MAX16052/MAX16053

High-Voltage, Adjustable Sequencing/Supervisory Circuits

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 de-asserted (EN = low), the output deasserts (OUT = low). The devices 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 28V 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).

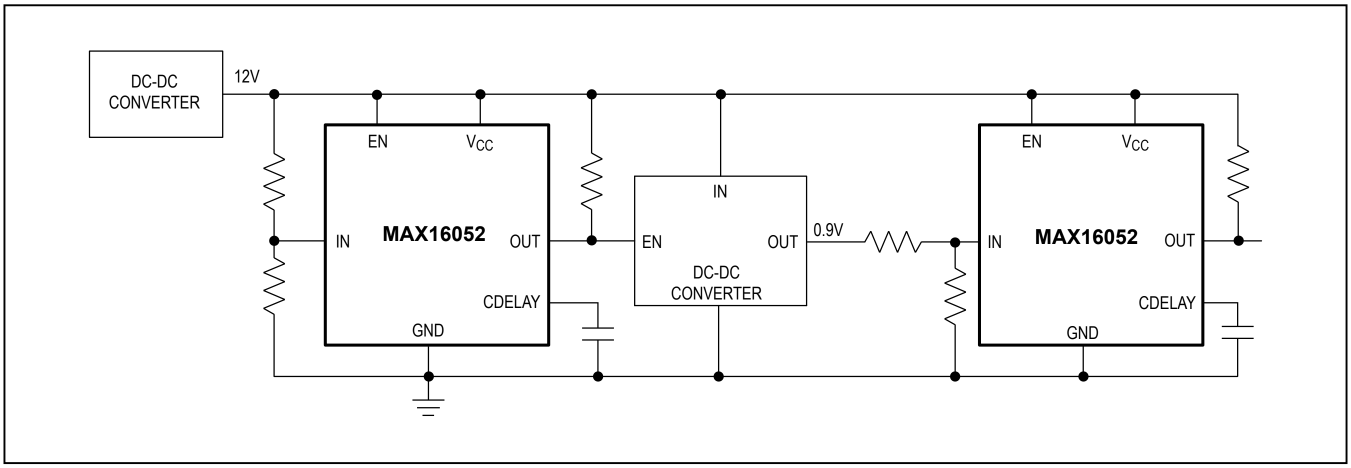
Benefits and Features

- Less External Circuitry Results in Smaller Solution Size
  - Open-Drain (28V Tolerant) Output Allows Interfacing to 12V Intermediate Bus Voltage
  - Operates from V_{CC} of 2.25V to 28V
  - Small 6-Pin SOT23 Package
- Ideal for Use in Power-Supply Sequencing, Reset Sequencing, and Power-Switching Applications
  - Active-High Logic-Enable Input
  - 1.8% Accurate Adjustable Threshold Over Temperature
- Fully Specified from -40°C to +125°C for Reliability in Extreme Temperatures
- Low Supply Current (18μA typ) Reduces Power Consumption

Applications

- Medical Equipment
- Intelligent Instruments
- Portable Equipment
- Computers/Servers
- Critical μP Monitoring
- Set-Top Boxes
- Telecom

