



# Microprocessor Supervisory Circuit

MAX791

## General Description

The MAX791 microprocessor ( $\mu$ P) supervisory circuit reduces the complexity and number of components needed to monitor power-supply and battery-control functions in  $\mu$ P systems. The 50 $\mu$ A supply current makes the MAX791 ideal for use in portable equipment, while the 6ns chip-enable propagation delay and 250mA output capability (25mA in battery-backup mode) make it suitable for larger, higher-performance equipment.

The MAX791 comes in 16-pin DIP and narrow SO packages and provides the following functions:

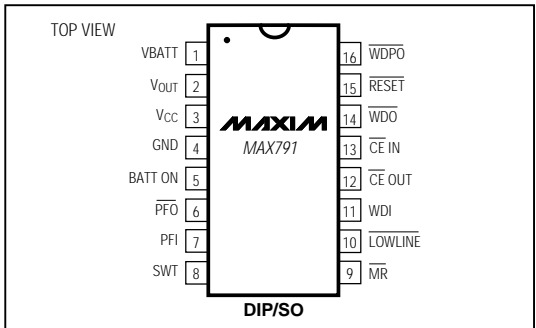
- 1)  $\mu$ P reset— $\overline{\text{RESET}}$  output is asserted during power-up, power-down, and brownout conditions, and is guaranteed to be in the correct state for  $V_{CC}$  down to 1V, even with no battery in the circuit.
- 2) Manual-reset input.
- 3) A 1.25V threshold detector provides for power-fail warning and low-battery detection, or monitors a power supply other than +5V.
- 4) Two-stage power-fail warning—a separate low-line comparator compares  $V_{CC}$  to a threshold 150mV above the reset threshold.
- 5) Backup-battery switchover for CMOS RAM, real-time clocks,  $\mu$ Ps, or other low-power logic.
- 6) Software monitoring of backup-battery voltage.
- 7) A watchdog-fault output is asserted if the watchdog input has not been toggled within either a preset or an adjustable timeout period.
- 8) Write protection of CMOS RAM or EEPROM.
- 9) Pulsed watchdog output, to give advance warning of impending WDO assertion caused by watchdog timeout.

## Applications

Computers  
Controllers  
Portable/Battery-Powered Equipment

Critical  $\mu$ P Power Monitoring  
Intelligent Instruments

## Pin Configuration



## Features

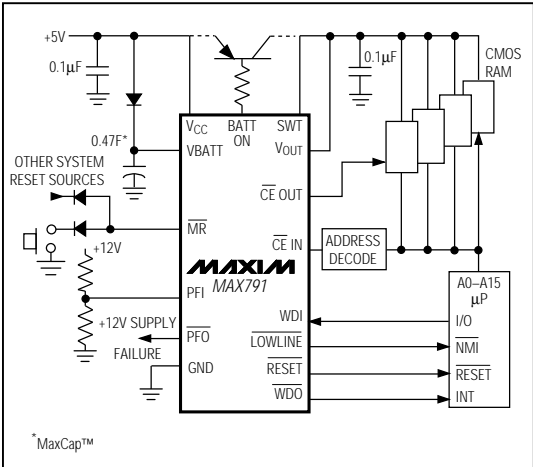
- ◆ Precision 4.65V Voltage Monitoring
- ◆ 200ms Power-OK/Reset Time Delay
- ◆ Independent Watchdog Timer—Preset or Adjustable
- ◆ 1 $\mu$ A Standby Current
- ◆ Power Switching
  - 250mA Output in  $V_{CC}$  Mode
  - 25mA Output in Battery-Backup Mode
- ◆ On-Board Gating of Chip-Enable Signals
  - Memory Write-Cycle Completion
  - 6ns CE Gate Propagation Delay
- ◆ MaxCap™ or SuperCap™ Compatible
- ◆ Voltage Monitor for Power-Fail or Low-Battery Warning
- ◆ Backup-Battery Monitor
- ◆ Guaranteed  $\overline{\text{RESET}}$  Valid to  $V_{CC} = 1V$

## Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX791CPE	0°C to +70°C	16 Plastic DIP
MAX791CSE	0°C to +70°C	16 Narrow SO
MAX791C/D	0°C to +70°C	Dice*
MAX791EPE	-40°C to +85°C	16 Plastic DIP
MAX791ESE	-40°C to +85°C	16 Narrow SO
MAX791EJE	-40°C to +85°C	16 CERDIP
MAX791MJE	-55°C to +125°C	16 CERDIP

\* Dice are specified at  $T_A = +25^\circ\text{C}$ .

## Typical Operating Circuit



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Maxim Integrated Products 1

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## ABSOLUTE MAXIMUM RATINGS

Input Voltage (with respect to GND)

V<sub>CC</sub> ..... -0.3V to +6V  
 VBATT ..... -0.3V to +6V  
 All Other Inputs ..... -0.3V to (V<sub>OUT</sub> + 0.3V)

Input Current

V<sub>CC</sub> Peak ..... 1.0A  
 V<sub>CC</sub> Continuous ..... 250mA  
 VBATT Peak ..... 250mA  
 VBATT Continuous ..... 25mA  
 GND, BATT ON ..... 100mA  
 All Other Outputs ..... 25mA

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

Plastic DIP (derate 10.53mW/°C above +70°C) ..... 842mW  
 Narrow SO (derate 8.70mW/°C above +70°C) ..... 696mW  
 CERDIP (derate 10.00mW/°C above +70°C) ..... 800mW

Operating Temperature Ranges

MAX791C\_ \_ ..... 0°C to +70°C  
 MAX791E\_ \_ ..... -40°C to +85°C  
 MAX791MJE ..... -55°C to +125°C  
 Storage Temperature Range ..... -65°C to +160°C  
 Lead Temperature (soldering, 10sec) ..... +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> = 4.75V to 5.5V, VBATT = 2.8V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Operating Voltage Range V <sub>CC</sub> , VBATT (Note 1)			0		5.5	V
V <sub>OUT</sub> in Normal Operating Mode	V <sub>CC</sub> = 4.5V	I <sub>OUT</sub> = 25mA	V <sub>CC</sub> - 0.05   V <sub>CC</sub> - 0.02		V	
		I <sub>OUT</sub> = 250mA	MAX791C/E	V <sub>CC</sub> - 0.3   V <sub>CC</sub> - 0.2		
			MAX791M	V <sub>CC</sub> - 0.40		
	V <sub>CC</sub> = 3V, VBATT = 2.8V, I <sub>OUT</sub> = 100mA		V <sub>CC</sub> - 0.2   V <sub>CC</sub> - 0.12			
V <sub>CC</sub> -to-V <sub>OUT</sub> On-Resistance	V <sub>CC</sub> = 4.5V	MAX791C/E	0.8	1.2	Ω	
		MAX791M	0.8	1.6		
	V <sub>CC</sub> = 3V			1.2		2.0
V <sub>OUT</sub> in Battery-Backup Mode	VBATT = 4.5V, I <sub>OUT</sub> = 20mA		VBATT - 0.3		V	
	VBATT = 2.8V, I <sub>OUT</sub> = 10mA		VBATT - 0.25			
	VBATT = 2.0V, I <sub>OUT</sub> = 5mA		VBATT - 0.15			
VBATT-to-V <sub>OUT</sub> On-Resistance	VBATT = 4.5V		8	15	Ω	
	VBATT = 2.8V		13	25		
	VBATT = 2.0V		17	30		
Supply Current in Normal Operating Mode (Excludes I <sub>OUT</sub> )	V <sub>CC</sub> > VBATT - 1V		50	150	μA	
Supply Current in Battery-Backup Mode (Excludes I <sub>OUT</sub> ) (Note 2)	V <sub>CC</sub> < VBATT - 1.2V, VBATT = 2.8V	T <sub>A</sub> = +25°C	0.04	1	μA	
		T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>	5			
VBATT Standby Current (Note 3)	VBATT + 0.2V ≤ V <sub>CC</sub>	T <sub>A</sub> = +25°C	-0.1	0.02	μA	
		T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>	-1.0	0.02		
Battery-Switchover Threshold	Power up		VBATT + 0.03		V	
	Power down		VBATT - 0.03			
Battery-Switchover Hysteresis			60		mV	
Low-Battery Detector Threshold			2		V	

