

## MAX16000–MAX16007

### General Description

The MAX16000–MAX16007 are low-voltage, quad/hex/octal-voltage  $\mu$ P supervisors in small TQFN and TSSOP packages. These devices provide supervisory functions for complex multivoltage systems. The MAX16000/MAX16001/MAX16002 monitor four voltages, the MAX16003/MAX16004/MAX16005 monitor six voltages, and the MAX16006/MAX16007 monitor eight voltages.

The MAX16000/MAX16001/MAX16003/MAX16004/MAX16006 offer independent outputs for each monitored voltage. The MAX16001/MAX16002/MAX16004–MAX16007 offer a reset output that asserts whenever any of the monitored voltages fall below their respective thresholds or the manual reset input is asserted. The reset output remains asserted for the reset timeout after all voltages are above their respective thresholds and the manual reset input is deasserted. The minimum reset timeout is internally set to 140ms or can be adjusted with an external capacitor.

All open-drain outputs have internal  $30\mu\text{A}$  pullups that eliminate the need for external pullup resistors. However, each output can be driven with an external voltage up to 5.5V. Other features offered include a manual reset input, a tolerance pin for selecting 5% or 10% input thresholds, and a margin enable function for deasserting the outputs during margin testing.

The MAX16001/MAX16002/MAX16004–MAX16007 offer a watchdog timer that asserts  $\overline{\text{RESET}}$  or an independent watchdog output (MAX16005) when the watchdog timeout period (1.6s typ) is exceeded. The watchdog timer can be disabled by leaving the input open.

These devices are offered in 12, 16, 20, and 24-pin TQFN and 16-pin TSSOP packages. These are fully specified from  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

### Applications

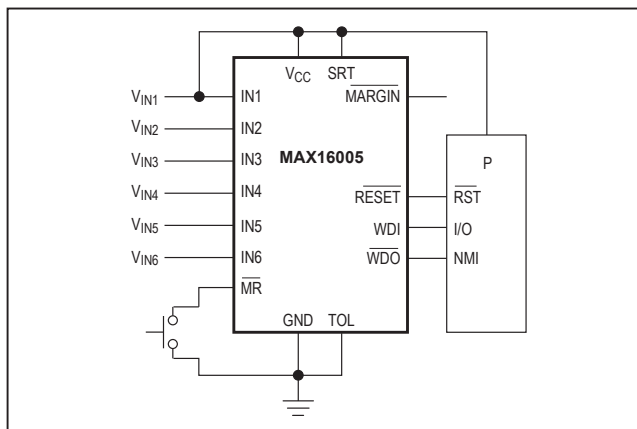
- Storage Equipment
- Servers
- Networking/Telecommunication Equipment
- Multivoltage ASICs

## Low-Voltage, Quad/Hex/Octal-Voltage $\mu$ P Supervisors

### Benefits and Features

- Fixed Thresholds for 5V, 3.3V, 3V, 2.5V, 1.8V, 1.5V, 1.2V, and 0.9V Systems
- Adjustable Thresholds Monitor Voltages Down to 0.4V
- Open-Drain Outputs with Internal Pullups Reduce the Number of External Components
- Fixed 140ms (min) or Capacitor-Adjustable Reset Timeout
- Manual Reset, Margin Enable, and Tolerance Select Inputs
- Watchdog Timer
  - 1.6s (typ) Timeout Period
  - 54s Startup Delay After Reset (Except MAX16005)
- Independent Watchdog Output (MAX16005)
- RESET Output Indicates All Voltages Present
- Independent Voltage Monitors
- Guaranteed Correct Logic State Down to  $V_{\text{CC}} = 1\text{V}$
- Small (4mm x 4mm) TQFN Package
- TSSOP (5mm x 4.4mm) Package (MAX16005)
- AEC-Q100 Qualified (MAX16001ATE/V+ and MAX16001DTE/V+ Only)

### Typical Operating Circuit



[Selector Guide and Ordering Information](#) appear at end of data sheet.

**Absolute Maximum Ratings**

V<sub>CC</sub>, OUT\_, IN\_, RESET, WDO to GND .....-0.3V to +6V  
 TOL, MARGIN, MR, SRT, WDI, to GND ..... -0.3V to VCC + 0.3  
 Input/Output Current (RESET, MARGIN,  
SRT, MR, TOL, OUT\_, WDO, WDI) ..... ±20mA  
 Continuous Power Dissipation (TA = +70°C)  
 12-Pin TQFN (derate 16.9mW/°C above +70°C) .....1349mW  
 16-Pin TQFN (derate 16.9mW/°C above +70°C) .....1349mW  
 20-Pin TQFN (derate 16.9mW/°C above +70°C) .....1355mW  
 24-Pin TQFN (derate 16.9mW/°C above +70°C) .....1666mW  
 16-Pin TSSOP (derate 9.4mW/°C above +70°C) .....754mW

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.*

**Package Information**

<b>PACKAGE TYPE: 12 TQFN</b>	
Package Code	T1244+4
Outline Number	<a href="#">21-0139</a>
Land Pattern Number	<a href="#">90-0068</a>
<b>PACKAGE TYPE: 16 TSSOP</b>	
Package Code	U16+2
Outline Number	<a href="#">21-0066</a>
Land Pattern Number	<a href="#">90-0117</a>
<b>PACKAGE TYPE: 16 TQFN</b>	
Package Code	T1644+4
Outline Number	<a href="#">21-0139</a>
Land Pattern Number	<a href="#">90-0070</a>
<b>PACKAGE TYPE: 20 TQFN</b>	
Package Code	T2044+3
Outline Number	<a href="#">21-0139</a>
Land Pattern Number	<a href="#">90-0037</a>
<b>PACKAGE TYPE: 24 TQFN</b>	
Package Code	T2444+4
Outline Number	<a href="#">21-0139</a>
Land Pattern Number	<a href="#">90-0022</a>

For the latest package outline information and land patterns (footprints), go to [www.maximintegrated.com/packages](http://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.

**Electrical Characteristics**(V<sub>CC</sub> = 2.0V to 5.5V, T<sub>A</sub> = -40°C to +125°C, unless otherwise specified. Typical values are at V<sub>CC</sub> = 3.3V, T<sub>A</sub> = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Voltage Range	V <sub>CC</sub>	(Note 2)	1.0		5.5	V
Supply Current	I <sub>CC</sub>	V <sub>CC</sub> = 3.3V, OUT_, RESET not asserted (Note 3)		45	65	µA
		V <sub>CC</sub> = 5V, OUT_, RESET not asserted		50	70	
UVLO (Undervoltage Lockout)	V <sub>UVLO</sub>	V <sub>CC</sub> rising	1.62	1.8	1.98	V
<b>IN_ (See Table 1)</b>						
Threshold Voltages (IN_ Falling)	V <sub>TH</sub>	5V threshold, TOL = GND	4.50	4.625	4.75	V
		5V threshold, TOL = V <sub>CC</sub>	4.25	4.375	4.50	
		3.3V threshold, TOL = GND	2.970	3.053	3.135	
		3.3V threshold, TOL = V <sub>CC</sub>	2.805	2.888	2.970	
		3.0V threshold, TOL = GND	2.70	2.775	2.85	
		3.0V threshold, TOL = V <sub>CC</sub>	2.55	2.625	2.70	
		2.5V threshold, TOL = GND	2.250	2.313	2.375	
		2.5V threshold, TOL = V <sub>CC</sub>	2.125	2.188	2.250	
		1.8V threshold, TOL = GND	1.62	1.665	1.71	
		1.8V threshold, TOL = V <sub>CC</sub>	1.53	1.575	1.62	
		1.5V threshold, TOL = GND	1.350	1.388	1.425	
		1.5V threshold, TOL = V <sub>CC</sub>	1.275	1.313	1.350	
		1.2V threshold, TOL = GND	1.08	1.11	1.14	
		1.2V threshold, TOL = V <sub>CC</sub>	1.02	1.05	1.08	
		0.9V threshold, TOL = GND	0.810	0.833	0.855	
		0.9V threshold, TOL = V <sub>CC</sub>	0.765	0.788	0.810	
Adjustable Threshold (IN_ Falling)	V <sub>TH</sub>	TOL = GND	0.388	0.394	0.400	V
		TOL = V <sub>CC</sub>	0.366	0.372	0.378	
IN_ Hysteresis	V <sub>TH_HYS</sub>	IN_ rising		0.5		% V <sub>TH</sub>
IN_ Input Current		Fixed thresholds		3	16	µA
		Adjustable thresholds	-100		+100	nA

**Electrical Characteristics (continued)**(V<sub>CC</sub> = 2.0V to 5.5V, T<sub>A</sub> = -40°C to +125°C, unless otherwise specified. Typical values are at V<sub>CC</sub> = 3.3V, T<sub>A</sub> = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>RESET</b>						
Reset Timeout	t <sub>RP</sub>	SRT = V <sub>CC</sub>	140	200	280	ms
		C <sub>SRT</sub> = 1500pF (Note 4)	2.43	3.09	3.92	
		C <sub>SRT</sub> = 100pF	0.206			
		C <sub>SRT</sub> = open	50			µs
SRT Ramp Current	I <sub>SRT</sub>	V <sub>SRT</sub> = 0V	460	600	740	nA
SRT Threshold			1.173	1.235	1.293	V
SRT Hysteresis			100			mV
IN_ to Reset Delay	t <sub>RD</sub>	IN_ falling	20			µs
RESET Output-Voltage Low	V <sub>OL</sub>	V <sub>CC</sub> = 3.3V, I <sub>SINK</sub> = 10mA, RESET asserted	0.30			V
		V <sub>CC</sub> = 2.5V, I <sub>SINK</sub> = 6mA, RESET asserted	0.30			
		V <sub>CC</sub> = 1.2V, I <sub>SINK</sub> = 50µA, RESET asserted	0.30			
RESET Output-Voltage High	V <sub>OH</sub>	V <sub>CC</sub> ≥ 2.0V, I <sub>SOURCE</sub> = 6µA, RESET deasserted	0.8 x V <sub>CC</sub>			V
MR Input-Voltage Low	V <sub>IL</sub>		0.3 x V <sub>CC</sub>			V
MR Input-Voltage High	V <sub>IH</sub>		0.7 x V <sub>CC</sub>			V
MR Minimum Pulse Width			1			µs
MR Glitch Rejection			100			ns
MR to Reset Delay			200			ns
MR Pullup Resistance		Pulled up to V <sub>CC</sub>	12	20	28	kΩ
<b>OUTPUTS (OUT_)</b>						
OUT_ Output-Voltage Low	V <sub>OL</sub>	V <sub>CC</sub> = 3.3V, I <sub>SINK</sub> = 2mA	0.30			V
		V <sub>CC</sub> = 2.5V, I <sub>SINK</sub> = 1.2mA	0.30			
OUT_ Output-Voltage High	V <sub>OH</sub>	V <sub>CC</sub> R 2.0V, I <sub>SOURCE</sub> = 6µA	0.8 x V <sub>CC</sub>			V
IN_ to OUT_ Propagation Delay	t <sub>D</sub>	(V <sub>TH</sub> + 100mV) to (V <sub>TH</sub> - 100mV)	20			µs
<b>REFERENCE OUTPUT (MAX16005 Only)</b>						
Reference Short-Circuit Current		Shorted to GND	0.8			mA
Reference Output Accuracy	V <sub>REF</sub>	No load	1.200	1.235	1.270	V
Line Regulation			0.005			% / V
Reference Load Regulation		Sourcing, 0 ≤ I <sub>REF</sub> ≤ 40µA	10			Ω