Typical Operating Circuit



19-4144; Rev 7; 5/18

Absolute Maximum Ratings

(All voltages referenced to GND.)
V_{CC} .... -0.3V to +30V
OUT (push-pull, MAX16053) .... -0.3V to (V_{CC} + 0.3V)
OUT (open-drain, MAX16052) .... -0.3V to +30V
EN, IN .... -0.3V to (V_{CC} + 0.3V)
CDELAY .... -0.3V to +6V
Input/Output Current (all pins) .... ±20mA
Continuous Power Dissipation (T_A = +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
Soldering Temperature (reflow) .... +260°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} = 2.25V to 28V, V_{EN} = V_{CC}, T_A = T_J = -40°C to +125°C, unless otherwise specified. Typical values are at V_{CC} = 3.3V and T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
SUPPLY							
Operating Voltage Range	V_{CC}			2.25		28	V
Undervoltage Lockout	UVLO	V_{CC} falling (Note 2)		1.8		2	V
V_{CC} Supply Current	I_{CC}	MAX16052, no load	V_{CC} = 3.3V		18	37	µA
			V_{CC} = 12V		23	45	
			V_{CC} = 28V		38	61	
		MAX16053, no load	V_{CC} = 3.3V		22	47	
			V_{CC} = 12V		29	57	
			V_{CC} = 28V		44	71	
IN							
Threshold Voltage	V_{TH}	V_{IN} rising, 2.25V ≤ V_{CC} ≤ 28V		0.491	0.500	0.509	V
Hysteresis	V_{HYST}	V_{IN} falling			5		mV
Input Current	I_{IN}	V_{IN} = 0 or 28V		-110	+25	+110	nA
C_{DELAY}							
C_{DELAY} Charge Current	I_{CD}	V_{CDELAY} = 0V		200	250	300	nA
C_{DELAY} Threshold	V_{TCD}	V_{CDELAY} rising		0.95	1.00	1.05	V
C_{DELAY} Pulldown Resistance	R_{CDELAY}	V_{CC} ≥ 2.25V, I_{SINK} = 200µA			15	60	Ω
		V_{CC} ≥ 3.3V, I_{SINK} = 1mA			15	60	
EN							
EN Low Voltage	V_{IL}					0.5	V
EN High Voltage	V_{IH}			1.4			V
EN Leakage Current	I_{LEAK}	V_{EN} = 0 or 28V		-110	+20	+110	nA
OUT							
OUT Low Voltage (Open-Drain or Push-Pull)	V_{OL}	V_{CC} ≥ 1.2V, I_{SINK} = 90µA				0.2	V
		V_{CC} ≥ 2.25V, I_{SINK} = 0.5mA				0.3	
		V_{CC} > 4.5V, I_{SINK} = 1mA				0.4	
OUT High Voltage (Push-Pull, MAX16053)	V_{OH}	V_{CC} ≥ 2.25V, I_{SOURCE} = 500µA		0.8 x V_{CC}			V
		V_{CC} ≥ 4.5V, I_{SOURCE} = 800µA		0.9 x V_{CC}			
OUT Leakage Current (Open-Drain, MAX16052)	I_{LKG}	Output not asserted low, V_{OUT} = 28V				150	nA

Electrical Characteristics (continued)

(V_{CC} = 2.25V to 28V, V_{EN} = V_{CC}, T_A = T_J = -40°C to +125°C, unless otherwise specified. Typical values are at V_{CC} = 3.3V and T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
TIMING						
IN to OUT Propagation Delay	t_{DELAY}	V_{CC} = 3.3V, V_{IN} rising, V_{IN} = V_{TH} + 25mV; MAX16052, 100kΩ pullup resistor, C_{CDELAY} = 0		30		µs
		V_{CC} = 3.3V, V_{IN} rising, V_{IN} = V_{TH} + 25mV; MAX16053, C_{CDELAY} = 0		30		
		V_{CC} = 3.3V, V_{IN} rising, V_{IN} = V_{TH} + 25mV; MAX16052, 100kΩ pullup resistor, C_{CDELAY} = 0.047µF		190		ms
		V_{CC} = 3.3V, V_{IN} rising, V_{IN} = V_{TH} + 25mV; MAX16053, C_{CDELAY} = 0.047µF		190		
		V_{CC} = 12V, V_{IN} rising, V_{IN} = V_{TH} + 25mV; MAX16052, 100kΩ pullup resistor, C_{CDELAY} = 0		30		µs
		V_{CC} = 12V, V_{IN} rising, V_{IN} = V_{TH} + 25mV; MAX16053, C_{CDELAY} = 0		30		
	t_{DL}	V_{CC} = 3.3V, V_{IN} falling, V_{IN} = V_{TH} - 30mV		18		
		V_{CC} = 12V, V_{IN} falling, V_{IN} = V_{TH} - 30mV		18		
Startup Delay (Note 3)		V_{CC} = 2.25V, V_{IN} = 0.525V, C_{CDELAY} = 0		0.5		ms
		V_{CC} = 12V, V_{IN} = 12V, C_{CDELAY} = 0		0.5		
EN Minimum Input Pulse Width	t_{MPW}		1			µs
EN Glitch Rejection				100		ns
EN to OUT Delay	t_{OFF}	From device enabled to device disabled; MAX16052, 100kΩ pullup resistor; V_{CC} = 3.3V		250		ns
		From device enabled to device disabled; MAX16052, 100kΩ pullup resistor; V_{CC} = 12V		300		
		From device enabled to device disabled; MAX16053; V_{CC} = 3.3V		350		
		From device enabled to device disabled; MAX16053; V_{CC} = 12V		400		
EN to OUT Delay	t_{PROP}	From device disabled to device enabled; MAX16052, 100kΩ pullup resistor, C_{CDELAY} = 0; V_{CC} = 3.3V		14		µs
		From device disabled to device enabled; MAX16052, 100kΩ pullup resistor, C_{CDELAY} = 0; V_{CC} = 12V		14		
		From device disabled to device enabled; MAX16053; V_{CC} = 3.3V		14		
		From device disabled to device enabled; MAX16053; V_{CC} = 12V		14		
		From device disabled to device enabled; MAX16052, 100kΩ pullup resistor, C_{CDELAY} = 0.047µF		190		ms
		From device disabled to device enabled; MAX16053, C_{CDELAY} = 0.047µF		190		

Note 1: All devices are production tested at T_A = +25°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.