# Microprocessor Supervisory Circuit

MAX791

## ELECTRICAL CHARACTERISTICS (continued)

(V<sub>CC</sub> = 4.75V to 5.5V, V<sub>BATT</sub> = 2.8V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
BATT ON Output Low Voltage	I <sub>SINK</sub> = 3.2mA		0.1	0.4	V
	I <sub>SINK</sub> = 25mA		0.7	1.5	
BATT ON Output Short-Circuit Current	Sink current		60		mA
	Source current	1	15	100	μA
<b>RESET, LOW-LINE AND WATCHDOG TIMER</b>					
RESET Threshold Voltage		4.50	4.65	4.75	V
RESET Threshold Hysteresis			15		mV
LOWLINE-to-RESET Threshold Voltage			150		mV
V <sub>CC</sub> -to-RESET Delay	Power down		100		μs
V <sub>CC</sub> -to-LOWLINE Delay	Power down		80		μs
RESET Active Timeout Period	Power up	140	200	280	ms
Watchdog Timeout Period	SWT connected to V <sub>OUT</sub>	1.0	1.6	2.25	sec
Minimum Watchdog Timeout Period	4.7nF capacitor connected from SWT to GND		10		ms
Minimum Watchdog Input Pulse Width	V <sub>IL</sub> = 0.8V, V <sub>IH</sub> = 0.75 x V <sub>CC</sub>	100			ns
WDPO Pulse Width			1		ms
WDPO-to-WDO Delay			70		ns
RESET Output Voltage	MAX791C, I <sub>SINK</sub> = 50μA, V <sub>CC</sub> = 1.0V, V <sub>CC</sub> falling		0.004	0.3	V
	MAX791E/M, I <sub>SINK</sub> = 50μA, V <sub>CC</sub> = 1.2V, V <sub>CC</sub> falling		0.004	0.3	
	I <sub>SINK</sub> = 3.2mA, V <sub>CC</sub> = 4.25V		0.1	0.4	
	I <sub>SOURCE</sub> = 1.6mA, V <sub>CC</sub> = 5V	3.5			
RESET Output Short-Circuit Current	Output source current		7	20	mA
LOWLINE Output Voltage	I <sub>SINK</sub> = 3.2mA, V <sub>CC</sub> = 4.25V			0.4	V
	I <sub>SOURCE</sub> = 1μA, V <sub>CC</sub> = 5V	3.5			
LOWLINE Output Short-Circuit Current	Output source current		15	100	μA
WDO Output Voltage	I <sub>SINK</sub> = 3.2mA			0.4	V
	I <sub>SOURCE</sub> = 500μA, V <sub>CC</sub> = 5V	3.5			
WDO Output Short-Circuit Current	Output source current		3	10	mA
WDPO Output Voltage	I <sub>SINK</sub> = 3.2mA			0.4	V
	I <sub>SOURCE</sub> = 1mA	3.5			
WDPO Output Short-Circuit Current	Output source current		7	20	mA

## Microprocessor Supervisory Circuit

MAX791

### ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = 4.75V$  to  $5.5V$ ,  $V_{BATT} = 2.8V$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
WDI Threshold Voltage (Note 4)	V <sub>IH</sub>	0.75 x V <sub>CC</sub>			V
	V <sub>IL</sub>	0.8			
WDI Input Current	WDI = 0V	-50	-10		μA
	WDI = V <sub>OUT</sub>		20	50	
POWER-FAIL COMPARATOR					
PFI Input Threshold	V <sub>CC</sub> = 5V	1.20	1.25	1.30	V
PFI Leakage Current			±0.01	±25	nA
PFO Output Voltage	I <sub>SINK</sub> = 3.2mA			0.4	V
	I <sub>SOURCE</sub> = 1μA, V <sub>CC</sub> = 5V	3.5			
PFO Short-Circuit Current	Output sink current		60		mA
	Output source current	1	15	100	μA
PFI-to-PFO Delay	V <sub>IN</sub> = -20mV, V <sub>OD</sub> = 15mV		15		μs
	V <sub>IN</sub> = 20mV, V <sub>OD</sub> = 15mV		55		
CHIP-ENABLE GATING					
CE IN Leakage Current	Disabled mode		±0.005	±1	μA
CE IN-to-CE OUT Resistance (Note 5)	Enabled mode		75	150	Ω
CE OUT Short-Circuit Current (Reset Active)	Disabled mode, CE OUT = 0V	0.1	0.75	2.0	mA
CE IN-to-CE OUT Propagation Delay (Note 6)	50Ω source impedance driver, C <sub>LOAD</sub> = 50pF		6	10	ns
CE OUT Output Voltage High (Reset Active)	V <sub>CC</sub> = 5V, I <sub>OUT</sub> = -100μA	3.5			V
	V <sub>CC</sub> = 0V, V <sub>BATT</sub> = 2.8V, I <sub>OUT</sub> = 1μA	2.7			
RESET-to-CE OUT Delay	Power down		15		μs
MANUAL RESET INPUT					
MR Minimum Pulse Width		25	15		μs
MR-to -RESET Propagation Delay			7		μs
MR Threshold	V <sub>CC</sub> = 5V		1.25		V
MR Pull-Up Current	MR = 0V		23	250	μA

**Note 1:** Either  $V_{CC}$  or  $V_{BATT}$  can go to 0V, if the other is greater than 2.0V.

**Note 2:** The supply current drawn by the MAX791 from the battery (excluding  $I_{OUT}$ ) typically goes to  $10\mu A$  when  $(V_{BATT} - 1V) < V_{CC} < V_{BATT}$ . In most applications, this is a brief period as  $V_{CC}$  falls through this region.

**Note 3:** "+" = battery-discharging current, "-" = battery-charging current.

**Note 4:** WDI is internally connected to a voltage divider between  $V_{OUT}$  and GND. If unconnected, WDI is driven to 1.6V (typ), disabling the watchdog function.

**Note 5:** The chip-enable resistance is tested with  $V_{CC} = 4.75V$ ,  $\overline{CE}_{IN} = V$ ,  $\overline{CE}_{OUT} = V_{CC} / 2$ .

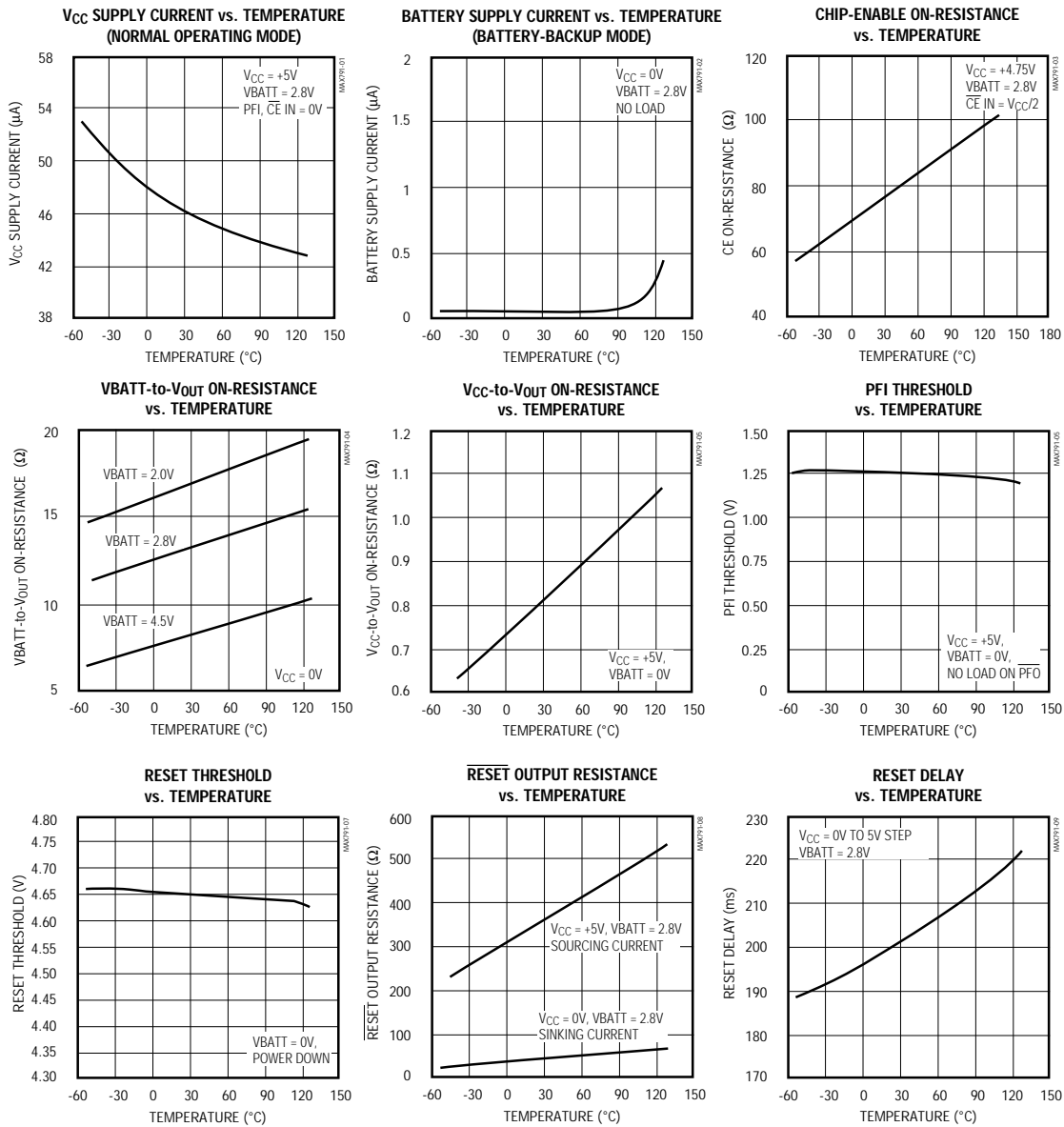
**Note 6:** The chip-enable propagation delay is measured from the 50% point at  $\overline{CE}_{IN}$  to the 50% point at  $\overline{CE}_{OUT}$ .