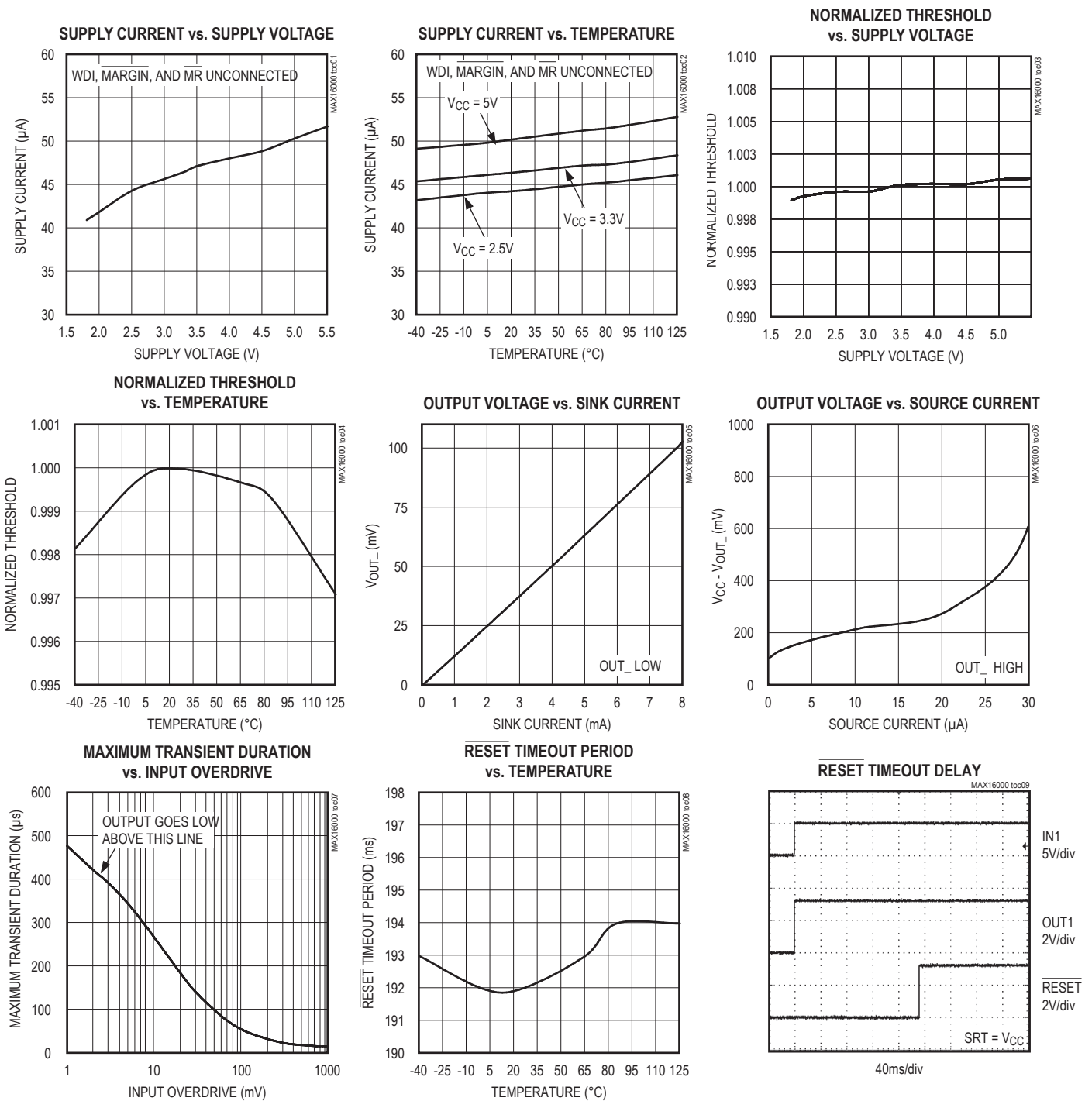
**Electrical Characteristics (continued)**(V<sub>CC</sub> = 2.0V to 5.5V, T<sub>A</sub> = -40°C to +125°C, unless otherwise specified. Typical values are at V<sub>CC</sub> = 3.3V, T<sub>A</sub> = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>WATCHDOG TIMER (MAX16001/MAX16002/MAX16004–MAX16007)</b>						
WDI Input-Voltage Low	V <sub>IL</sub>				0.3 x V <sub>CC</sub>	V
WDI Input-Voltage High	V <sub>IH</sub>		0.7 x V <sub>CC</sub>			V
WDI Pulse Width		(Note 5)	50			ns
Watchdog Timeout Period	t <sub>WDI</sub>		1.12	1.6	2.40	s
Watchdog Startup Period		MAX16001/2/4/6/7	35	54	72	s
Watchdog Input Current		V <sub>WDI</sub> = 0 to V <sub>CC</sub> (Note 5)	-1		+1	μA
W <sub>D</sub> O Output-Voltage Low (MAX16005 Only)	V <sub>OL</sub>	V <sub>CC</sub> = 3.3V, I <sub>SINK</sub> = 2mA			0.30	V
		V <sub>CC</sub> = 2.5V, I <sub>SINK</sub> = 1.2mA			0.30	
W <sub>D</sub> O Output-Voltage High (MAX16005 Only)	V <sub>OH</sub>	V <sub>CC</sub> ≥ 2.0V, I <sub>SOURCE</sub> = 6μA, W <sub>D</sub> O deasserted	0.8 x V <sub>CC</sub>			V
<b>DIGITAL LOGIC</b>						
TOL Input-Voltage Low	V <sub>IL</sub>				0.3 x V <sub>CC</sub>	V
TOL Input-Voltage High	V <sub>IH</sub>		0.7 x V <sub>CC</sub>			V
TOL Input Current		TOL = V <sub>CC</sub>			100	nA
MARGIN Input-Voltage Low	V <sub>IL</sub>				0.3 x V <sub>CC</sub>	V
MARGIN Input-Voltage High	V <sub>IH</sub>		0.7 x V <sub>CC</sub>			V
MARGIN Pullup Resistance		Pulled up to V <sub>CC</sub>	12	20	28	kΩ
MARGIN Delay Time	t <sub>MD</sub>	Rising or falling (Note 6)		50		μs

**Note 1:** Devices are tested at T<sub>A</sub> = +25°C and guaranteed by design for T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>.**Note 2:** The outputs are guaranteed to be in the correct logic state down to V<sub>CC</sub> = 1V.**Note 3:** Measured with WDI, MARGIN, and MR unconnected.**Note 4:** The minimum and maximum specifications for this parameter are guaranteed by using the worst case of the SRT ramp current and SRT threshold specifications.**Note 5:** Guaranteed by design and not production tested.**Note 6:** Amount of time required for logic to lock/unlock outputs from margin testing.

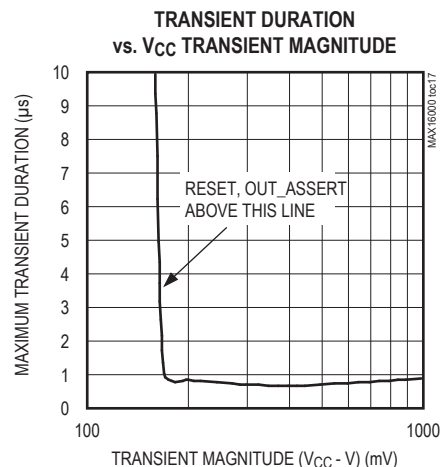
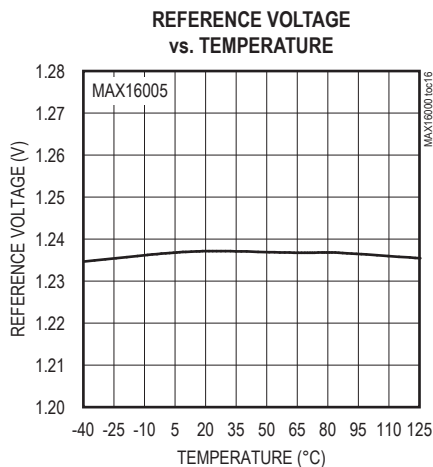
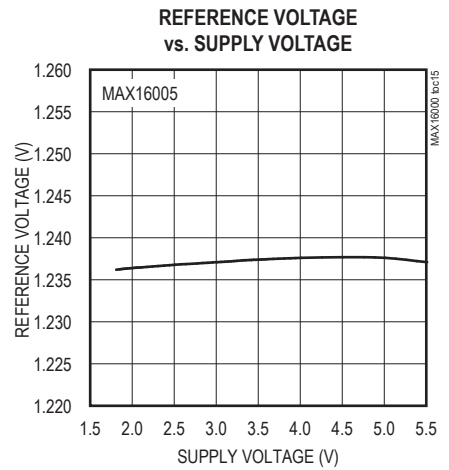
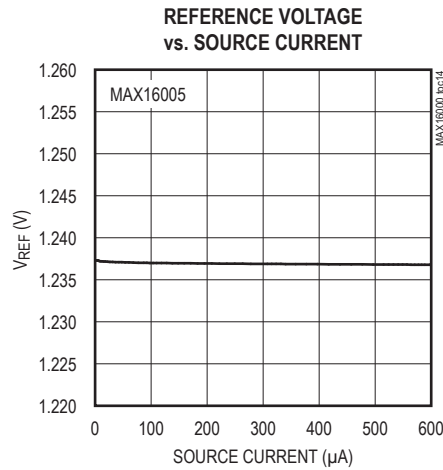
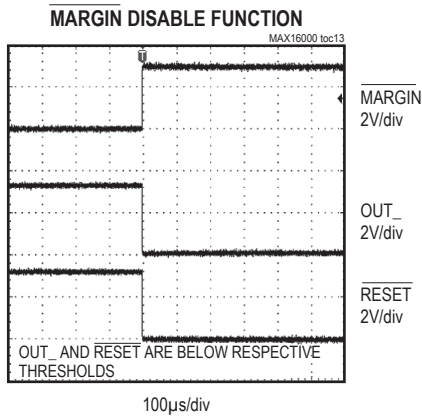
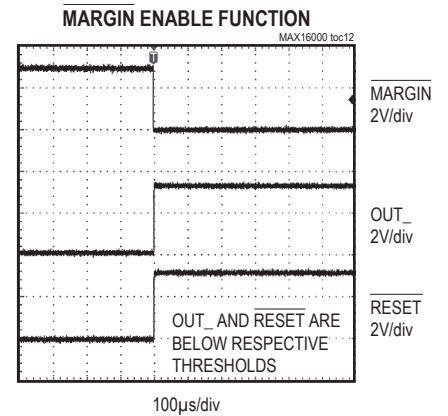
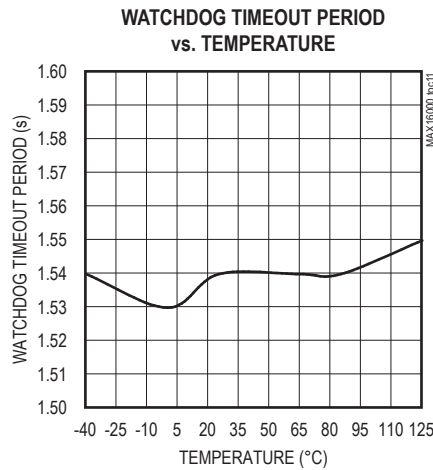
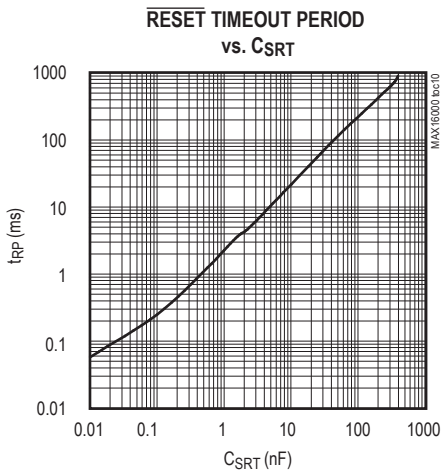
Typical Operating Characteristics