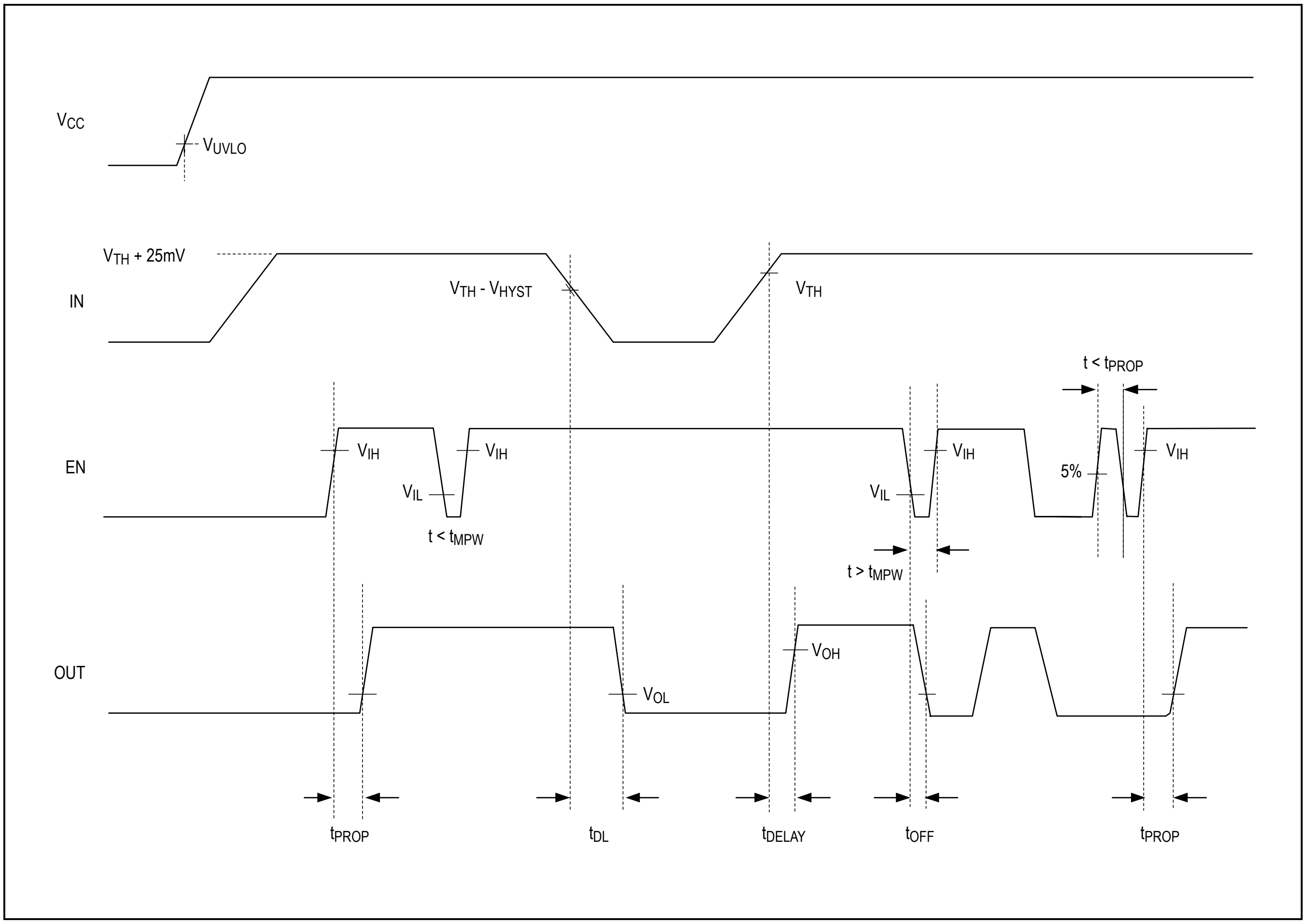
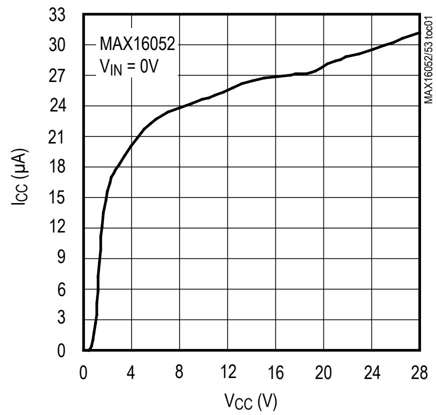