# Microprocessor Supervisory Circuit

## Typical Operating Characteristics

(T<sub>A</sub> = +25°C, unless otherwise noted.)

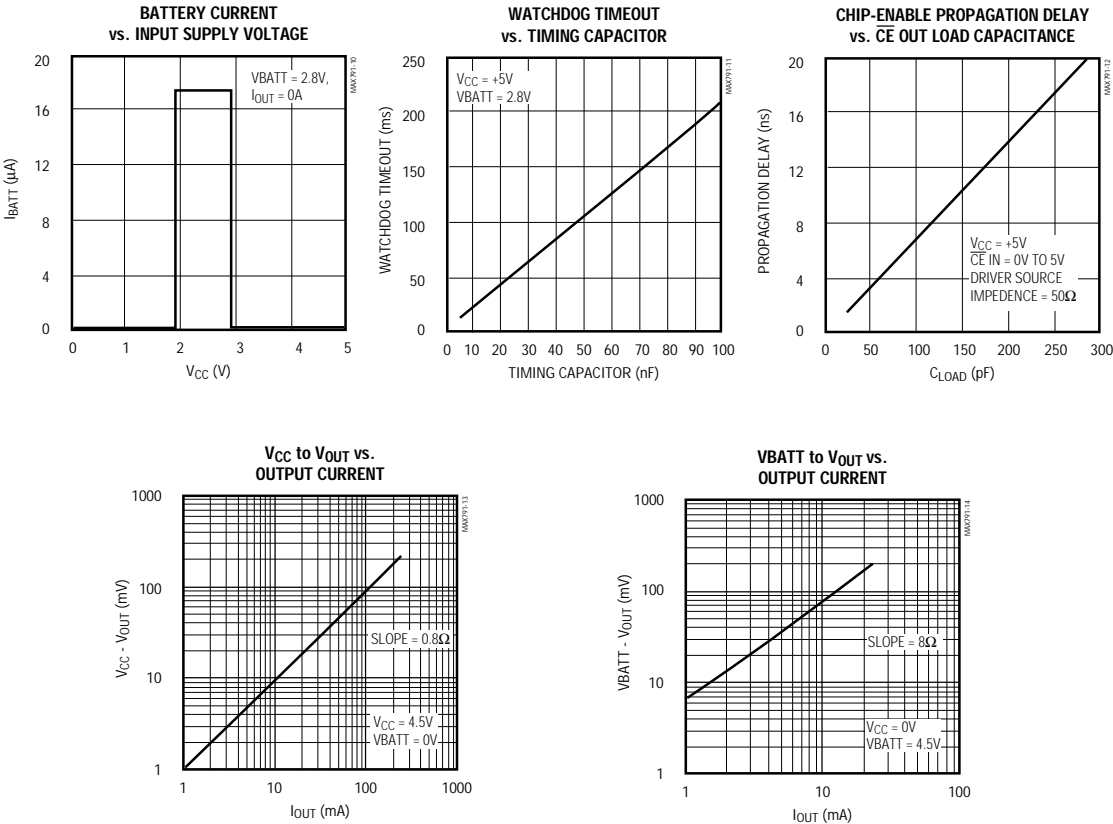
MAX791



# Microprocessor Supervisory Circuit

MAX791

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



# Microprocessor Supervisory Circuit

## Pin Description

MAX791

PIN	NAME	FUNCTION
1	VBATT	Backup-Battery Input. Connect to external battery or capacitor and charging circuit.
2	V <sub>OUT</sub>	Output Supply Voltage. V <sub>OUT</sub> connects to V <sub>CC</sub> when V <sub>CC</sub> is greater than VBATT and V <sub>CC</sub> is above the reset threshold. When V <sub>CC</sub> falls below VBATT and V <sub>CC</sub> is below the reset threshold, V <sub>OUT</sub> connects to VBATT. Connect a 0.1µF capacitor from V <sub>OUT</sub> to GND.
3	V <sub>CC</sub>	Input Supply Voltage—+5V input
4	GND	Ground. 0V reference for all signals
5	BATT ON	Battery On Output. Goes high when V <sub>OUT</sub> switches to VBATT. Goes low when V <sub>OUT</sub> switches to V <sub>CC</sub> . Connect the base of a PNP through a current-limiting resistor to BATT ON for V <sub>OUT</sub> current requirements greater than 250mA.
6	P <sub>FO</sub>	Power-Fail Output. This is the output of the power-fail comparator. P <sub>FO</sub> goes low when PFI is less than 1.25V. This is an uncommitted comparator, and has no effect on any other internal circuitry.
7	PFI	Power-Fail Input. This is the noninverting input to the power-fail comparator. When PFI is less than 1.25V, P <sub>FO</sub> goes low. Connect PFI to GND or V <sub>OUT</sub> when not used.
8	SWT	Set Watchdog-Timeout Input. Connect this input to V <sub>OUT</sub> to select the default 1.6sec watchdog timeout period. Connect a capacitor between this input and GND to select another watchdog-timeout period. Watchdog-timeout period = 2.1 x (capacitor value in nF) ms.
9	M <sub>R</sub>	Manual-Reset Input. This input can be tied to an external momentary pushbutton switch, or to a logic gate output. RESET remains low as long as M <sub>R</sub> is held low and for 200ms after M <sub>R</sub> returns high.
10	LOWLINE	LOWLINE Output goes low when V <sub>CC</sub> falls to 150mV above the reset threshold. The output can be used to generate an NMI if the unregulated supply is inaccessible.
11	WDI	Watchdog Input. WDI is a three-level input. If WDI remains either high or low for longer than the watchdog time-out period, WDO goes low. WDO remains low until the next transition at WDI. Leaving WDI unconnected disables the watchdog function. WDI connects to an internal voltage divider between V <sub>OUT</sub> and GND, which sets it to mid-supply when left unconnected.
12	C <sub>E</sub> OUT	Chip-Enable Output. C <sub>E</sub> OUT goes low only when C <sub>E</sub> IN is low and V <sub>CC</sub> is above the reset threshold. If C <sub>E</sub> IN is low when reset is asserted, C <sub>E</sub> OUT will stay low for 15µs or until C <sub>E</sub> IN goes high, whichever occurs first.
13	C <sub>E</sub> IN	Chip-Enable Input. The input to chip-enable gating circuit. Connect to GND or V <sub>OUT</sub> if not used.
14	WDO	Watchdog Output. WDO goes low if WDI remains either high or low longer than the watchdog timeout period. WDO returns high on the next transition at WDI. WDO remains high if WDI is unconnected. WDO is also high when RESET is asserted.
15	RESET	RESET Output goes low whenever V <sub>CC</sub> falls below the reset threshold. RESET will remain low for typically 200ms after V <sub>CC</sub> crosses the reset threshold on power-up.
16	WDPO	Watchdog-Pulse Output. Upon the absence of a transition at WDI, WDPO will pulse low for a minimum of 1ms. WDPO precedes WDO by 70ns.