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

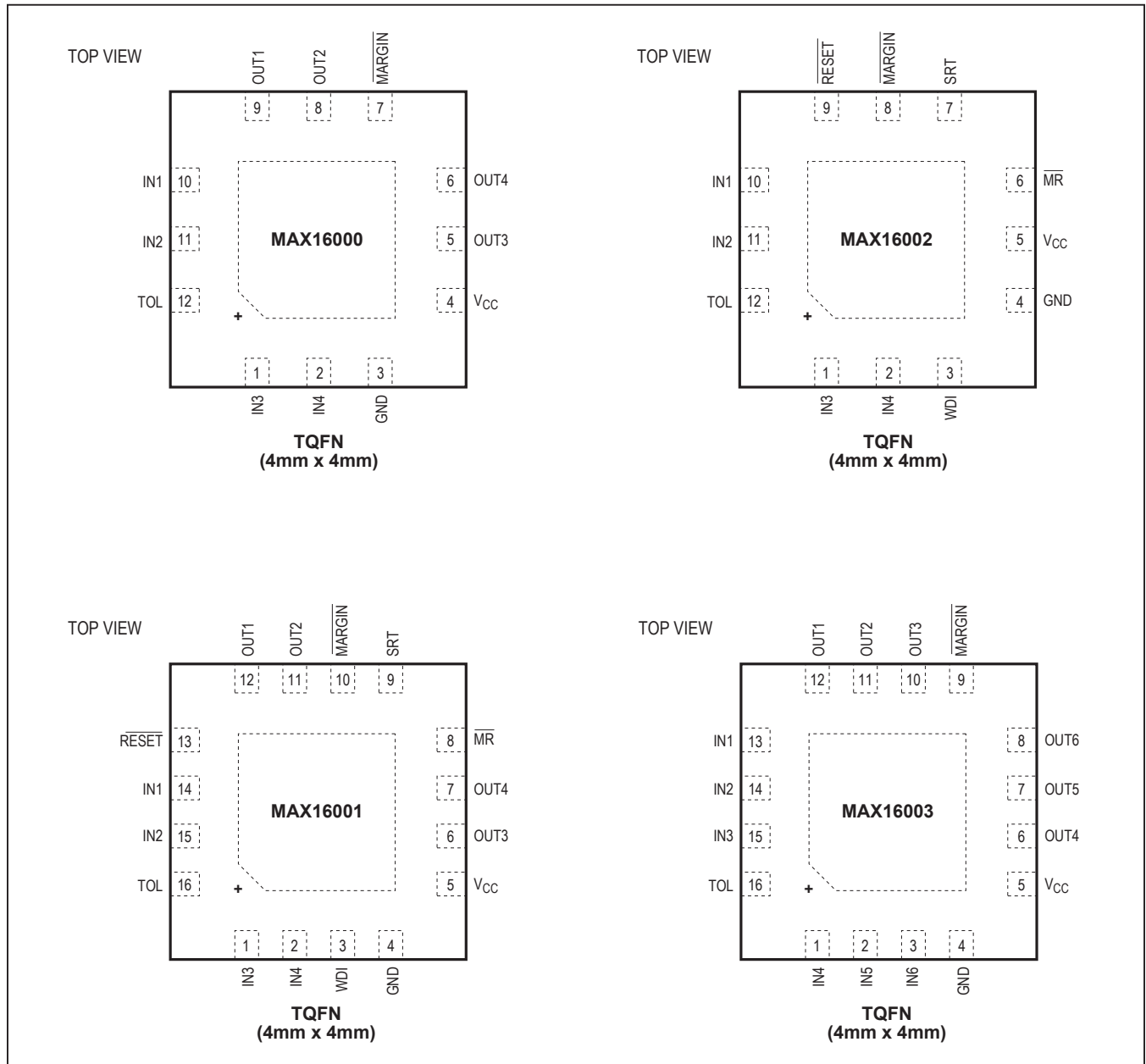


Typical Operating Characteristics (continued)

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

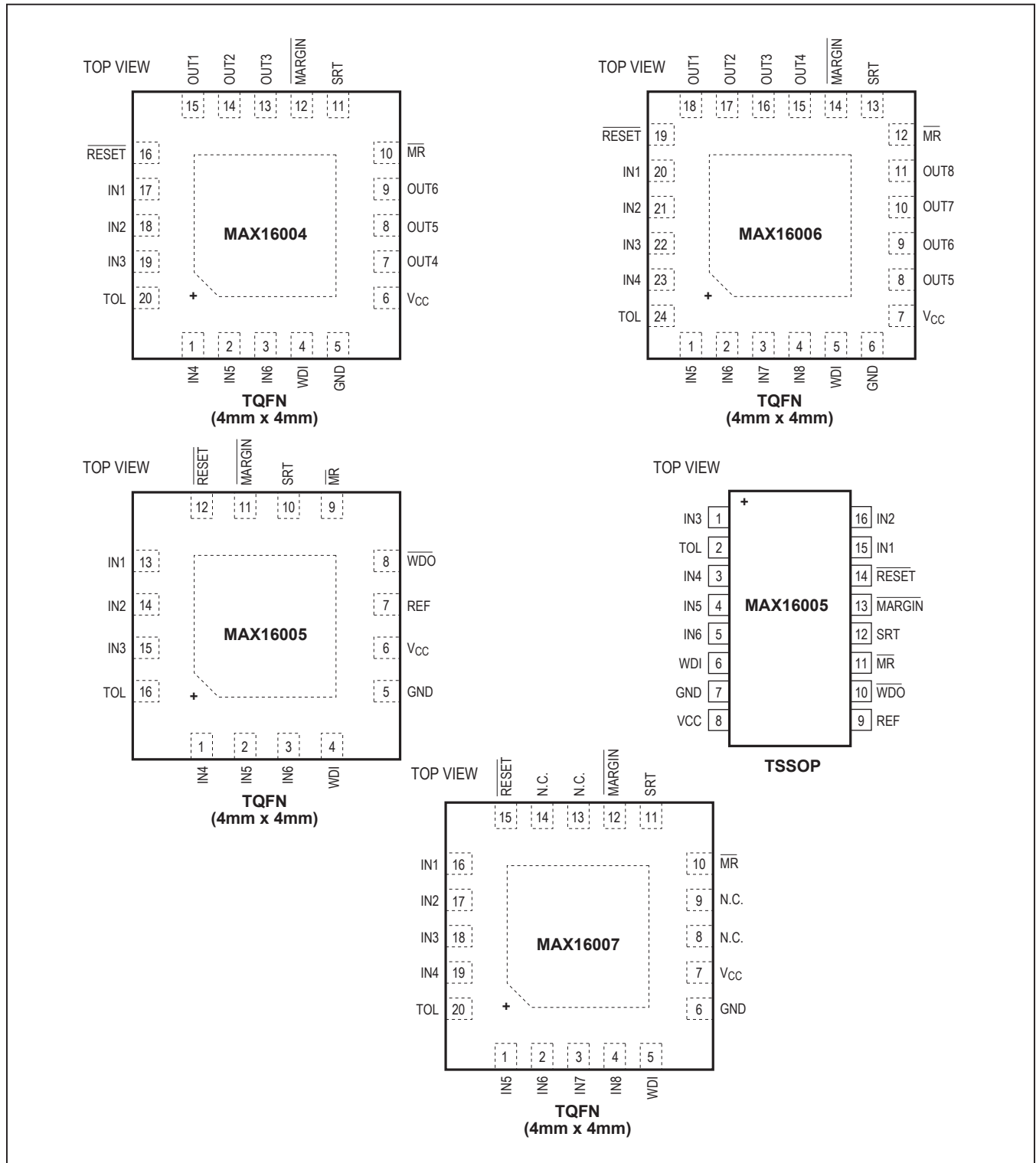


Pin Configurations





Pin Configurations (continued)



## Pin Description (MAX16000/MAX16001/MAX16002)

PIN			NAME	FUNCTION
MAX16000	MAX16001	MAX16002		
1	1	1	IN3	Monitored Input Voltage 3. See Table 1 for the input voltage threshold.
2	2	2	IN4	Monitored Input Voltage 4. See Table 1 for the input voltage threshold.
3	4	4	GND	Ground
4	5	5	V <sub>CC</sub>	Unmonitored Power-Supply Input. Bypass V <sub>CC</sub> with a 0.1µF capacitor to ground. See Power Supply Bypassing section for more detail.
5	6	—	OUT3	Output 3. When the voltage at IN3 falls below its threshold, OUT3 goes low and stays low until the voltage at IN3 exceeds its threshold. The open-drain output has a 30µA internal pullup to V <sub>CC</sub> .
6	7	—	OUT4	Output 4. When the voltage at IN4 falls below its threshold, OUT4 goes low and stays low until the voltage at IN4 exceeds its threshold. The open-drain output has a 30µA internal pullup to V <sub>CC</sub> .
7	10	8	$\overline{\text{MARGIN}}$	Active-Low Manual Deassert Input. Pull $\overline{\text{MARGIN}}$ low to deassert all outputs (go into high state), regardless of the voltage at any monitored input.
8	11	—	OUT2	Output 2. When the voltage at IN2 falls below its threshold, OUT2 goes low and stays low until the voltage at IN2 exceeds its threshold. The open-drain output has a 30µA internal pullup to V <sub>CC</sub> .
9	12	—	OUT1	Output 1. When the voltage at IN1 falls below its threshold, OUT1 goes low and stays low until the voltage at IN1 exceeds its threshold. The open-drain output has a 30µA internal pullup to V <sub>CC</sub> .
10	14	10	IN1	Monitored Input Voltage 1. See Table 1 for the input voltage threshold.
11	15	11	IN2	Monitored Input Voltage 2. See Table 1 for the input voltage threshold.
12	16	12	TOL	Threshold Tolerance Input. Connect TOL to GND to select 5% threshold tolerance. Connect TOL to V <sub>CC</sub> to select 10% threshold tolerance.
—	3	3	WDI	Watchdog Timer Input. If WDI remains low or high for longer than the watchdog timeout period, $\overline{\text{RESET}}$ is asserted. The timer clears whenever a reset is asserted or a rising or falling edge on WDI is detected. The watchdog timer enters a startup period that allows 54s for the first transition to occur before a reset. Leave WDI unconnected to disable the watchdog timer. The WDI open-state detector uses a small 400nA current. Therefore, do not connect WDI to anything that will source or sink more than 200nA. Note that the leakage current specification for most three-state drivers exceeds 200nA.
—	8	6	MR	Active-Low Manual Reset Input. Pull $\overline{\text{MR}}$ low to assert $\overline{\text{RESET}}$ low. $\overline{\text{RESET}}$ remains low for the reset timeout period after $\overline{\text{MR}}$ is deasserted. $\overline{\text{MR}}$ is pulled up to V <sub>CC</sub> through a 20kΩ resistor.
—	9	7	SRT	Set Reset Timeout Input. Connect a capacitor from SRT to GND to set the reset timeout period. The reset timeout period can be calculated as follows: Reset Timeout (s) = 2.06 × 10 <sup>6</sup> (Ω) × C <sub>SRT</sub> (F). For the internal timeout period of 140ms (min), connect SRT to V <sub>CC</sub> .
—	13	9	$\overline{\text{RESET}}$	Active-Low Reset Output. $\overline{\text{RESET}}$ asserts low when any of the monitored voltages falls below its respective threshold or $\overline{\text{MR}}$ is asserted. $\overline{\text{RESET}}$ remains asserted for the reset timeout period after all monitored voltages exceed their respective thresholds and $\overline{\text{MR}}$ is deasserted. This open-drain output has a 30µA internal pullup.
—	—	—	EP	Exposed Pad. EP is internally connected to GND. Connect EP to the ground plane to provide a low thermal resistance path from the IC junction to the PCB. Do not use as the electrical connection to GND.

## Pin Description (MAX16003/MAX16004/MAX16005)

PIN				NAME	FUNCTION
MAX16003	MAX16004	MAX16005 TSSOP	MAX16005 TQFN		
1	1	3	1	IN4	Monitored Input Voltage 4. See Table 1 for the input voltage threshold.
2	2	4	2	IN5	Monitored Input Voltage 5. See Table 1 for the input voltage threshold.
3	3	5	3	IN6	Monitored Input Voltage 6. See Table 1 for the input voltage threshold.
4	5	7	5	GND	Ground
5	6	8	6	V <sub>CC</sub>	Unmonitored Power-Supply Input. Bypass V <sub>CC</sub> with a 0.1μF capacitor to ground. See <i>Power Supply Bypassing</i> section for more detail.
6	7	—	—	OUT4	Output 4. When the voltage at IN4 falls below its threshold, OUT4 goes low and stays low until the voltage at IN4 exceeds its threshold. The open-drain output has a 30μA internal pullup to V <sub>CC</sub> .
7	8	—	—	OUT5	Output 5. When the voltage at IN5 falls below its threshold, OUT5 goes low and stays low until the voltage at IN5 exceeds its threshold. The open-drain output has a 30μA internal pullup to V <sub>CC</sub> .
8	9	—	—	OUT6	Output 6. When the voltage at IN6 falls below its threshold, OUT6 goes low and stays low until the voltage at IN6 exceeds its threshold. The open-drain output has a 30μA internal pullup to V <sub>CC</sub> .
9	12	13	11	$\overline{\text{MARGIN}}$	Manual Deassert Input. Pull $\overline{\text{MARGIN}}$ low to deassert all outputs (go into high state), regardless of the voltage at any monitored input.
10	13	—	—	OUT3	Output 3. When the voltage at IN3 falls below its threshold, OUT3 goes low and stays low until the voltage at IN3 exceeds its threshold. The open-drain output has a 30μA internal pullup to V <sub>CC</sub> .
11	14	—	—	OUT2	Output 2. When the voltage at IN2 falls below its threshold, OUT2 goes low and stays low until the voltage at IN2 exceeds its threshold. The open-drain output has a 30μA internal pullup to V <sub>CC</sub> .
12	15	—	—	OUT1	Output 1. When the voltage at IN1 falls below its threshold, OUT1 goes low and stays low until the voltage at IN1 exceeds its threshold. The open-drain output has a 30μA internal pullup to V <sub>CC</sub> .
13	17	15	13	IN1	Monitored Input Voltage 1. See Table 1 for the input voltage threshold.
14	18	16	14	IN2	Monitored Input Voltage 2. See Table 1 for the input voltage threshold.
15	19	1	15	IN3	Monitored Input Voltage 3. See Table 1 for the input voltage threshold.