Figure 1. MAX16052/MAX16053 Timing Diagram (C_{CDELAY} = 0)

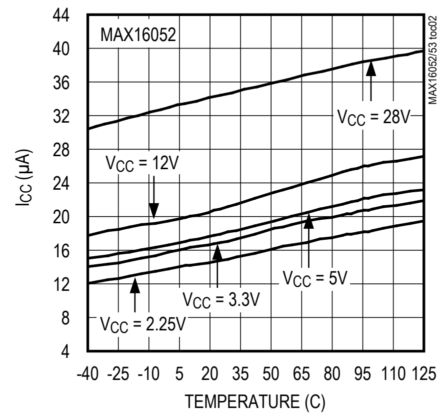
Typical Operating Characteristics

(V_{CC} = 3.3V and T_A = +25°C, unless otherwise noted.)

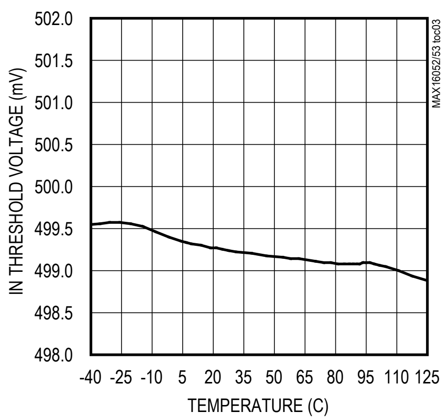
SUPPLY CURRENT vs. SUPPLY VOLTAGE



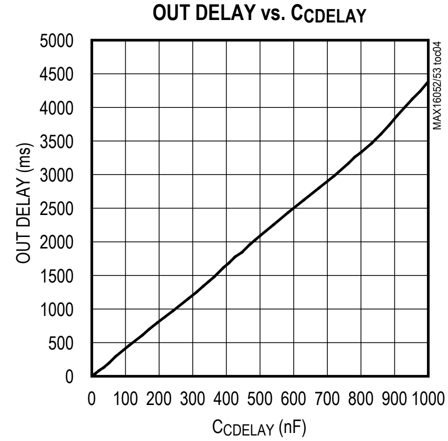
SUPPLY CURRENT vs. TEMPERATURE



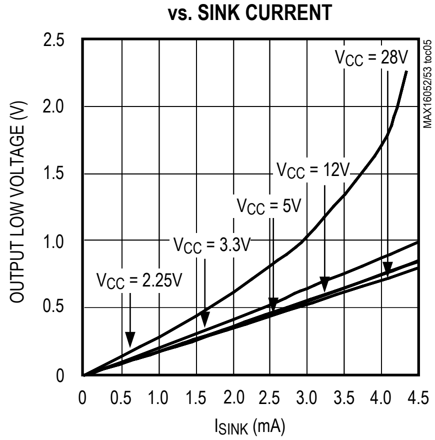
IN THRESHOLD VOLTAGE vs. TEMPERATURE



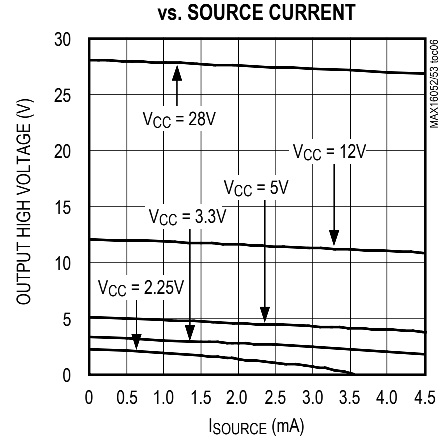
OUT DELAY vs. CCDELAY



OUTPUT LOW VOLTAGE vs. SINK CURRENT



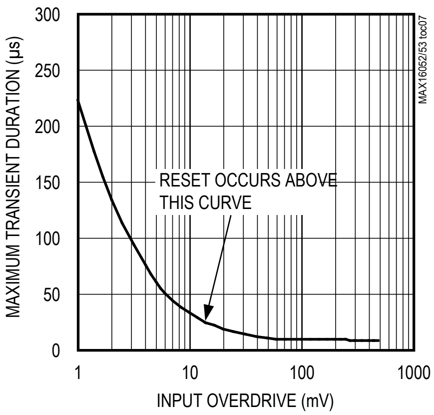
OUTPUT HIGH VOLTAGE vs. SOURCE CURRENT



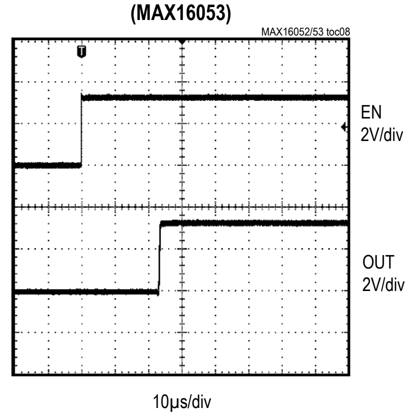
Typical Operating Characteristics (continued)

(V_{CC} = 3.3V and T_A = +25°C, unless otherwise noted.)

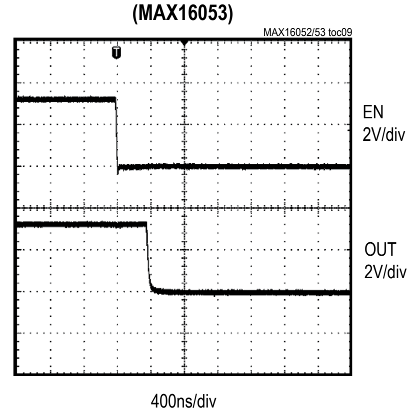
MAXIMUM TRANSIENT DURATION vs. INPUT OVERDRIVE



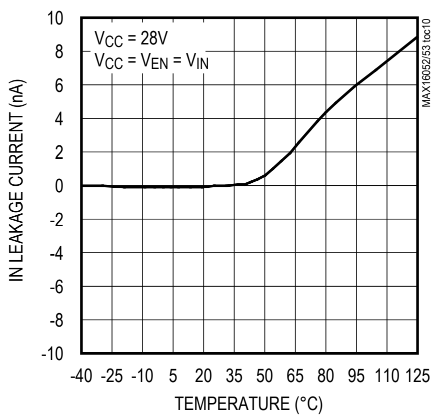
ENABLE TURN-ON DELAY (MAX16053)



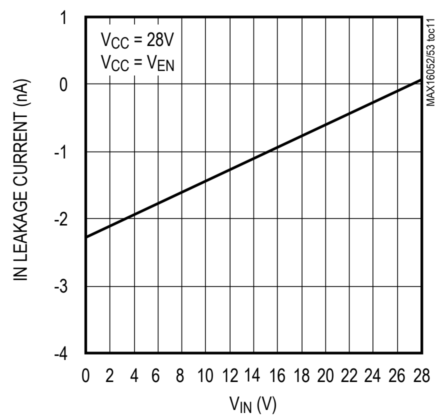
ENABLE TURN-OFF DELAY (MAX16053)