## Microprocessor Supervisory Circuit

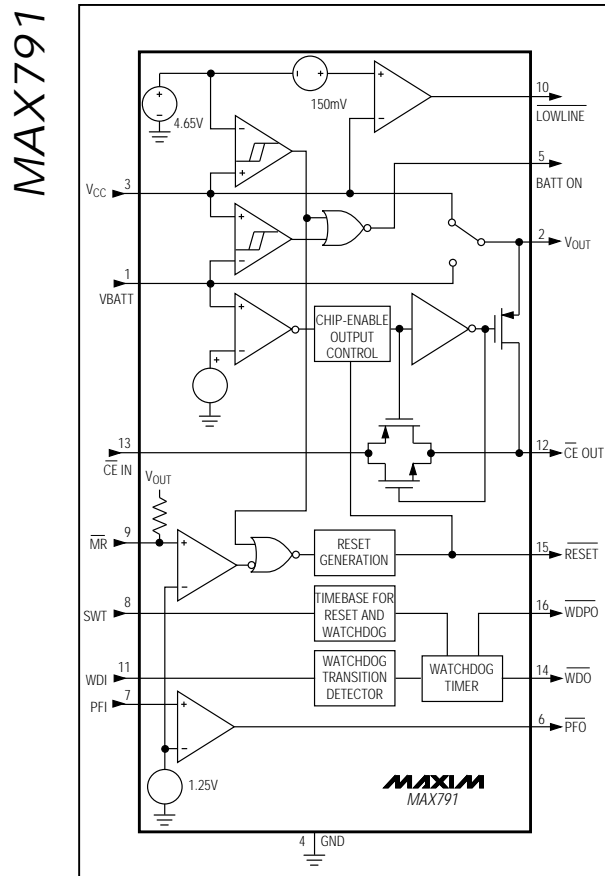


Figure 1. Block Diagram

### Detailed Description

#### Manual Reset Input

Many  $\mu$ P-based products require manual-reset capability, allowing the operator or test technician to initiate a reset. The Manual Reset Input ( $\overline{\text{MR}}$ ) can be connected directly to a switch, without an external pull-up resistor. It connects to a 1.25V comparator, and has a pull-up to  $V_{\text{OUT}}$  as shown in Figure 1. The propagation delay from asserting  $\overline{\text{MR}}$  to  $\overline{\text{RESET}}$  asserted is 4 $\mu$ s typical. Pulsing  $\overline{\text{MR}}$  low for a minimum of 15 $\mu$ s resets all the internal counters, sets the Watchdog Output ( $\overline{\text{WDO}}$ ) and Watchdog-Pulse Output

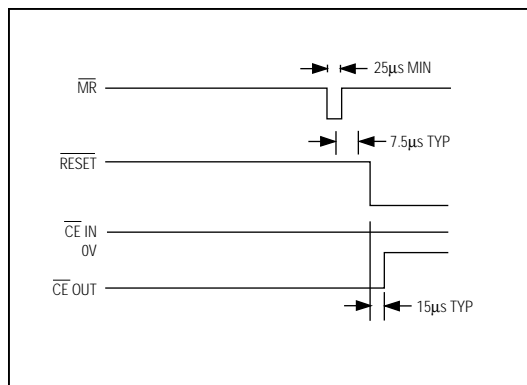


Figure 2. Manual-Reset Timing Diagram

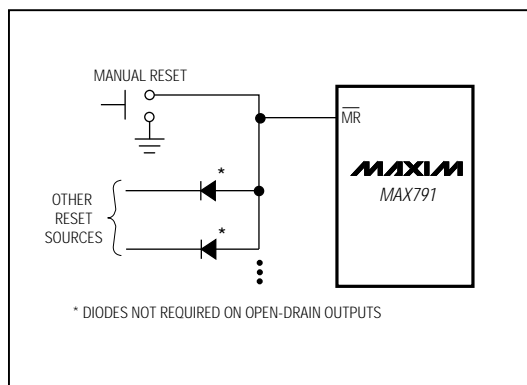


Figure 3. Diode "OR" connections allow multiple reset sources to connect to  $\overline{\text{MR}}$ .

( $\overline{\text{WDPO}}$ ) high, and sets the Set Watchdog-Timeout ( $\overline{\text{SWT}}$ ) input to  $V_{\text{OUT}} - 0.6\text{V}$ , if it is not already connected to  $V_{\text{OUT}}$  (for internal timeouts). It also disables the chip-enable function, setting the Chip-Enable Output ( $\overline{\text{CE OUT}}$ ) to a high state. The  $\overline{\text{RESET}}$  output remains active as long as  $\overline{\text{MR}}$  is held low, and the reset-timeout period begins after  $\overline{\text{MR}}$  returns high (Figure 2).

Use this input as either a digital-logic input or a second low-line comparator. Normal TTL/CMOS levels can be wire-OR connected via pull-down diodes (Figure 3), and open-drain/collector outputs can be wire-ORed directly.



## Microprocessor Supervisory Circuit

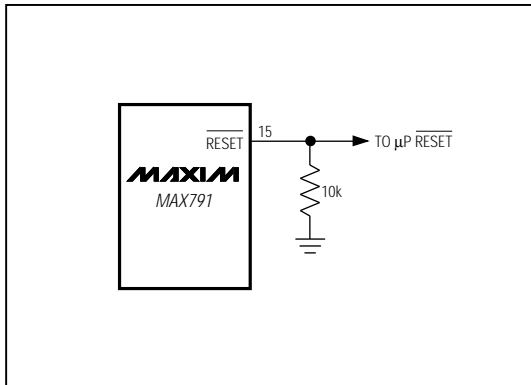


Figure 4. Adding an external pull-down resistor ensures  $\overline{\text{RESET}}$  is valid with  $V_{CC}$  down to GND.

### $\overline{\text{RESET}}$ Output

The MAX791's  $\overline{\text{RESET}}$  output ensures that the  $\mu\text{P}$  powers up in a known state, and prevents code-execution errors during power-down or brownout conditions.

The  $\overline{\text{RESET}}$  output is active low, and typically sinks 3.2mA at 0.1V saturation voltage in its active state. When deasserted,  $\overline{\text{RESET}}$  sources 1.6mA at typically  $V_{OUT} - 0.5\text{V}$ . When no backup battery is used,  $\overline{\text{RESET}}$  output is guaranteed to be valid down to  $V_{CC} = 1\text{V}$ , and an external  $10\text{k}\Omega$  pull-down resistor on  $\overline{\text{RESET}}$  ensures that  $\overline{\text{RESET}}$  will be valid with  $V_{CC}$  down to GND (Figure 4). As  $V_{CC}$  goes below 1V, the gate drive to the  $\overline{\text{RESET}}$  output switch reduces accordingly, increasing the  $r_{DS(ON)}$  and the saturation voltage. The  $10\text{k}\Omega$  pull-down resistor ensures the parallel combination of switch plus resistor is around  $10\text{k}\Omega$  and the output saturation voltage is below 0.4V while sinking  $40\mu\text{A}$ . When using a  $10\text{k}\Omega$  external pull-down resistor, the high state for the  $\overline{\text{RESET}}$  output with  $V_{CC} = 4.75\text{V}$  is 4.5V typical. For battery voltages  $\geq 2\text{V}$  connected to VBATT,  $\overline{\text{RESET}}$  remains valid for  $V_{CC}$  from 0V to 5.5V.

$\overline{\text{RESET}}$  will be asserted during the following conditions:

- 1)  $V_{CC} < 4.65\text{V}$  (typ)
- 2)  $\overline{\text{MR}} < 1.25\text{V}$  (typ)
- 3)  $\overline{\text{RESET}}$  remains asserted for 200ms (typ) after  $V_{CC}$  rises above 4.65V or after  $\overline{\text{MR}}$  has exceeded 1.25V.

The MAX791 battery-switchover comparator does not affect  $\overline{\text{RESET}}$  assertion. However,  $\overline{\text{RESET}}$  is asserted in battery-backup mode since  $V_{CC}$  must be below the reset threshold to enter this mode.