## Pin Description (MAX16003/MAX16004/MAX16005) (continued)

PIN				NAME	FUNCTION
MAX16003	MAX16004	MAX16005 TSSOP	MAX16005 TQFN		
16	20	2	16	TOL	Threshold Tolerance Input. Connect TOL to GND to select 5% threshold tolerance. Connect TOL to V <sub>CC</sub> to select 10% threshold tolerance.
—	4	6	4	WDI	<p>Watchdog Timer Input.</p> <p><b>MAX16004:</b> If WDI remains low or high for longer than the watchdog timeout period, <math>\overline{\text{RESET}}</math> is asserted and the timer is cleared. The timer also clears whenever a reset is asserted or a rising or falling edge on WDI is detected. The watchdog timer enters a startup period that allows 54s for the first transition to occur before a reset. Leave WDI unconnected to disable the watchdog timer.</p> <p><b>MAX16005:</b> If WDI remains low or high for longer than the watchdog timeout period, <math>\overline{\text{WDO}}</math> is asserted. The timer clears whenever a rising or falling edge on WDI is detected. Leave WDI unconnected to disable the watchdog timer. The MAX16005 does not have a startup period.</p> <p><b>MAX16004/MAX16005:</b> The WDI open-state detector uses a small 100nA current. Therefore, do not connect WDI to anything that will source or sink more than 50nA. Note that the leakage current specification for most three-state drivers exceeds 50nA.</p>
—	10	11	9	$\overline{\text{MR}}$	Active-Low Manual Reset Input. Pull $\overline{\text{MR}}$ low to assert $\overline{\text{RESET}}$ low. $\overline{\text{RESET}}$ remains low for the reset timeout period after $\overline{\text{MR}}$ is deasserted. $\overline{\text{MR}}$ is pulled up to V <sub>CC</sub> through a 20kΩ resistor.
—	11	12	10	SRT	Set Reset Timeout Input. Connect a capacitor from SRT to GND to set the reset timeout period. The reset timeout period can be calculated as follows: Reset Timeout (s) = $2.06 \times 10^6 (\Omega) \times C_{\text{SRT}} (\text{F})$ . For the internal timeout period of 140ms (min), connect SRT to V <sub>CC</sub> .
—	16	14	12	$\overline{\text{RESET}}$	Active-Low Reset Output. $\overline{\text{RESET}}$ asserts low when any of the monitored voltages falls below its respective threshold or $\overline{\text{MR}}$ is asserted. $\overline{\text{RESET}}$ remains asserted for the reset timeout period after all monitored voltages exceed their respective thresholds and $\overline{\text{MR}}$ is deasserted. This open-drain output has a 30µA internal pullup.
—	—	9	7	REF	Reference Output. The reference output voltage of 1.23V can source up to 40µA.
—	—	10	8	$\overline{\text{WDO}}$	Active-Low Watchdog Output. $\overline{\text{WDO}}$ asserts and stays low whenever any of the IN_ inputs fall below their respective thresholds. $\overline{\text{WDO}}$ deasserts without a timeout delay when all the IN_ inputs rise above their thresholds. When all the IN_ inputs rise above their thresholds, $\overline{\text{WDO}}$ asserts low whenever the watchdog timer times out. $\overline{\text{WDO}}$ deasserts after a valid WDI transition or if $\overline{\text{MR}}$ is pulled low. The watchdog timer begins counting after the reset timeout period once $\overline{\text{MR}}$ goes high. Pull $\overline{\text{MARGIN}}$ low to deassert $\overline{\text{WDO}}$ .
—	—	—	—	EP	Exposed Pad. EP is internally connected to GND. Connect EP to the ground plane to provide a low thermal resistance path from the IC junction to the PCB. Do not use as the electrical connection to GND.

## Pin Description (MAX16006/MAX16007)

PIN		NAME	FUNCTION
MAX16006	MAX16007		
1	1	IN5	Monitored Input Voltage 5. See Table 1 for the input voltage threshold.
2	2	IN6	Monitored Input Voltage 6. See Table 1 for the input voltage threshold.
3	3	IN7	Monitored Input Voltage 7. See Table 1 for the input voltage threshold.
4	4	IN8	Monitored Input Voltage 8. See Table 1 for the input voltage threshold.
5	5	WDI	Watchdog Timer Input. If WDI remains low or high for longer than the watchdog timeout period, $\overline{\text{RESET}}$ is asserted and the timer is cleared. The timer also clears whenever a reset is asserted or a rising or falling edge on WDI is detected. The watchdog timer enters a startup period that allows 54s for the first transition to occur before a reset. Leave WDI unconnected to disable the watchdog timer. The WDI open-state detector uses a small 400nA current. Therefore, do not connect WDI to anything that will source or sink more than 200nA. Note that the leakage current specification for most three-state drivers exceeds 200nA.
6	6	GND	Ground
7	7	V <sub>CC</sub>	Unmonitored Power-Supply Input. Bypass V <sub>CC</sub> with a 0.1μF capacitor to ground. See <i>Power Supply Bypassing</i> section for more detail.
8	—	OUT5	Output 5. When the voltage at IN5 falls below its threshold, OUT5 goes low and stays low until the voltage at IN5 exceeds its threshold. The open-drain output has a 30μA internal pullup to V <sub>CC</sub> .
9	—	OUT6	Output 6. When the voltage at IN6 falls below its threshold, OUT6 goes low and stays low until the voltage at IN6 exceeds its threshold. The open-drain output has a 30μA internal pullup to V <sub>CC</sub> .
10	—	OUT7	Output 7. When the voltage at IN7 falls below its threshold, OUT7 goes low and stays low until the voltage at IN7 exceeds its threshold. The open-drain output has a 30μA internal pullup to V <sub>CC</sub> .
11	—	OUT8	Output 8. When the voltage at IN8 falls below its threshold, OUT8 goes low and stays low until the voltage at IN8 exceeds its threshold. The open-drain output has a 30μA internal pullup to V <sub>CC</sub> .
12	10	$\overline{\text{MR}}$	Active-Low Manual Reset Input. Pull $\overline{\text{MR}}$ low to assert $\overline{\text{RESET}}$ low. $\overline{\text{RESET}}$ remains low for the reset timeout period after $\overline{\text{MR}}$ is deasserted. $\overline{\text{MR}}$ is pulled up to V <sub>CC</sub> through a 20kΩ resistor.
13	11	SRT	Set Reset Timeout Input. Connect a capacitor from SRT to GND to set the reset timeout period. The reset timeout period can be calculated as follows: Reset Timeout (s) = 2.06 × 10 <sup>6</sup> (Ω) × C <sub>SRT</sub> (F). For the internal timeout period of 140ms (min), connect SRT to V <sub>CC</sub> .

## Pin Description (MAX16006/MAX16007) (continued)

PIN		NAME	FUNCTION
MAX16006	MAX16007		
14	12	$\overline{\text{MARGIN}}$	Margin Disable Input. Pull $\overline{\text{MARGIN}}$ low to deassert all outputs (go into high state), regardless of the voltage at any monitored input.
15	—	OUT4	Output 4. When the voltage at IN4 falls below its threshold, OUT4 goes low and stays low until the voltage at IN4 exceeds its threshold. The open-drain output has a 30μA internal pullup to $V_{CC}$ .
16	—	OUT3	Output 3. When the voltage at IN3 falls below its threshold, OUT3 goes low and stays low until the voltage at IN3 exceeds its threshold. The open-drain output has a 30μA internal pullup to $V_{CC}$ .
17	—	OUT2	Output 2. When the voltage at IN2 falls below its threshold, OUT2 goes low and stays low until the voltage at IN2 exceeds its threshold. The open-drain output has a 30μA internal pullup to $V_{CC}$ .
18	—	OUT1	Output 1. When the voltage at IN1 falls below its threshold, OUT1 goes low and stays low until the voltage at IN1 exceeds its threshold. The open-drain output has a 30μA internal pullup to $V_{CC}$ .
19	15	$\overline{\text{RESET}}$	Active-Low Reset Output. $\overline{\text{RESET}}$ asserts low when any of the monitored voltages falls below its respective threshold or $\overline{\text{MR}}$ is asserted. $\overline{\text{RESET}}$ remains asserted for the reset timeout period after all monitored voltages exceed their respective thresholds and $\overline{\text{MR}}$ is deasserted. This open-drain output has a 30μA internal pullup.
20	16	IN1	Monitored Input Voltage 1. See Table 1 for the input voltage threshold.
21	17	IN2	Monitored Input Voltage 2. See Table 1 for the input voltage threshold.
22	18	IN3	Monitored Input Voltage 3. See Table 1 for the input voltage threshold.
23	19	IN4	Monitored Input Voltage 4. See Table 1 for the input voltage threshold.
24	20	TOL	Threshold Tolerance Input. Connect TOL to GND to select 5% threshold tolerance. Connect TOL to $V_{CC}$ to select 10% threshold tolerance.
—	8, 9, 13, 14	N.C.	Not Internally Connected
—	—	EP	Exposed Pad. EP is internally connected to GND. Connect EP to the ground plane to provide a low thermal resistance path from the IC junction to the PCB. Do not use as the electrical connection to GND.

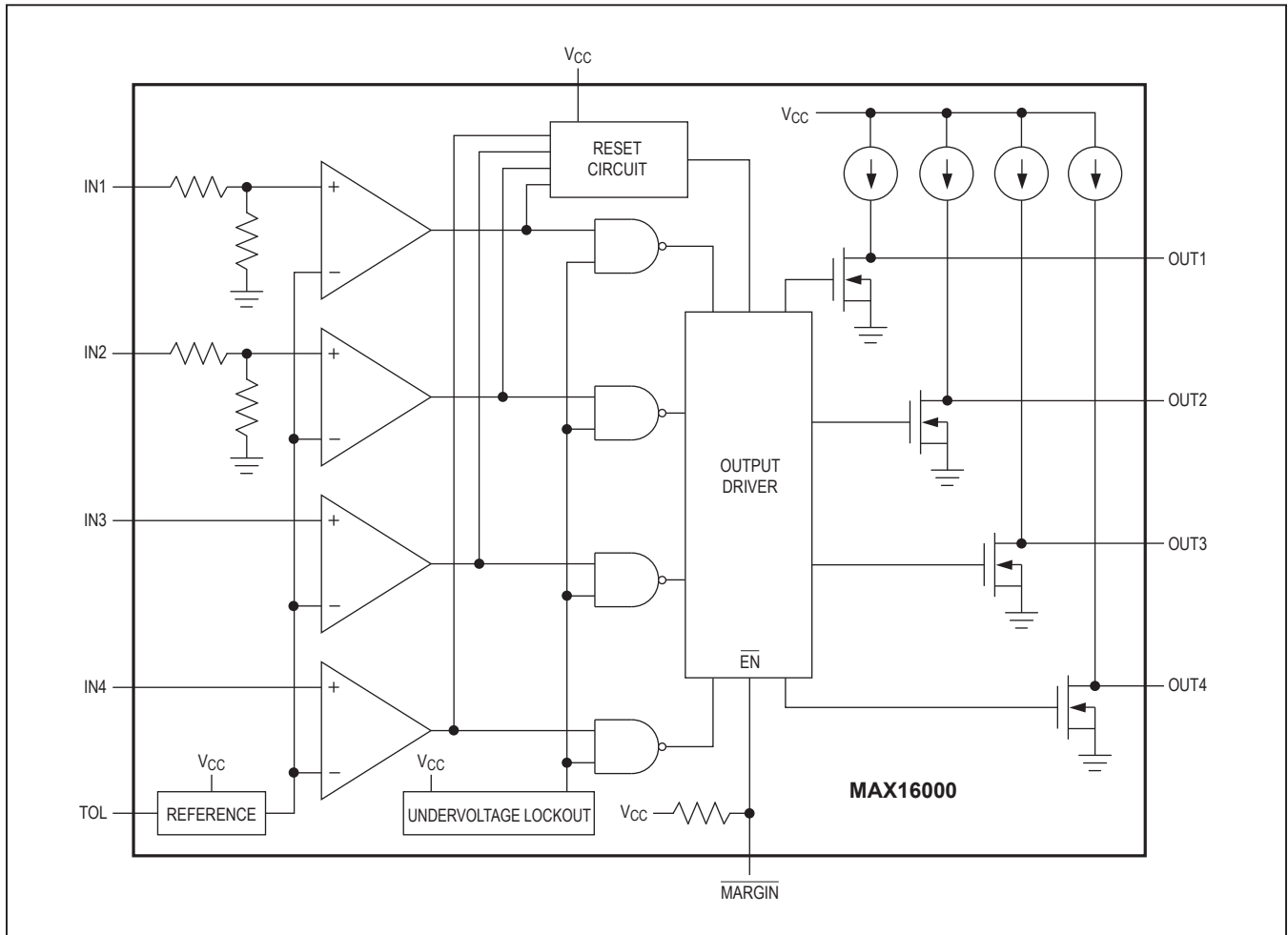
**Table 1. Input-Voltage-Threshold Selector**