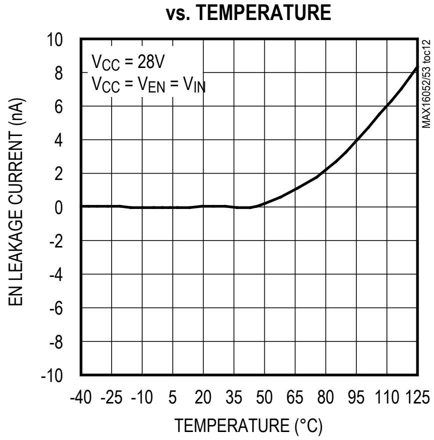
IN LEAKAGE CURRENT vs. TEMPERATURE



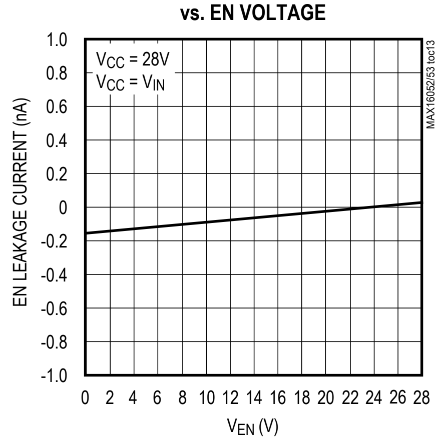
IN LEAKAGE CURRENT vs. IN VOLTAGE



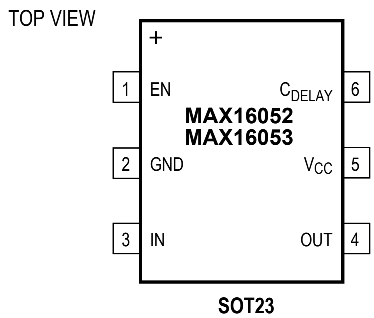
EN LEAKAGE CURRENT vs. TEMPERATURE



EN LEAKAGE CURRENT vs. EN VOLTAGE



Pin Configuration



Pin Description

PIN	NAME	FUNCTION
1	EN	Active-High Logic-Enable Input. Drive EN low to immediately de-assert 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 de-asserted 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 28V supply to V_{CC} to power the device. For noisy systems, bypass with a 0.1µF ceramic capacitor to GND.
6	C_{DELAY}	Capacitor-Adjustable Delay Input. Connect an external capacitor (C_{CDELAY}) from C_{DELAY} to GND to set the IN-to-OUT and EN-to-OUT delay period. For V_{IN} rising, t_{DELAY} = (C_{CDELAY} x 4.0 x 106) + 30µs. For EN rising, t_{PROP} = (C_{CDELAY} x 4.0 x 10^6) + 14µs.

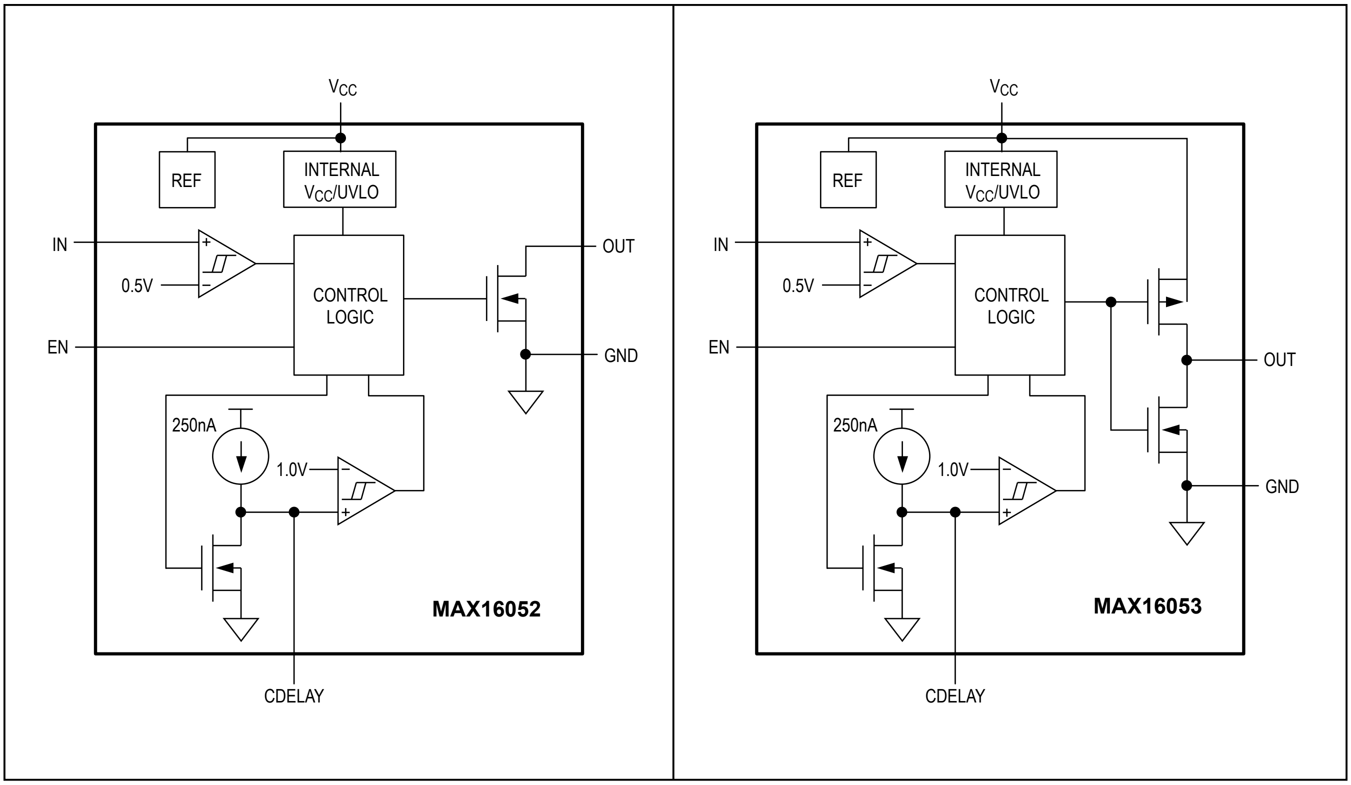


Figure 2. Simplified Functional Diagram

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 de-asserted (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 28V. 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 0.1µF ceramic capacitor from V_{CC} to GND as close to the device as possible.