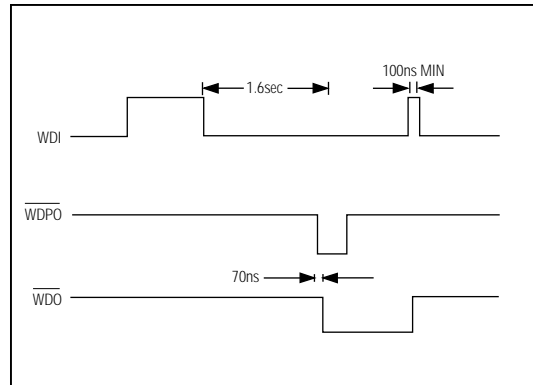


Figure 5. WDI,  $\overline{\text{WDO}}$  and  $\overline{\text{WDPO}}$  Timing Diagram ( $V_{CC}$  mode)

### Watchdog Function

The watchdog monitors  $\mu\text{P}$  activity via the Watchdog Input (WDI). If the  $\mu\text{P}$  becomes inactive,  $\overline{\text{WDO}}$  and  $\overline{\text{WDPO}}$  are asserted. To use the watchdog function, connect WDI to a bus line or  $\mu\text{P}$  I/O line. If WDI remains high or low for longer than the watchdog timeout period (1.6sec nominal),  $\overline{\text{WDPO}}$  and  $\overline{\text{WDO}}$  are asserted, indicating a software fault condition (see *Watchdog Output* and *Watchdog-Pulse Output* sections).

### Watchdog Input

A change of state (high to low, low to high, or a minimum 100ns pulse) at WDI during the watchdog period resets the watchdog timer. The watchdog default timeout is 1.6sec. Select alternative timeout periods by connecting an external capacitor from SWT to GND (see *Selecting an Alternative Watchdog Timeout* section).

To disable the watchdog function, leave WDI floating. An internal resistor network ( $100\text{k}\Omega$  equivalent impedance at WDI) biases WDI to approximately 1.6V. Internal comparators detect this level and disable the watchdog timer. When  $V_{CC}$  is below the reset threshold, the watchdog function is disabled and WDI is disconnected from its internal resistor network, thus becoming high impedance.

### Watchdog Output

$\overline{\text{WDO}}$  remains high if there is a transition or pulse at WDI during the watchdog-timeout period. The watchdog function is disabled and  $\overline{\text{WDO}}$  is a logic high when  $V_{CC}$  is below the reset threshold, battery-backup mode is enabled, or WDI is an open circuit. In watchdog mode, if no transition occurs at WDI during the watch-

MAX791

## Microprocessor Supervisory Circuit

MAX791

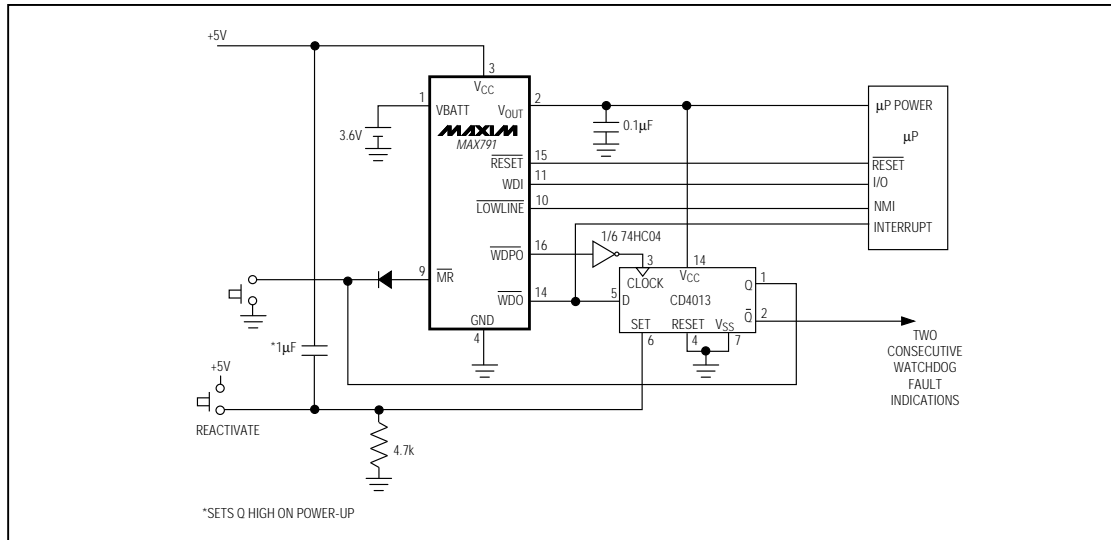


Figure 6. Two consecutive watchdog faults latch the system in reset.

dog-timeout period,  $\overline{\text{WDO}}$  goes low 70ns after the falling edge of  $\overline{\text{WDPO}}$  and remains low until the next transition at WDI (Figure 5). A flip-flop can force the system into a hardware shutdown if there are two successive watchdog faults (Figure 6).  $\overline{\text{WDO}}$  has a 2 x TTL output characteristic.

### Watchdog-Pulse Output

As described in the preceding section,  $\overline{\text{WDPO}}$  can be used as the clock input to an external D flip-flop. Upon the absence of a watchdog edge or pulse at WDI at the end of a watchdog-timeout period,  $\overline{\text{WDPO}}$  will pulse low for 1ms. The falling edge of  $\overline{\text{WDPO}}$  precedes  $\overline{\text{WDO}}$  by 70ns. Since  $\overline{\text{WDO}}$  is high when  $\overline{\text{WDPO}}$  goes low, the flip-flop's Q output remains high as  $\overline{\text{WDO}}$  goes low (Figure 5). If the watchdog timer is not reset by a transition at WDI,  $\overline{\text{WDO}}$  remains low and  $\overline{\text{WDPO}}$  clocks a logic low to the Q output, causing the MAX791 to latch in reset. If the watchdog timer is reset by a transition at WDI,  $\overline{\text{WDO}}$  goes high and the flip-flop's Q output remains high. Thus, a system shutdown is only caused by two successive watchdog faults.

The internal pull-up resistors associated with  $\overline{\text{WDO}}$  and  $\overline{\text{WDPO}}$  connect to  $\text{VOUT}$ . Therefore, do not connect these outputs directly to CMOS logic that is powered from  $\text{VCC}$  since, in the absence of  $\text{VCC}$  (i.e., battery

mode), excessive current will flow from  $\overline{\text{WDO}}$  or  $\overline{\text{WDPO}}$  through the protection diode(s) of the CMOS logic inputs to ground.

### Selecting an Alternative Watchdog Timeout Period

SWT input controls the watchdog-timeout period. Connecting SWT to  $\text{VOUT}$  selects the internal 1.6sec watchdog-timeout period. Select an alternative timeout period by connecting a capacitor between SWT and GND. Do not leave SWT floating, and do not connect it to ground. The following formula determines the watchdog-timeout period:

$$\text{Watchdog Timeout Period} = 2.1 \times (\text{capacitor value in nF}) \text{ ms}$$

This formula is valid for capacitance values between 4.7nF and 100nF (see the Watchdog Timeout vs. Timing Capacitor graph in the *Typical Operating Characteristics*). SWT is internally connected to a  $\pm 100\text{nA}$  (typ) current source, which charges and discharges the timing capacitor to create the oscillator frequency that sets the watchdog timeout period (see *Connecting a Timing Capacitor to SWT* in the *Applications Information* section).

## Microprocessor Supervisory Circuit

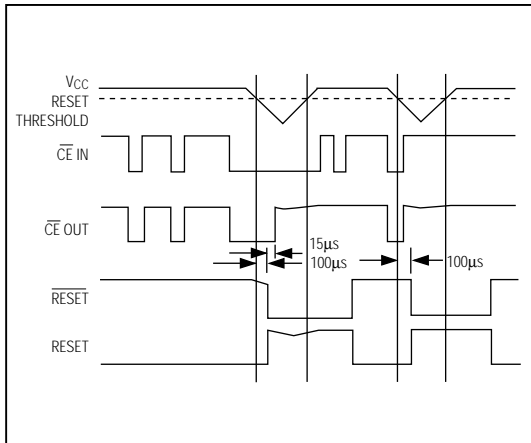


Figure 7. Reset and Chip-Enable Timing

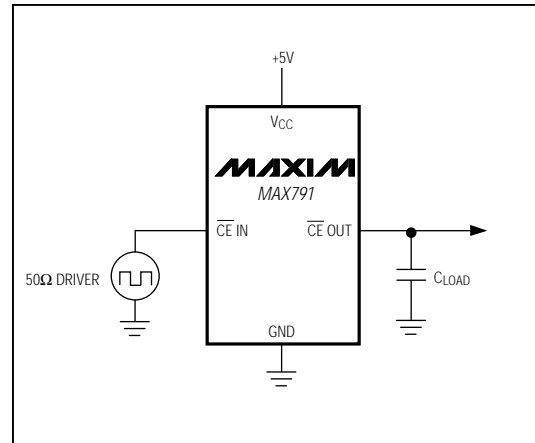


Figure 8. CE Propagation Delay Test Circuit

MAX791

### Chip-Enable Signal Gating

The MAX791 provides internal gating of chip-enable (CE) signals, to prevent erroneous data from corrupting the CMOS RAM in the event of a power failure. During normal operation, the CE gate is enabled and passes all CE transitions. When reset is asserted, this path becomes disabled, preventing erroneous data from corrupting the CMOS RAM. The MAX791 uses a series transmission gate from the Chip-Enable Input ( $\overline{\text{CE IN}}$ ) to  $\overline{\text{CE OUT}}$  (Figure 1).