PART	IN1	IN2	IN3	IN4	IN5	IN6	IN7	IN8
MAX16000A	3.3	2.5	ADJ	1.8	—	—	—	—
MAX16000B	3.3	ADJ	ADJ	1.8	—	—	—	—
MAX16000C	ADJ	2.5	ADJ	1.8	—	—	—	—
MAX16000D	3.3	2.5	ADJ	ADJ	—	—	—	—
MAX16000E	ADJ	ADJ	ADJ	ADJ	—	—	—	—
<b>MAX16001A</b>	3.3	2.5	ADJ	1.8	—	—	—	—
MAX16001B	3.3	ADJ	ADJ	1.8	—	—	—	—
MAX16001C	ADJ	2.5	ADJ	1.8	—	—	—	—
MAX16001D	3.3	2.5	ADJ	ADJ	—	—	—	—
MAX16001E	ADJ	ADJ	ADJ	ADJ	—	—	—	—
<b>MAX16002A</b>	3.3	2.5	ADJ	1.8	—	—	—	—
MAX16002B	3.3	ADJ	ADJ	1.8	—	—	—	—
MAX16002C	ADJ	2.5	ADJ	1.8	—	—	—	—
MAX16002D	3.3	2.5	ADJ	ADJ	—	—	—	—
MAX16002E	ADJ	ADJ	ADJ	ADJ	—	—	—	—
<b>MAX16003A</b>	3.3	2.5	ADJ	1.8	ADJ	ADJ	—	—
MAX16003B	3.3	ADJ	ADJ	1.8	ADJ	ADJ	—	—
MAX16003C	3.3	2.5	ADJ	ADJ	ADJ	ADJ	—	—
MAX16003D	ADJ	2.5	ADJ	1.8	ADJ	ADJ	—	—
MAX16003E	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ	—	—
<b>MAX16004A</b>	3.3	2.5	ADJ	1.8	ADJ	ADJ	—	—
MAX16004B	3.3	ADJ	ADJ	1.8	ADJ	ADJ	—	—
MAX16004C	3.3	2.5	ADJ	ADJ	ADJ	ADJ	—	—
MAX16004D	ADJ	2.5	ADJ	1.8	ADJ	ADJ	—	—
MAX16004E	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ	—	—
<b>MAX16005A</b>	3.3	2.5	ADJ	1.8	ADJ	ADJ	—	—
MAX16005B	3.3	ADJ	ADJ	1.8	ADJ	ADJ	—	—
MAX16005C	3.3	2.5	ADJ	ADJ	ADJ	ADJ	—	—
MAX16005D	ADJ	2.5	ADJ	1.8	ADJ	ADJ	—	—
MAX16005E	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ	—	—
<b>MAX16006A</b>	3.3	2.5	ADJ	1.8	ADJ	ADJ	ADJ	ADJ
MAX16006B	3.3	ADJ	ADJ	1.8	ADJ	ADJ	ADJ	ADJ
MAX16006C	3.3	2.5	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ
MAX16006D	ADJ	2.5	ADJ	1.8	ADJ	ADJ	ADJ	ADJ
MAX16006E	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ
MAX16006F	5.0	3.3	3.0	2.5	1.8	1.5	1.2	0.9
<b>MAX16007A</b>	3.3	2.5	ADJ	1.8	ADJ	ADJ	ADJ	ADJ
MAX16007B	3.3	ADJ	ADJ	1.8	ADJ	ADJ	ADJ	ADJ
MAX16007C	3.3	2.5	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ
MAX16007D	ADJ	2.5	ADJ	1.8	ADJ	ADJ	ADJ	ADJ
MAX16007E	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ	ADJ

**Note:** Other fixed thresholds may be available. Contact factory for availability.

Functional Diagrams

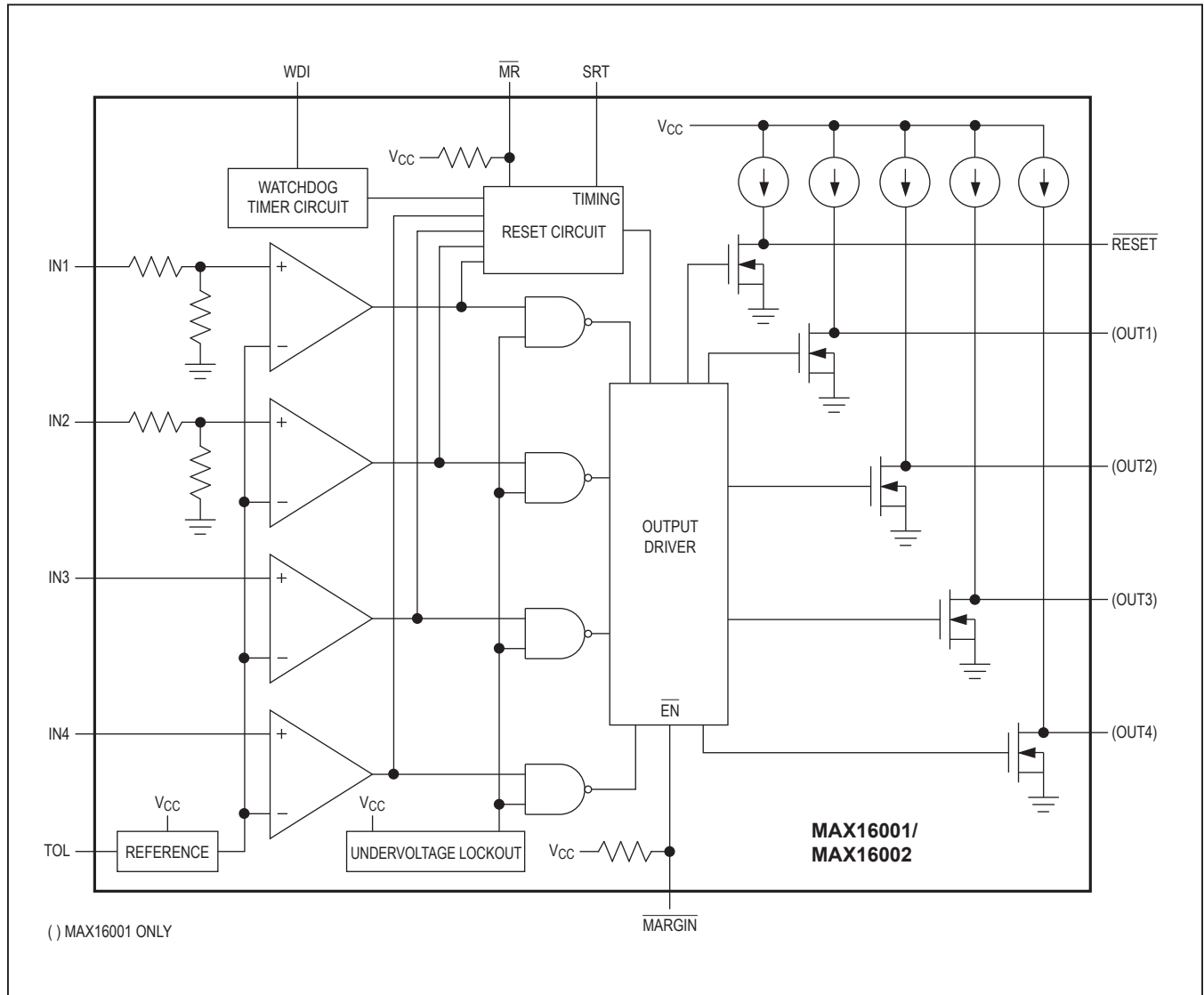
MAX16000D Functional Diagram





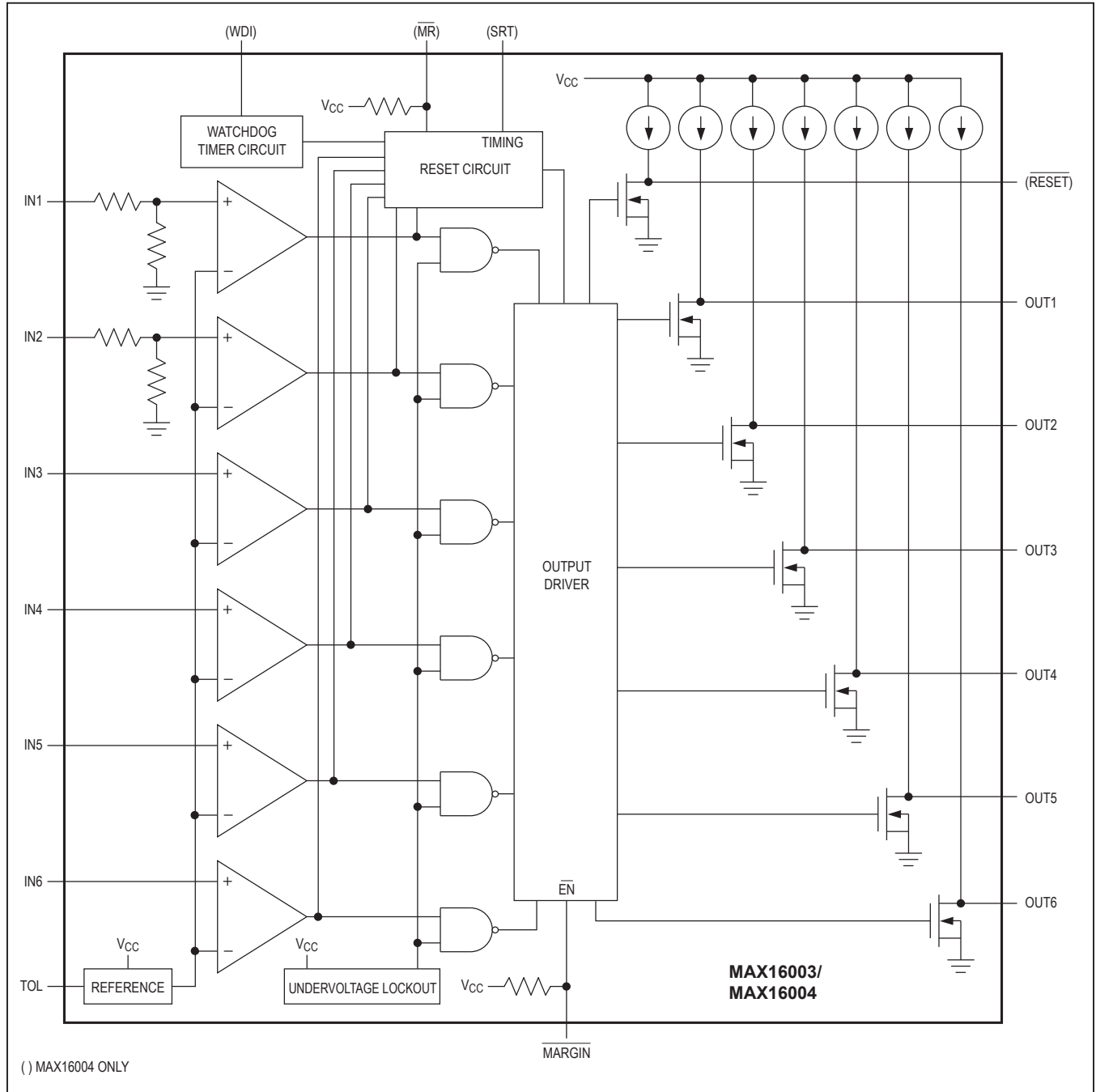
Functional Diagrams (continued)

