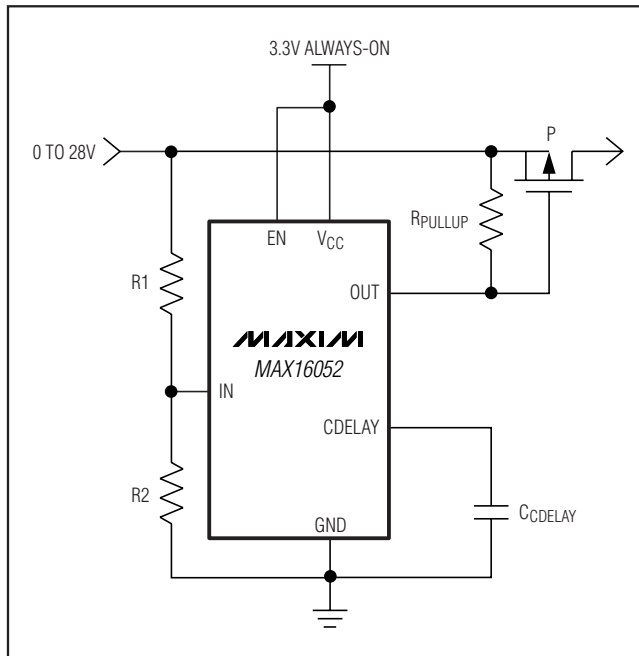


Figure 4. Overvoltage Protection

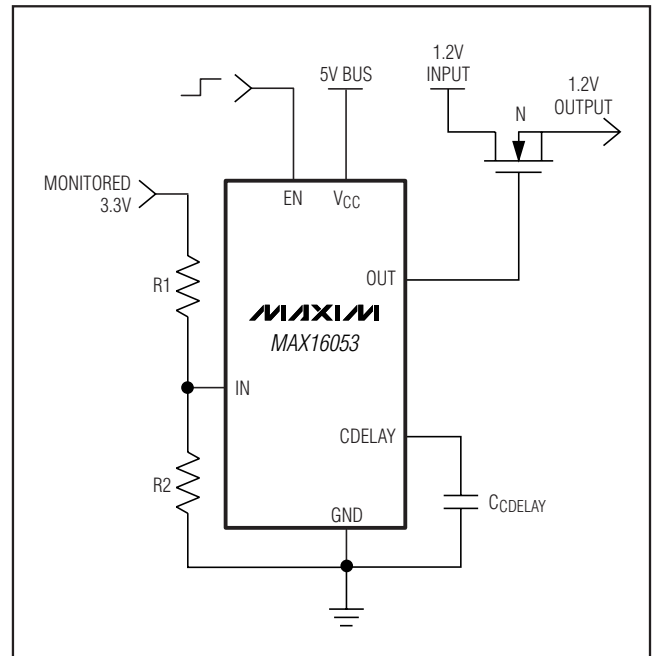


Figure 5. Low-Voltage Sequencing Using an n-Channel MOSFET

# High-Voltage, Adjustable Sequencing/Supervisory Circuits

**MAX16052/MAX16053**

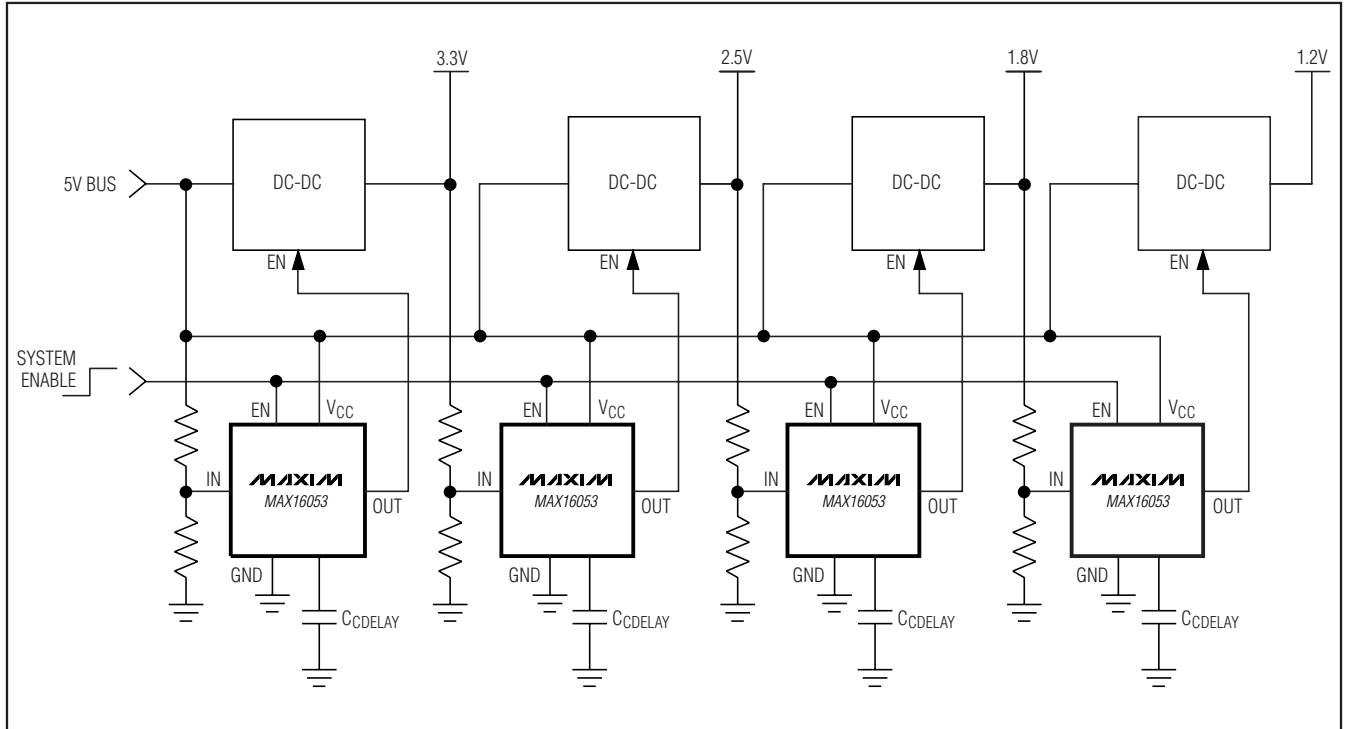


Figure 6. Multiple Output Sequencing

## Chip Information

PROCESS: BiCMOS

## Package Information

For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO.            |
|--------------|--------------|-------------------------|
| 6 SOT23      | U6+1         | <a href="#">21-0058</a> |

# High-Voltage, Adjustable Sequencing/Supervisory Circuits

## Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION   | PAGES CHANGED |
|-----------------|---------------|---|---------------|
| 0               | 5/08          | Initial release   | —             |
| 1               | 10/08         | Update <i>Adjustable Delay (CDELAY)</i> and <i>Power-Supply Bypassing</i> sections. | 8, 10         |

**MAX16052/MAX16053**

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