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 18µs 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 C_{DELAY} to GND. When the voltage at C_{DELAY} reaches 1V, the output asserts (OUT goes high). When the output asserts, C_{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 (200kΩ for ±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 56kΩ. For a 12V pullup, the resistor should be larger than 24kΩ. 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; 100kΩ 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.

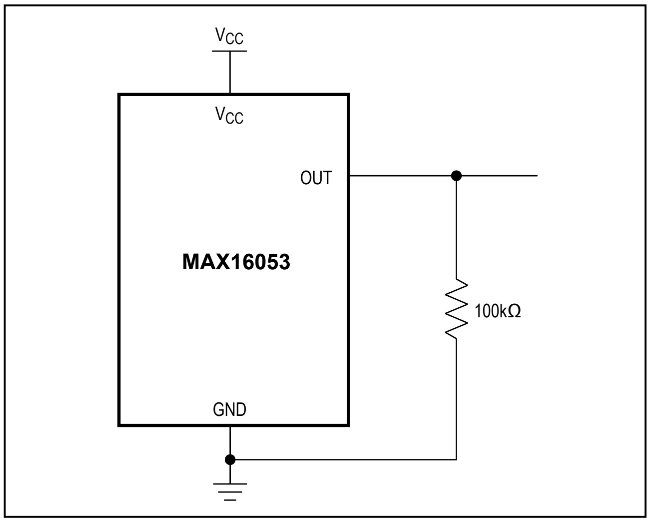


Figure 3. Ensuring OUT Valid to V_{CC} = 0V

Typical Application Circuits

Figure 4 through Figure 6 show typical applications for the MAX16052/MAX16053. Figure 4 shows the MAX16052 used with a pMOSFET in an overvoltage protection circuit. Figure 5 shows the MAX16053 in a low-voltage sequencing application using an nMOSFET. 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 nMOSFET 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 nMOSFET.

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 0.1µF 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.