MAX16001D/MAX16002D Functional Diagram



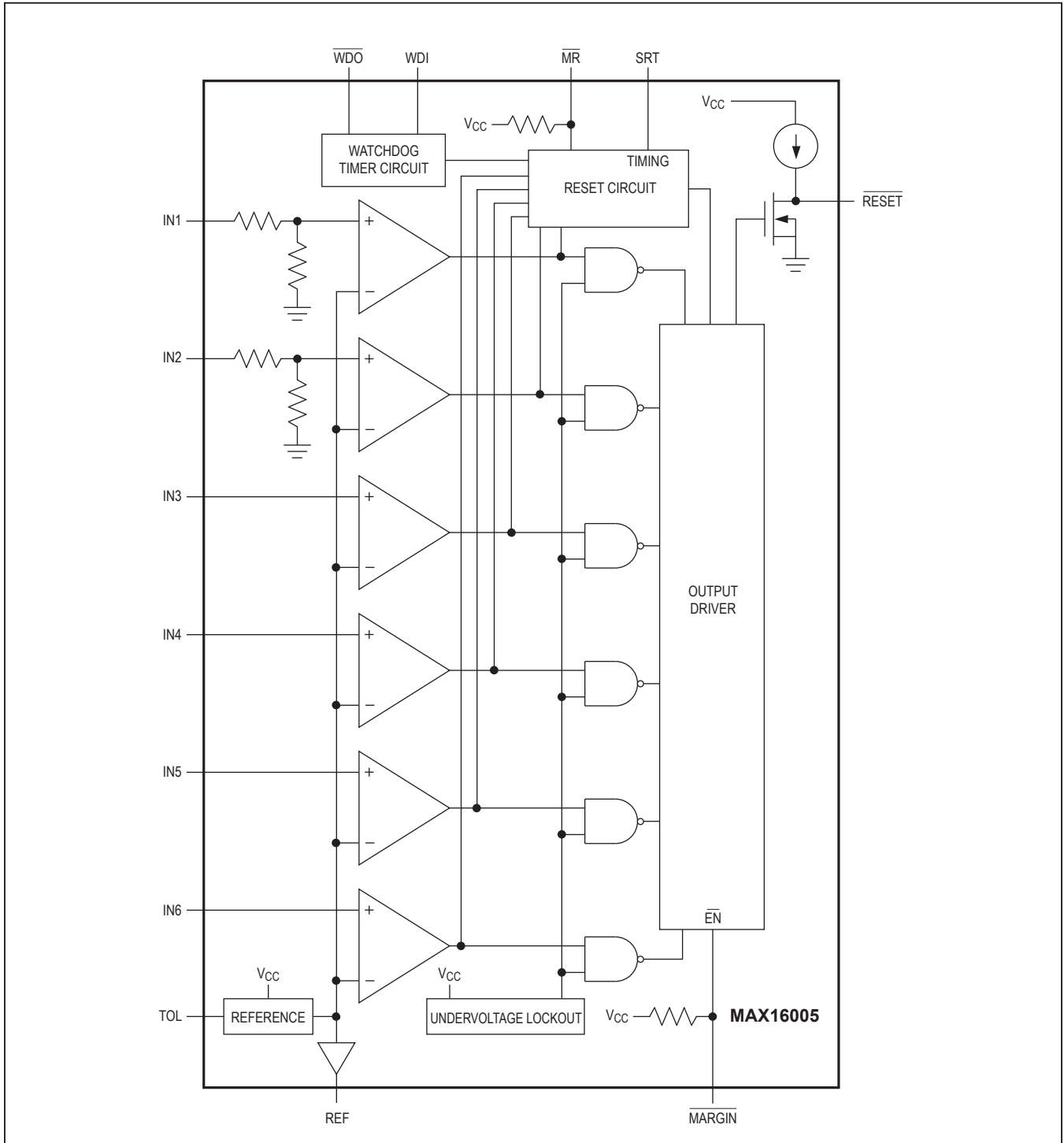
Functional Diagrams (continued)

MAX16003C/MAX16004C Functional Diagram



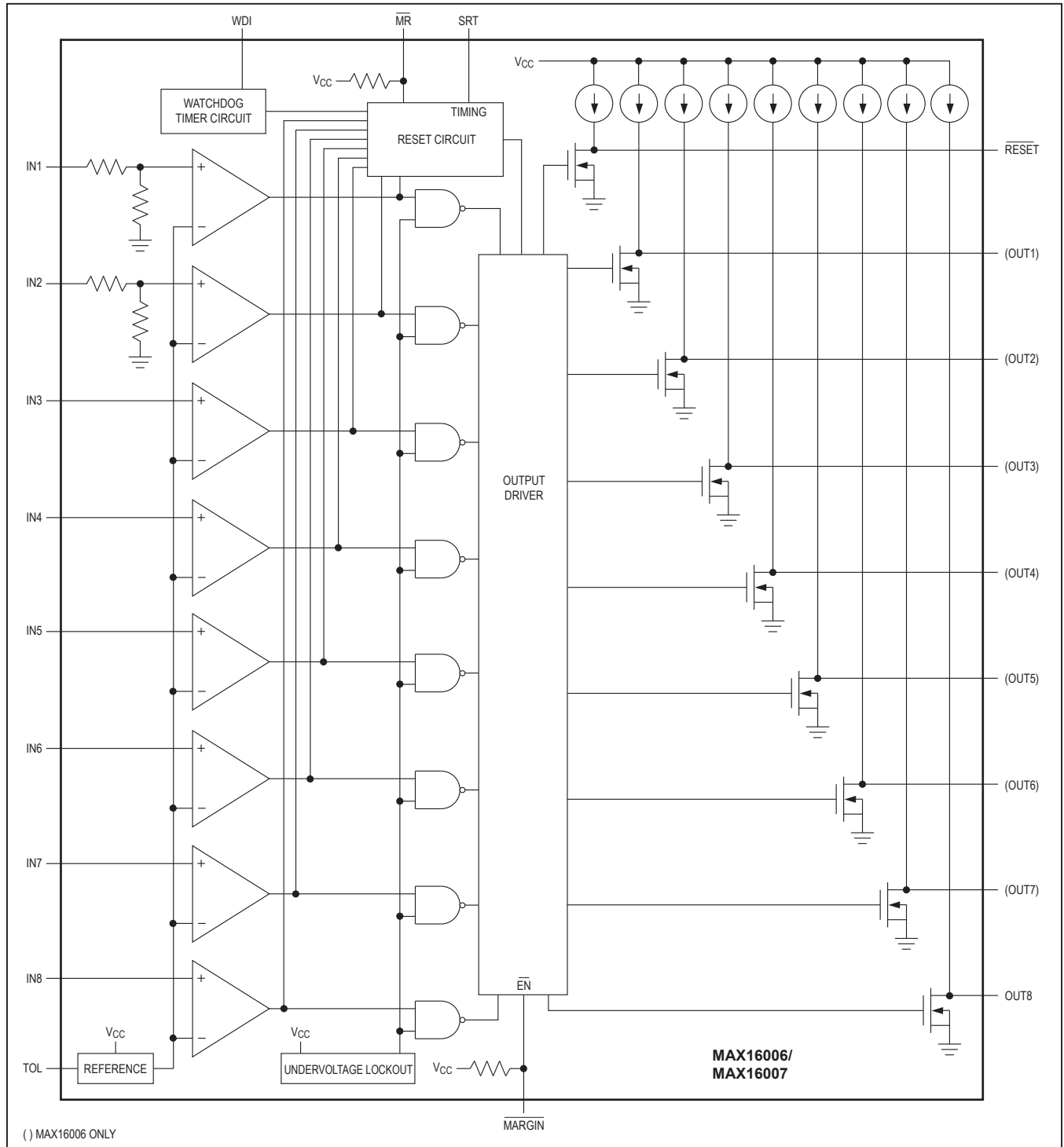
Functional Diagrams (continued)

MAX16005C Functional Diagram



Functional Diagrams (continued)

MAX16006C/MAX16007C Functional Diagram



### Detailed Description

The MAX16000–MAX16007 are low-voltage, quad/hex/octal-voltage  $\mu$ P supervisors in small TQFN and TSSOP packages. These devices provide supervisory functions for complex multivoltage systems. The MAX16000/MAX16001/MAX16002 monitor four voltages, the MAX16003/MAX16004/MAX16005 monitor six voltages, and the MAX16006/MAX16007 monitor eight voltages.

The MAX16000/MAX16001/MAX16003/MAX16004/MAX16006 offer independent outputs for each monitored voltage. The MAX16001/MAX16002/MAX16004–MAX16007 offer a reset output that asserts whenever any of the monitored voltages fall below their respective thresholds or the manual reset input is asserted. The reset output remains asserted for the reset timeout after all voltages are above their respective thresholds and the manual reset input is deasserted. The minimum reset timeout is internally set to 140ms or can be adjusted with an external capacitor.

All open-drain outputs have internal 30 $\mu$ A pullups that eliminate the need for external pullup resistors. However, each output can be driven with an external voltage up to 5.5V. Other features offered include a manual reset input, a tolerance pin for selecting 5% or 10% input thresholds, and a margin enable function for deasserting the outputs during margin testing.

The MAX16001/MAX16002/MAX16004–MAX16007 offer a watchdog timer that asserts  $\overline{\text{RESET}}$  or an independent watchdog output (MAX16005) when the watchdog timeout period (1.6s typ) is exceeded. The watchdog timer can be disabled by leaving input open.

### Applications Information

#### Undervoltage-Detection Circuit

The open-drain outputs of the MAX16000–MAX16007 can be configured to detect an undervoltage condition. [Figure 1](#) shows a configuration where an LED turns on when the comparator output is low, indicating an undervoltage condition. These devices can also be used in applications such as system supervisory monitoring, multivoltage level detection, and  $V_{CC}$  bar-graph monitoring ([Figure 2](#)).

#### Tolerance (TOL)

The MAX16000–MAX16007 feature a pin-selectable threshold tolerance. Connect TOL to GND to select 5% threshold tolerance. Connect TOL to  $V_{CC}$  to select 10% threshold tolerance.

### Window Detection

A window detector circuit uses two auxiliary inputs in the configuration shown in [Figure 3](#). External resistors set the two threshold voltages of the window detector circuit. External logic gates create the OUT signal. The window detection width is the difference between the threshold voltages ([Figure 4](#)).