The 10ns max CE propagation from  $\overline{\text{CE IN}}$  to  $\overline{\text{CE OUT}}$  enables the MAX791 to be used with most  $\mu\text{Ps}$ .

### Chip-Enable Input

$\overline{\text{CE IN}}$  is high impedance (disabled mode) while  $\overline{\text{RESET}}$  is asserted.

During a power-down sequence where  $V_{\text{CC}}$  passes 4.65V,  $\overline{\text{CE IN}}$  assumes a high-impedance state when the voltage at  $\overline{\text{CE IN}}$  goes high or 15 $\mu\text{s}$  after reset is asserted, whichever occurs first (Figure 7).

During a power-up sequence,  $\overline{\text{CE IN}}$  remains high impedance, regardless of  $\overline{\text{CE IN}}$  activity, until reset is deasserted following the reset-timeout period.

In the high-impedance mode, the leakage currents into this input are  $\pm 1\mu\text{A}$  max over temperature. In the low-impedance mode, the impedance of  $\overline{\text{CE IN}}$  appears as a 75 $\Omega$  resistor in series with the load at  $\overline{\text{CE OUT}}$ .

The propagation delay through the CE transmission gate depends on both the source impedance of the drive to  $\overline{\text{CE IN}}$  and the capacitive loading on  $\overline{\text{CE OUT}}$  (see the Chip-Enable Propagation Delay vs.  $\overline{\text{CE OUT}}$  Load Capacitance graph in the *Typical Operating Characteristics*). The CE propagation delay is production tested from the 50% point on  $\overline{\text{CE IN}}$  to the 50% point on  $\overline{\text{CE OUT}}$  using a 50 $\Omega$  driver and 50pF of load capacitance (Figure 8). For minimum propagation delay, minimize the capacitive load at  $\overline{\text{CE OUT}}$  and use a low output-impedance driver.

### Chip-Enable Output

In the enabled mode, the impedance of  $\overline{\text{CE OUT}}$  is equivalent to 75 $\Omega$  in series with the source driving  $\overline{\text{CE IN}}$ . In the disabled mode, the 75 $\Omega$  transmission gate is off and  $\overline{\text{CE OUT}}$  is actively pulled to  $V_{\text{OUT}}$ . This source turns off when the transmission gate is enabled.

### LOWLINE Output

The low-line comparator monitors  $V_{\text{CC}}$  with a typical threshold voltage 150mV above the reset threshold, and has 15mV of hysteresis.  $\overline{\text{LOWLINE}}$  typically sinks 3.2mA at 0.1V. For normal operation ( $V_{\text{CC}}$  above the  $\overline{\text{LOWLINE}}$  threshold),  $\overline{\text{LOWLINE}}$  is pulled to  $V_{\text{OUT}}$ . If access to the unregulated supply is unavailable, use  $\overline{\text{LOWLINE}}$  to provide a nonmaskable interrupt (NMI) to the  $\mu\text{P}$  as  $V_{\text{CC}}$  begins to fall (Figure 9a).

## Microprocessor Supervisory Circuit

MAX791

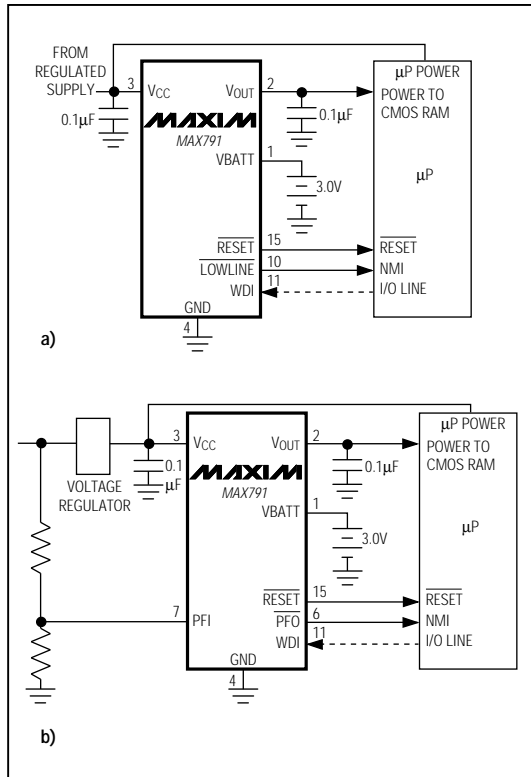


Figure 9. a) If the unregulated supply is inaccessible, LOWLINE generates the NMI for the  $\mu P$ . b) Use PFO to generate the  $\mu P$  NMI if the unregulated supply is inaccessible.

### Power-Fail Comparator

The power-fail comparator is an uncommitted comparator that has no effect on the other functions of the IC. Common uses include monitoring supplies other than 5V (see the *Typical Operating Circuit* and the *Monitoring a Negative Voltage* section) and early power-fail detection when the unregulated power is easily accessible (Figure 9b).

### Power-Fail Input

PFI is the input to the power-fail comparator. PFI has a guaranteed input leakage of  $\pm 25\text{nA}$  max over temperature. The typical comparator delay is  $15\mu\text{s}$  from  $V_{IL}$  to  $V_{OL}$  (power failing), and  $55\mu\text{s}$  from  $V_{IH}$  to  $V_{OH}$  (power being restored). If unused, connect this input to ground.

Table 1. Input and Output States in Battery-Backup Mode

PIN	NAME	STATUS
1	VBATT	Supply current is $1\mu\text{A}$ maximum.
2	VOUT	$V_{OUT}$ is connected to VBATT through an internal PMOS switch.
3	VCC	Battery-switchover comparator monitors $V_{CC}$ for active switchover.
4	GND	GND—0V reference for all signals.
5	BATT ON	Logic high. The open-circuit output is equal to $V_{OUT}$ .
6	$\overline{\text{PFO}}$	The power-fail comparator remains active in the battery-backup mode for $V_{CC} \geq \text{VBATT} - 1.2\text{V}$ typ. Below this voltage, $\overline{\text{PFO}}$ is forced low.
7	PFI	The power-fail comparator remains active in the battery-backup mode for $V_{CC} \geq \text{VBATT} - 1.2\text{V}$ typ.
8	SWT	SWT is ignored.
9	$\overline{\text{MR}}$	$\overline{\text{MR}}$ is ignored.
10	$\overline{\text{LOWLINE}}$	Logic low*
11	WDI	WDI is ignored, and goes high impedance.
12	$\overline{\text{CE OUT}}$	Logic high. The open-circuit output voltage is equal to $V_{OUT}$ .
13	$\overline{\text{CE IN}}$	High impedance
14	$\overline{\text{WDO}}$	Logic high. The open-circuit output voltage is equal to $V_{OUT}$ .
15	$\overline{\text{RESET}}$	Logic low*
16	$\overline{\text{WDPO}}$	Logic high. The open-circuit output voltage is equal to $V_{OUT}$ .

\*  $V_{CC}$  must be below the reset threshold to enter battery-backup mode.

### Power-Fail Output

The Power-Fail Output ( $\overline{\text{PFO}}$ ) goes low when PFI goes below  $1.25\text{V}$ . It typically sinks  $3.2\text{mA}$  with a saturation voltage of  $0.1\text{V}$ . With PFI above  $1.25\text{V}$ ,  $\overline{\text{PFO}}$  is actively pulled to  $V_{OUT}$ . Connecting PFI through a voltage divider to an unregulated supply allows  $\overline{\text{PFO}}$  to generate an NMI as the unregulated power begins to fail (Figure 9b). If the unregulated supply is inaccessible, use LOWLINE to generate the NMI. The LOWLINE threshold is typically  $150\text{mV}$  above the reset threshold (see *LOWLINE Output* section).