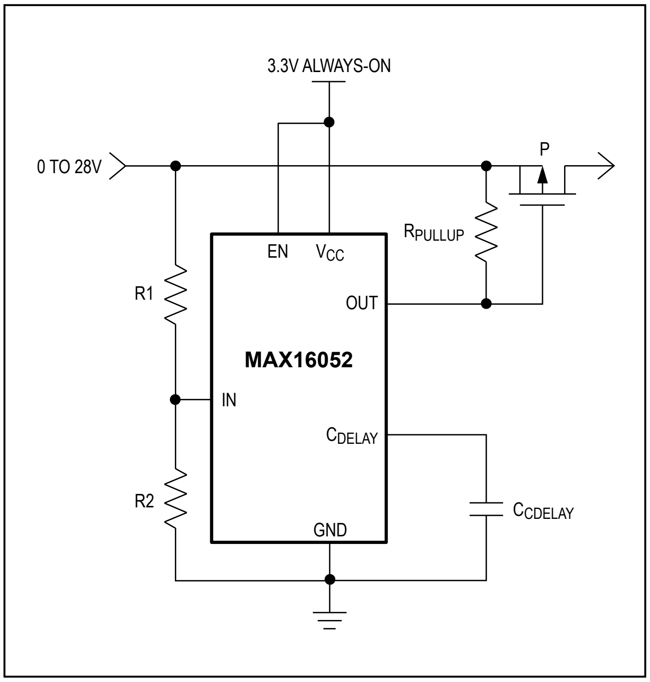


Figure 4. Overvoltage Protection

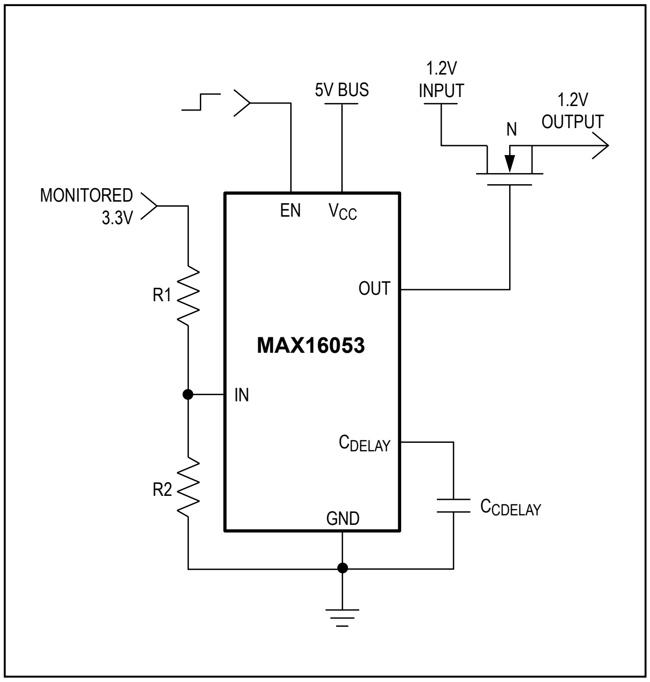


Figure 5. Low-Voltage Sequencing Using an nMOSFET

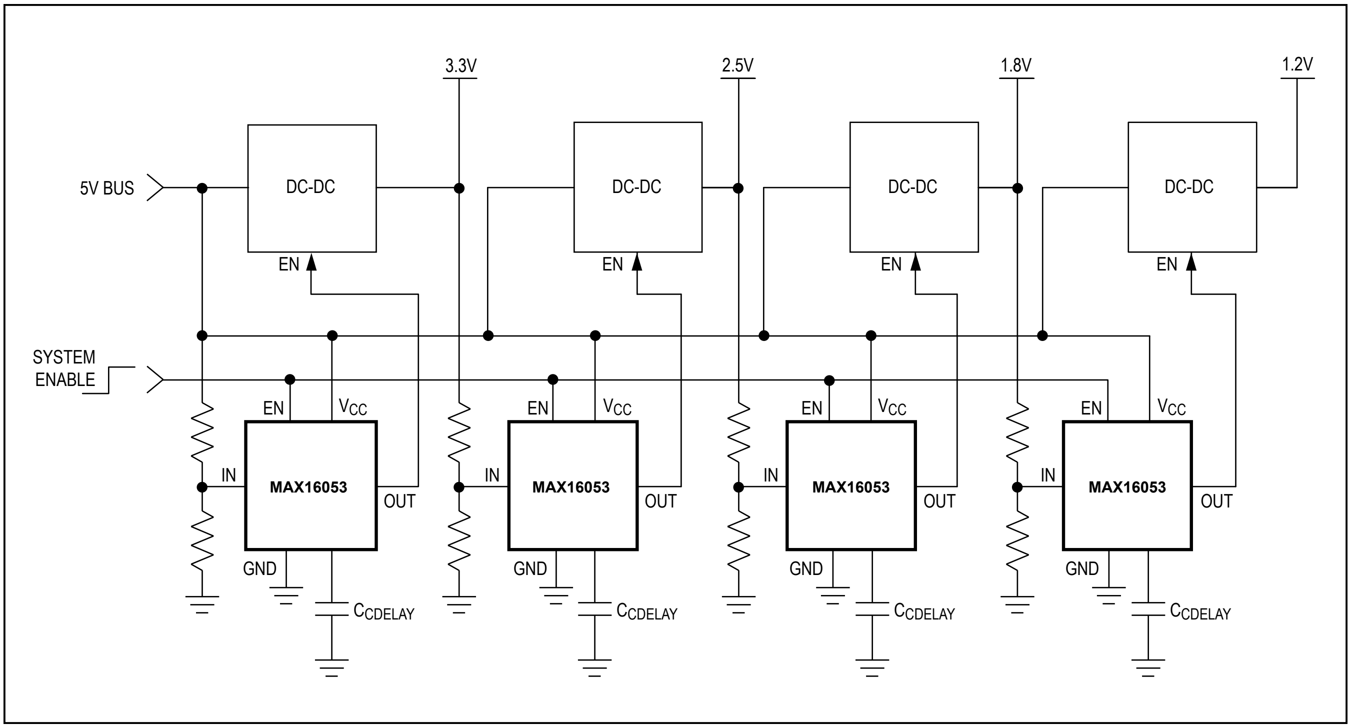


Figure 6. Multiple Output Sequencing

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(Pb)-free/RoHS-compliant package.

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

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	OUTLINE NO.	LAND PATTERN NO.
6 SOT23	U6+1	21-0058	90-0175

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	5/08	Initial release	—
1	10/08	Update *Adjustable Delay (CDELAY)* and *Power-Supply Bypassing* sections.	9, 10
2	1/10	Revised the *Features, General Description, Absolute Maximum Ratings, Electrical Characteristics, Typical Operating Characteristics, Pin Description*, and the *Supply Input (V_{CC})* sections.	1, 2, 3, 5–8
3	4/14	No /V OPNs; removed Automotive reference from *Applications* section	1
4	5/15	Added the *Benefits and Features* section	1
5	3/16	Updated package outline drawing number in *Ordering Information* table	12
6	8/16	Updated Table 1	8
7	5/18	Updated TOC10	6