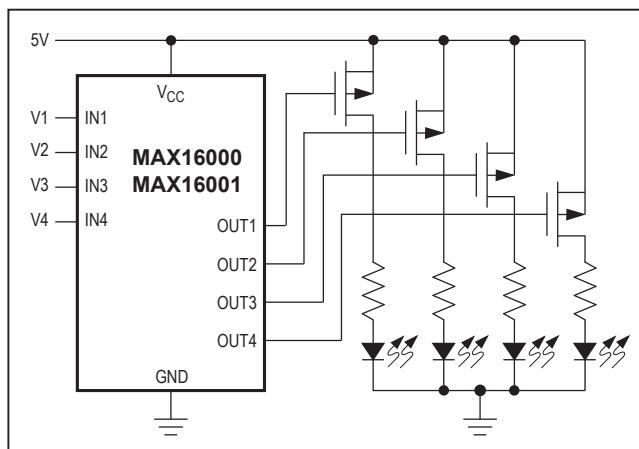


Figure 1. Quad Undervoltage Detector with LED Indicators

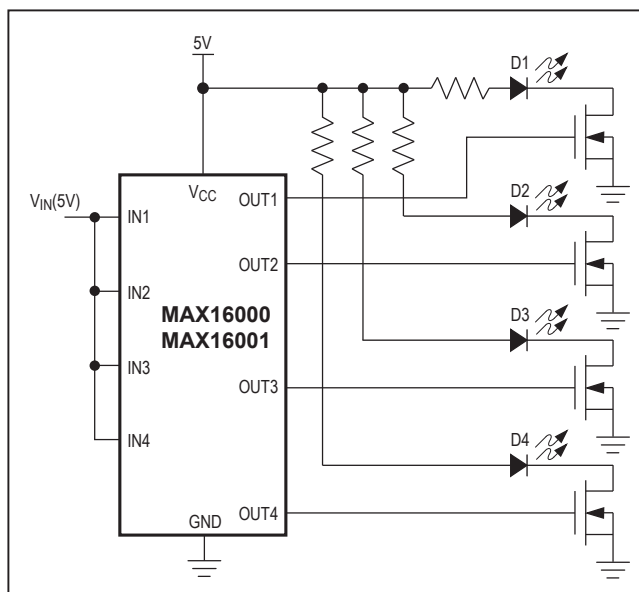


Figure 2.  $V_{CC}$  Bar-Graph Monitoring

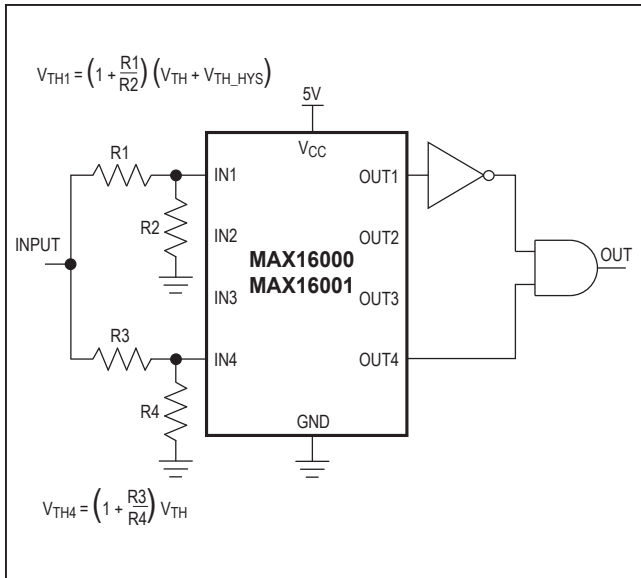


Figure 3. Window Detection

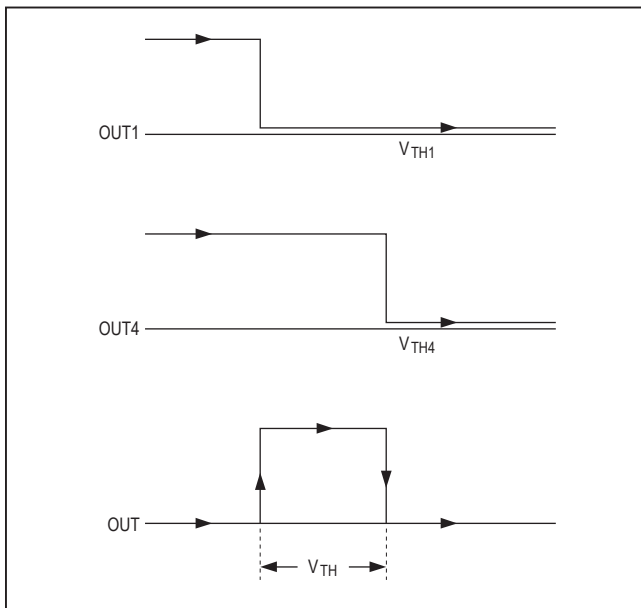


Figure 4. Output Response of Window Detector Circuit

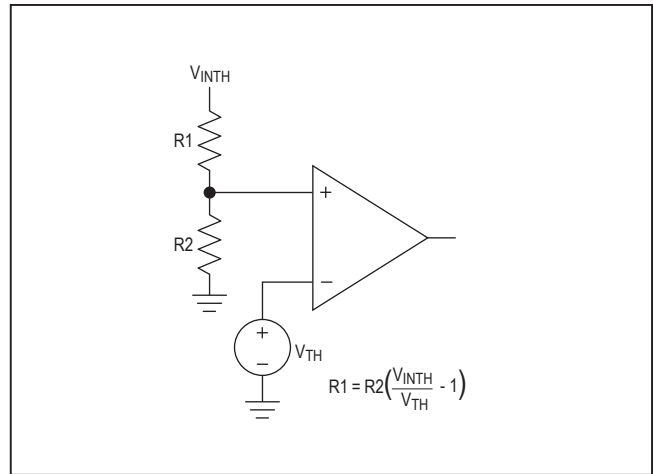


Figure 5. Setting the Adjustable Input

**Adjustable Input**

These devices offer several monitor options with adjustable input thresholds (see [Table 1](#)). The threshold voltage at each adjustable IN\_ input is typically 0.394V (TOL = GND) or 0.372 (TOL = V<sub>CC</sub>). To monitor a voltage V<sub>INTH</sub>, connect a resistive-divider network to the circuit as shown in [Figure 5](#).

$$V_{INTH} = V_{TH} \left( \frac{R1}{R2} + 1 \right)$$

$$R1 = R2 \left( \frac{V_{INTH}}{V_{TH}} - 1 \right)$$

Large resistors can be used to minimize current through the external resistors. For greater accuracy, use lower-value resistors.

**Unused Inputs**

Connect any unused IN\_ inputs to a voltage above its threshold.

**OUT\_ Outputs  
(MAX16000/MAX16001/MAX16003/  
MAX16004/MAX16006)**

The OUT\_ outputs go low when their respective IN\_ inputs drop below their specified thresholds. The output is open drain with a 30µA internal pullup to V<sub>CC</sub>. For many applications, no external pullup resistor is required to interface with other logic devices. An external pullup resistor to any voltage from 0 to 5.5V overrides the internal pullup if interfacing to different logic supply voltages. Internal circuitry prevents reverse current flow from the external pullup voltage to V<sub>CC</sub> ([Figure 6](#)).

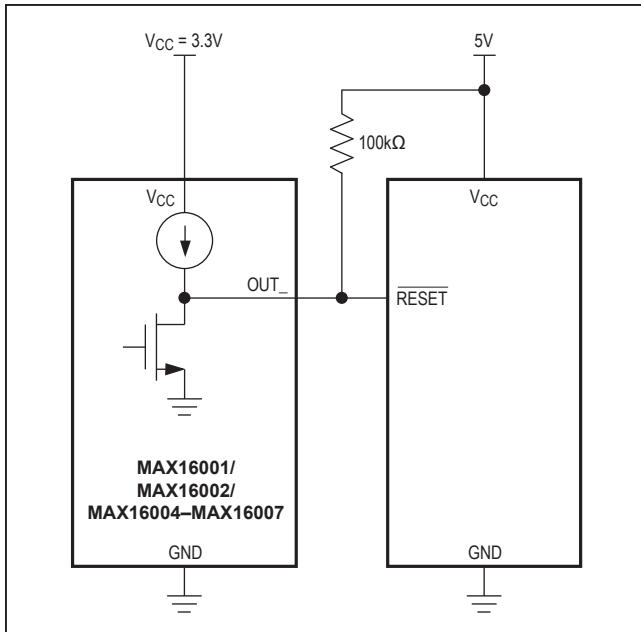


Figure 6. Interfacing to a Different Logic Supply Voltage

**RESET Output (MAX16001/MAX16002/  
MAX16004–MAX16007)**

RESET asserts low when any of the monitored voltages fall below their respective thresholds or MR is asserted. RESET remains asserted for the reset timeout period after all monitored voltages exceed their respective thresholds and MR is deasserted (see Figure 7). This open-drain output has a 30μA internal pullup. An external pullup resistor to any voltage from 0 to 5.5V overrides the internal pullup if interfacing to different logic supply voltages. Internal circuitry prevents reverse current flow from the external pullup voltage to VCC (Figure 6).

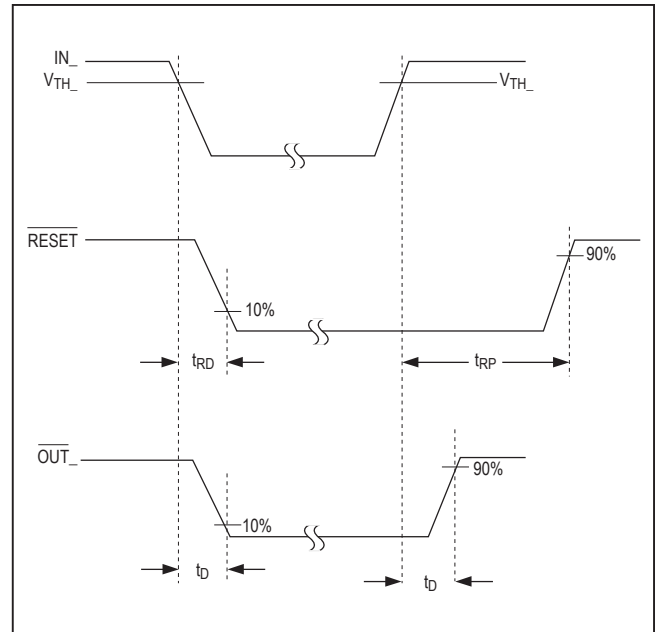


Figure 7. Output Timing Diagram

**WDO (MAX16005 Only)**

WDO asserts and stays low whenever any of the IN\_ inputs fall below their respective thresholds. WDO deasserts without a timeout delay when all the IN\_ inputs rise above their thresholds. When all the IN\_ inputs rise above their thresholds, WDO asserts low whenever the watchdog timer times out. WDO deasserts after a valid WDI transition or if MR is pulled low. The watchdog timer begins counting after the reset timeout period once MR goes high. Pull MARGIN low to deassert WDO regardless of any other condition. The watchdog timer continues to run when MARGIN is low and if a timeout occurs. WDO will assert MR after MARGIN is deasserted. This open-drain output has a 30μA internal pullup. An external pullup resistor to any voltage from 0 to 5.5V overrides the internal pullup if interfacing to different logic supply voltages. Internal circuitry prevents reverse current flow from the external pullup voltage to VCC (Figure 6).

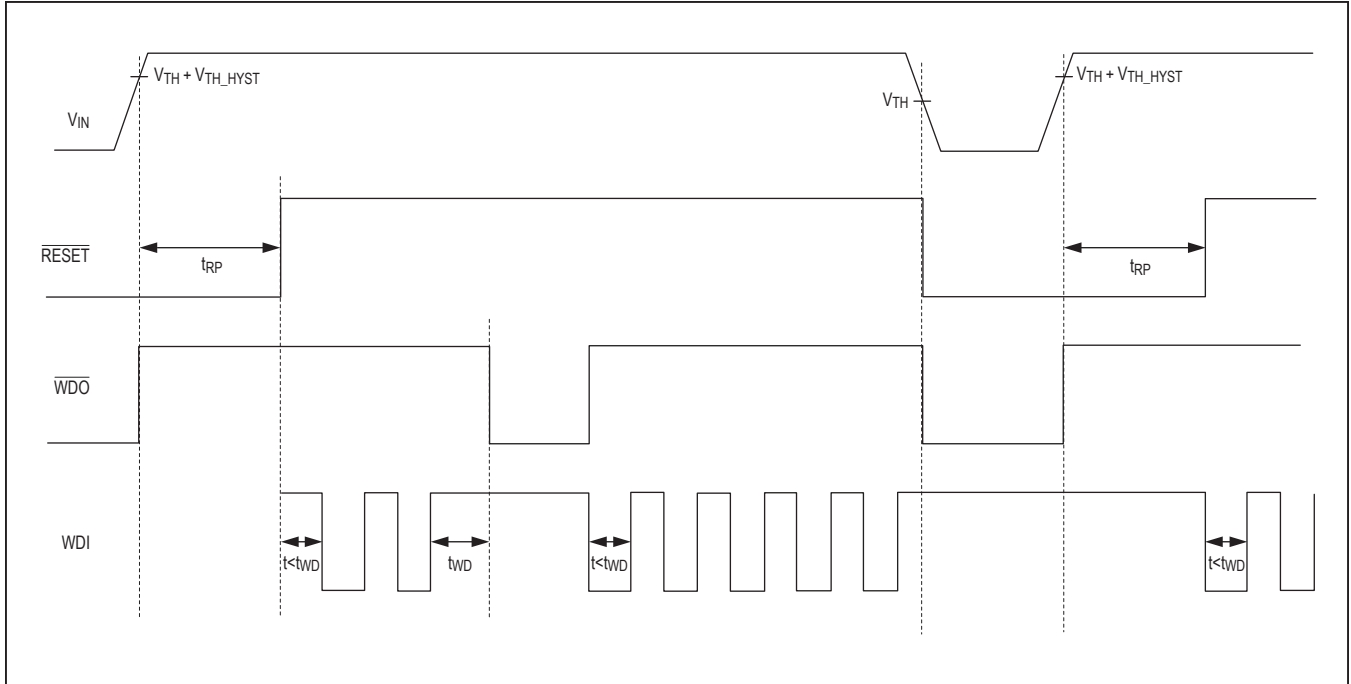


Figure 8.  $\overline{WDO}$  Timing Related to  $V_{TH}$  and  $t_{RP}$

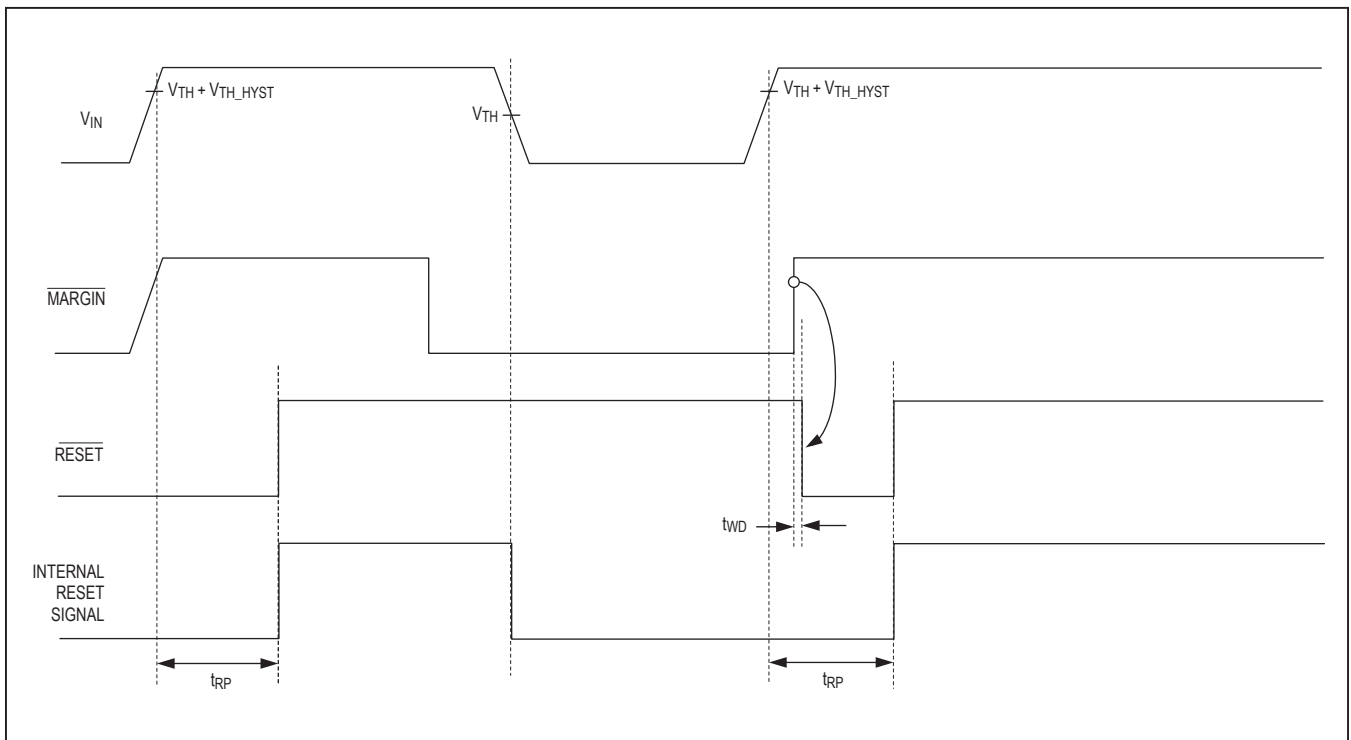


Figure 9. Margin Output Disable ( $\overline{MARGIN}$ ) Affect on  $\overline{RESET}$  within  $t_{RP}$