## Microprocessor Supervisory Circuit

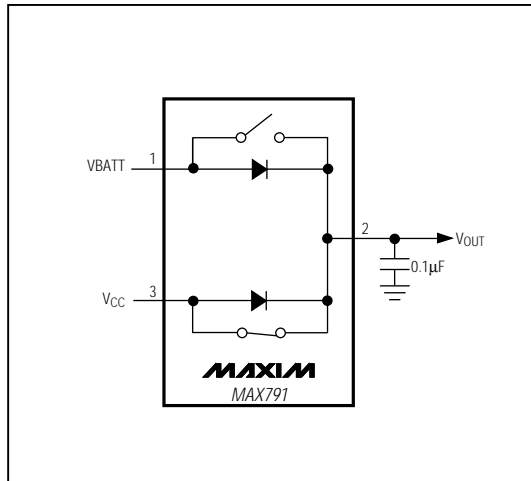


Figure 10. VCC and VBATT-to-VOUT Switch

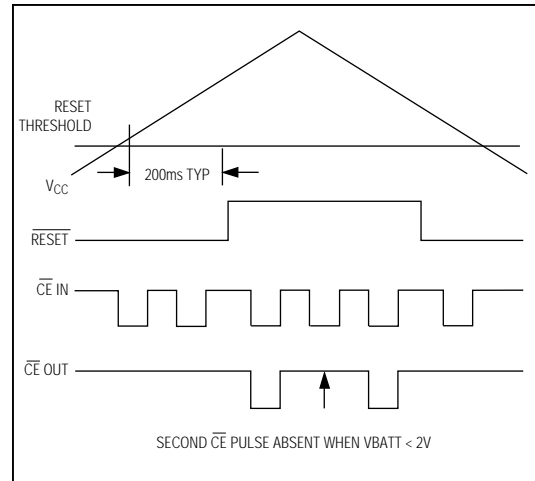


Figure 11. Backup-Battery Monitor Timing Diagram

MAX791

### Battery-Backup Mode

The MAX791 requires two conditions to switch to battery-backup mode: 1)  $V_{CC}$  must be below the reset threshold; 2)  $V_{CC}$  must be below  $V_{BATT}$ . Table 1 lists the status of the inputs and outputs in battery-backup mode.

### Battery On Output

The Battery On (BATT ON) output indicates the status of the internal  $V_{CC}$ /battery-switchover comparator, which controls the internal  $V_{CC}$  and  $V_{BATT}$  switches. For  $V_{CC}$  greater than  $V_{BATT}$  (ignoring the small hysteresis effect), BATT ON typically sinks 3.2mA at 0.1V saturation voltage. In battery-backup mode, this terminal sources approximately 10 $\mu$ A from  $V_{OUT}$ . Use BATT ON to indicate battery-switchover status or to supply base drive to an external pass transistor for higher-current applications (see *Typical Operating Circuit*).

### Input Supply Voltage

The Input Supply Voltage ( $V_{CC}$ ) should be a regulated +5V.  $V_{CC}$  connects to  $V_{OUT}$  via a parallel diode and a large PMOS switch. The switch carries the entire current load for currents less than 250mA. The parallel diode carries any current in excess of 250mA. Both the switch and the diode have impedances less than 1 $\Omega$  each (Figure 10). The maximum continuous current is 250mA, but power-on transients may reach a maximum of 1A.

### Backup-Battery Input

The Backup-Battery Input ( $V_{BATT}$ ) is similar to  $V_{CC}$ , except the PMOS switch and parallel diode are much smaller. Accordingly, the on-resistances of the diode and the switch are each approximately 10 $\Omega$ . Continuous current should be limited to 25mA and peak currents (only during power-up) limited to 250mA. The reverse leakage of this input is less than 1 $\mu$ A over temperature and supply voltage.

### Output Supply Voltage

The Output Supply Voltage ( $V_{OUT}$ ) is internally connected to the substrate of the IC and supplies all the current to the external system and internal circuitry. All open-circuit outputs will, for example, assume the  $V_{OUT}$  voltage in their high states rather than the  $V_{CC}$  voltage. At the maximum source current of 250mA,  $V_{OUT}$  will typically be 200mV below  $V_{CC}$ . Decouple this terminal with a 0.1 $\mu$ F capacitor.

## Microprocessor Supervisory Circuit

MAX791

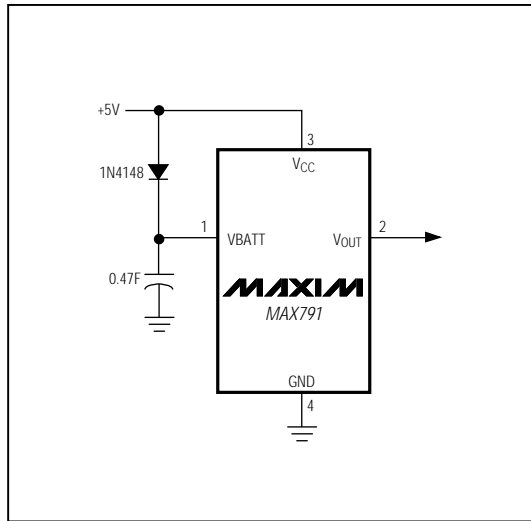


Figure 12. SuperCap or MaxCap on VBATT

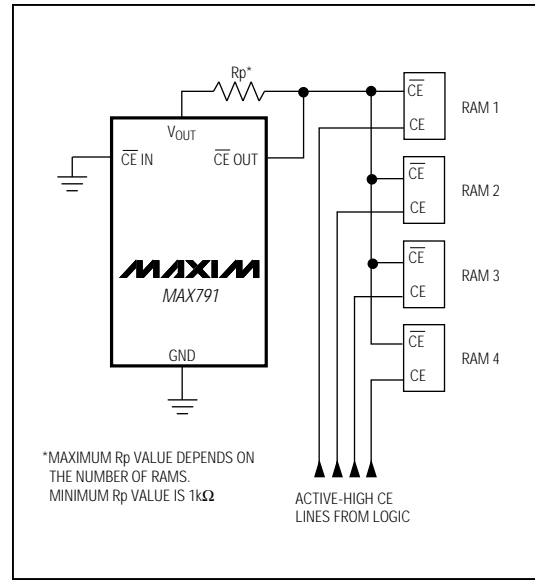


Figure 13. Alternate CE Gating

### Low-Battery Monitor

The MAX791 low-battery voltage function monitors VBATT. Low-battery detection of  $2.0V \pm 0.15V$  is monitored only during the reset-timeout period (200ms) that occurs either after a normal power-up sequence or after the  $\overline{MR}$  reset input has been returned to its high state. If the battery voltage is below 2.0V, the second CE pulse is inhibited after reset timeout. If the battery voltage is above 2.0V, all CE pulses are allowed through the CE gate after the reset timeout period. To use this function, after the 200ms reset delay, write 00 (HEX) to a location using the first CE pulse, and write FF (HEX) to the same location using the second CE pulse following RESET going inactive on power-up. The contents of the memory then indicates a good battery (FF) or a low battery (00) (Figure 11).

### Applications Information

The MAX791 is not short-circuit protected. Shorting VOUT to ground, other than power-up transients such as charging a decoupling capacitor, destroys the device.

All open-circuit outputs swing between VOUT and GND rather than VCC and GND.

If long leads connect to the chip inputs, ensure that these lines are free from ringing and other conditions that would forward bias the chip's protection diodes.

There are three distinct modes of operation:

- 1) Normal operating mode with all circuitry powered up. Typical supply current from VCC is 60μA, while only leakage currents flow from the battery.
- 2) Battery-backup mode where VCC is typically within 0.7V below VBATT. All circuitry is powered up and the supply current from the battery is typically less than 60μA.
- 3) Battery-backup mode where VCC is less than VBATT by at least 0.7V. VBATT supply current is than 1μA max.