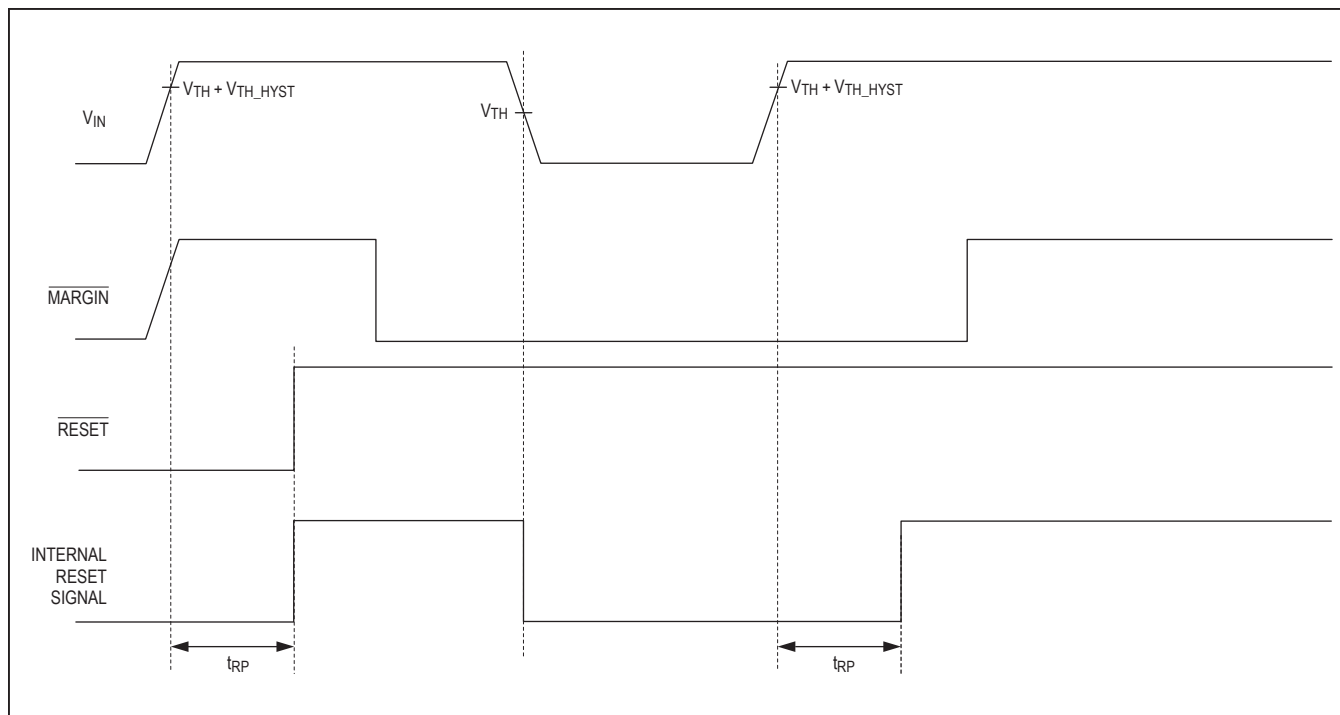


Figure 10. Margin Output Disable ( $\overline{MARGIN}$ ) Affect on  $\overline{RESET}$  Outside  $t_{RP}$

### Reset Timeout Capacitor

The reset timeout period can be adjusted to accommodate a variety of  $\mu P$  applications from 50 $\mu s$  to 1.12s. Adjust the reset timeout period ( $t_{RP}$ ) by connecting a capacitor ( $C_{SRT}$ ) between SRT and GND. Calculate the reset timeout capacitor as follows:

$$C_{SRT}(F) = \frac{t_{RP}(s) \times I_{SRT}}{V_{TH\_SRT}}$$

Connect SRT to  $V_{CC}$  for a factory-programmed reset timeout of 140ms (min).

### Manual Reset Input (MR) (MAX16001/MAX16002/ MAX16004–MAX16007)

Many  $\mu P$ -based products require manual reset capability, allowing the operator, a test technician, or external logic circuitry to initiate a reset. A logic-low on  $\overline{MR}$  asserts  $\overline{RESET}$  low.  $\overline{RESET}$  remains asserted while  $\overline{MR}$  is low, and during the reset timeout period (140ms min) after  $\overline{MR}$  returns high. The  $\overline{MR}$  input has an internal 20k $\Omega$  pullup resistor to  $V_{CC}$ , so it can be left unconnected if not used.  $\overline{MR}$  can be driven with TTL or CMOS-logic levels, or with open-drain/collector outputs. Connect a normally open momentary switch from MR to GND to create a manual

reset function. External debounce circuitry is not required. If  $\overline{MR}$  is driven from long cables or if the device is used in a noisy environment, connecting a 0.1 $\mu F$  capacitor from  $\overline{MR}$  to GND provides additional noise immunity.

### Margin Output Disable ( $\overline{MARGIN}$ )

$\overline{MARGIN}$  allows system-level testing while power supplies are adjusted from their nominal voltages. Drive  $\overline{MARGIN}$  low to force  $\overline{RESET}$ ,  $\overline{WDO}$ , and  $\overline{OUT\_high}$ , regardless of the voltage at any monitored input. The state of each output does not change while  $\overline{MARGIN} = \text{GND}$ . The watchdog timer continues to run when  $\overline{MARGIN}$  is low, and if a timeout occurs,  $\overline{WDO}/\overline{RESET}$  will assert  $t_{MD}$  after  $\overline{MARGIN}$  is deasserted.

The  $\overline{MARGIN}$  input is internally pulled up to  $V_{CC}$ . Leave  $\overline{MARGIN}$  unconnected or connect to  $V_{CC}$  if unused.

### Power-Supply Bypassing

The MAX16000–MAX16007 operate from a 2.0V to 5.5V supply. An undervoltage lockout ensures that the outputs are in the correct states when the UVLO is exceeded. In noisy applications, bypass  $V_{CC}$  to ground with a 0.1 $\mu F$  capacitor as close to the device as possible. The additional capacitor improves transient immunity. For  $V_{CC}$  transients with high slew rates, place an RC lowpass filter in front of  $V_{CC}$ , where R can be up to 100 $\Omega$ .

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX16000_TC+	-40°C to +125°C	12 TQFN-EP*
MAX16001_TE+	-40°C to +125°C	16 TQFN-EP*
MAX16001_TE/V	-40°C to +125°C	16 TQFN-EP*
MAX16001ATE/V+	-40°C to +125°C	16 TQFN-EP*
MAX16001DTE/V+	-40°C to +125°C	16 TQFN-EP*
MAX16002_TC+	-40°C to +125°C	12 TQFN-EP*
MAX16003_TE+	-40°C to +125°C	16 TQFN-EP*
MAX16004_TP+	-40°C to +125°C	20 TQFN-EP*
MAX16005_TE+	-40°C to +125°C	16 TQFN-EP*
MAX16005_UE+	-40°C to +125°C	16 TSSOP
MAX16006_TG+	-40°C to +125°C	24 TQFN-EP*
MAX16007_TP+	-40°C to +125°C	20 TQFN-EP*

**Note:** The “\_” is a placeholder for the input voltage threshold. See Table 1

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

For tape-and-reel, add a “T” after the “+.” Tape-and-reel are offered in 2.5k increments.

\*EP = Exposed pad.

/V denotes an automotive qualified part.

Chip Information

PROCESS: BiCMOS

Selector Guide

PART	MONITORED VOLTAGES	INDEPENDENT OUTPUTS	RESET	WDI/WDO	MR	ADJUSTABLE RESET TIMEOUT
MAX16000	4	4	—	—	—	—
MAX16001	4	4	✓	WDI	✓	✓
MAX16002	4	—	✓	WDI	✓	✓
MAX16003	6	6	—	—	—	—
MAX16004	6	6	✓	WDI	✓	✓
MAX16005	6	—	✓	WDI/WDO	✓	✓
MAX16006	8	8	✓	WDI	✓	✓
MAX16007	8	—	✓	WDI	✓	✓

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	12/05	Initial release	—
1	1/06	Released MAX16003 and MAX16004.	20, 21
2	7/06	Released MAX16005. Updated <i>Pin Description</i> and <i>Detailed Description</i> .	1, 4, 7, 9, 10, 20, 21
3	12/08	Added the MAX16005 TSSOP package. Modified the <i>Detailed Description</i> , and added Figures 13, 14, and 15.	1, 2, 7, 8, 9, 10, 20–26
4	8/10	Revised the <i>Absolute Maximum Ratings</i> and the <i>Power-Supply Bypassing</i> sections.	2, 22
5	10/10	Added new graph to the <i>Typical Operating Characteristics</i> .	6
6	9/12	Added automotive qualified part to <i>Ordering Information</i> .	25
7	4/16	Updated <i>Pin Configuration</i> table	7, 8, 10
8	4/18	Added MAX16001ATE/V+ and MAX16001DTE/V+ information to the AEC-Q100 Qualified statement in the <i>Benefits and Features</i> section and the <i>Ordering Information</i>	1, 26
9	9/18	Updated <i>Typical Operating Characteristics</i>	6

For pricing, delivery, and ordering information, please visit Maxim Integrated's online storefront at <https://www.maximintegrated.com/en/storefront/storefront.html>.

Maxim Integrated cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim Integrated product. No circuit patent licenses are implied. Maxim Integrated reserves the right to change the circuitry and specifications without notice at any time. The parametric values (min and max limits) shown in the Electrical Characteristics table are guaranteed. Other parametric values quoted in this data sheet are provided for guidance.

## X-ON Electronics

Largest Supplier of Electrical and Electronic Components

*Click to view similar products for [Supervisory Circuits](#) category:*

*Click to view products by [Maxim](#) manufacturer:*

Other Similar products are found below :

[CAT1161LI-25-G](#) [CAT853STBI-T3](#) [CAT1026LI-30-G](#) [CAT1320LI-25-G](#) [TC54VN2402EMB713](#) [MCP1316T-44NE/OT](#) [MCP1316MT-45GE/OT](#) [MCP1316MT-23LI/OT](#) [MAX8997EWW+](#) [MAX6725AKASYD3-LF-T](#) [DS1232L](#) [NCV302HSN45T1G](#) [PT7M6130NLTA3EX](#) [PT7M7811STBEX-2017](#) [S-1000N28-I4T1U](#) [CAT1161LI-28-G](#) [MCP1321T-29AE/OT](#) [MCP1319MT-47QE/OT](#) [S-1000N23-I4T1U](#) [S-1000N19-I4T1U](#) [CAT824UTDI-GT3](#) [TC54VC2502ECB713](#) [PT7M6133NLTA3EX](#) [PT7M6127NLTA3EX](#) [AP0809ES3-r](#) [HG811RM4/TR](#) [MD7030C](#) [MD7033C](#) [MD7019](#) [MD7020](#) [MD7021](#) [MD7023](#) [MD7024](#) [MD7027](#) [MD7030](#) [MD7033](#) [MD7035](#) [MD7036](#) [MD7039](#) [MD7040](#) [MD7044](#) [MD7050](#) [MD7015](#) [MD7022](#) [MD7028](#) [MD7031](#) [MD7042](#) [MD7043](#) [MD7047](#) [MD7060](#)