## Microprocessor Supervisory Circuit

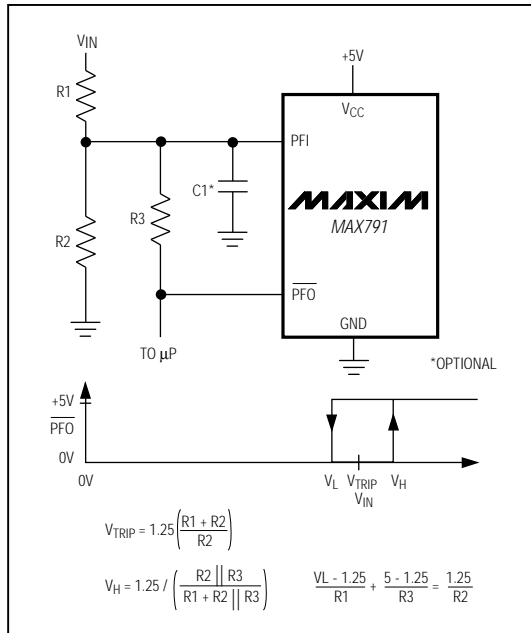


Figure 14. Adding Hysteresis to the Power-Fail Comparator

### Using SuperCaps or MaxCaps with the MAX791

VBATT has the same operating voltage range as VCC, and the battery-switchover threshold voltages are typically  $\pm 30\text{mV}$  centered at VBATT, allowing use of a SuperCap and a simple charging circuit as a backup source (Figure 12).

If VCC is above the reset threshold and VBATT is 0.5V above VCC, current flows to VOUT and VCC from VBATT until the voltage at VBATT is less than 0.5V above VCC. For example, with a SuperCap connected to VBATT and through a diode to VCC, if VCC quickly changes from 5.4V to 4.9V, the capacitor discharges through VOUT and VCC until VBATT reaches 5.3V typical.

Leakage current through the SuperCap charging diode and MAX791 internal power diode eventually discharges the SuperCap to VCC. Also, if VCC and VBATT start from 0.5V above the reset threshold and power is lost at VCC, the SuperCap on VBATT discharges through VCC until VBATT reaches the reset threshold; the MAX791 then switches to battery-backup mode and the current through VCC goes to zero (Figure 10).

### Using Separate Power Supplies for VBATT and VCC

If using separate power supplies for VCC and VBATT, VBATT must be less than 0.3V above VCC when VCC is above the reset threshold. As described in the previous section, if VBATT exceeds this limit and power is lost at VCC, current flows continuously from VBATT to VCC via the VBATT-to-VOUT diode and the VOUT-to-VCC switch until the circuit is broken (Figure 10).

### Alternative Chip-Enable Gating

Using memory devices with CE and  $\overline{\text{CE}}$  inputs allows the MAX791 CE loop to be bypassed. To do this, connect  $\overline{\text{CE}}$  IN to ground, pull up  $\overline{\text{CE}}$  OUT to VOUT, and connect  $\overline{\text{CE}}$  OUT to the CE input of each memory device (Figure 13). The CE input of each part then connects directly to the chip-select logic, which does not have to be gated by the MAX791.

### Adding Hysteresis to the Power-Fail Comparator

Hysteresis adds a noise margin to the power-fail comparator and prevents repeated triggering of PFO when VIN is near the power-fail comparator trip point. Figure 14 shows how to add hysteresis to the power-fail comparator. Select the ratio of R1 and R2 such that PFI sees 1.25V when VIN falls to the desired trip point (VTRIP). Resistor R3 adds hysteresis. It will typically be an order of magnitude greater than R1 or R2. The current through R1 and R2 should be at least 1μA to ensure that the 25nA (max) PFI input current does not shift the trip point. R3 should be larger than 10kΩ to prevent it from loading down the PFO pin. Capacitor C1 adds additional noise rejection.

MAX791

## Microprocessor Supervisory Circuit

MAX791

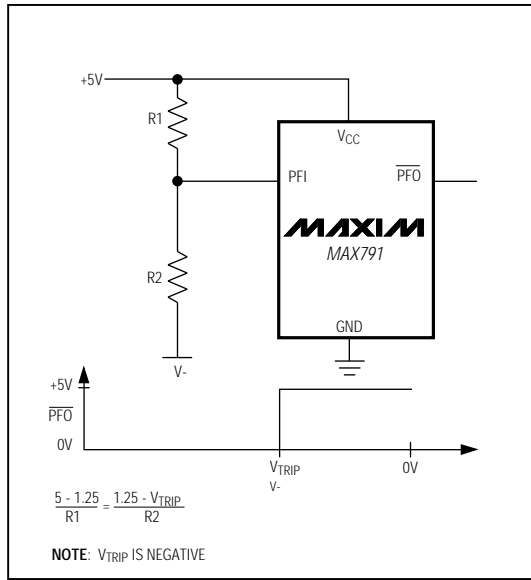


Figure 15. Monitoring a Negative Voltage

### Monitoring a Negative Voltage

The power-fail comparator can be used to monitor a negative supply voltage using Figure 15's circuit. When the negative supply is valid, PFO is low. When the negative supply voltage drops, PFO goes high. This circuit's accuracy is affected by the PFI threshold tolerance, the VCC voltage, and resistors R1 and R2.

### Backup-Battery Replacement

The backup battery may be disconnected while VCC is above the reset threshold. No precautions are necessary to avoid spurious reset pulses.

### Negative-Going VCC Transients

While issuing resets to the  $\mu P$  during power-up, power-down, and brownout conditions, these supervisors are relatively immune to short-duration negative-going VCC transients (glitches). It is usually undesirable to reset the  $\mu P$  when VCC experiences only small glitches.

Figure 16 shows maximum transient duration vs. reset comparator overdrive, for which reset pulses are not generated. The graph was produced using negative-going VCC pulses, starting at 5V and ending below the reset threshold by the magnitude indicated (reset com-

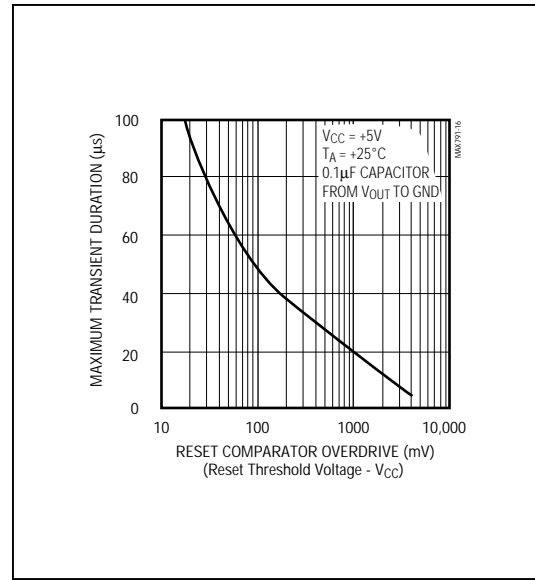


Figure 16. Maximum Transient Duration without Causing a Reset Pulse vs. Reset Comparator Overdrive

parator overdrive). The graph shows the maximum pulse width that a negative-going VCC transient may typically have without causing a reset pulse to be issued. As the amplitude of the transient increases (i.e., goes farther below the reset threshold), the maximum allowable pulse width decreases. Typically, a VCC transient that goes 100mV below the reset threshold and lasts for 40μs or less will not cause a reset pulse to be issued.

A 100nF bypass capacitor mounted close to the VCC pin provides additional transient immunity.

### Connecting a Timing Capacitor to the SWT

SWT is internally connected to a  $\pm 100$ nA current source. When a capacitor is connected from SWT to ground (to select an alternative watchdog timeout period), the current source charges and discharges the timing capacitor to create the oscillator that controls the watchdog timeout period. To prevent timing errors or oscillator start-up problems, minimize external current leakage sources at this pin, and locate the capacitor as close to SWT as possible. The sum of PC board leakage + SWT capacitor leakage must be small compared to  $\pm 100$ nA.



## Microprocessor Supervisory Circuit

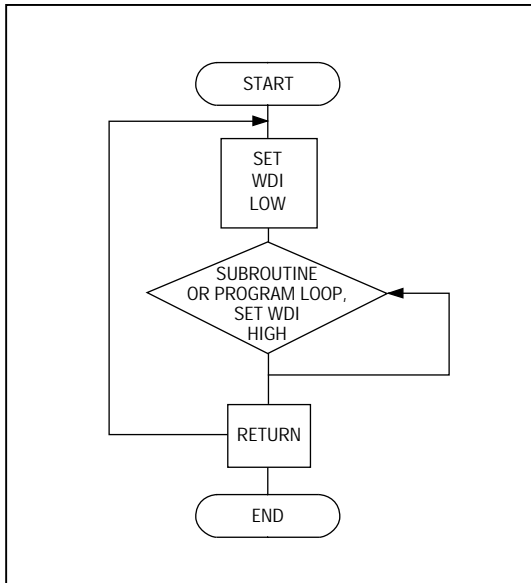


Figure 17. Watchdog Flow Diagram

### Watchdog Software Considerations

A way to help the watchdog timer keep a closer watch on software execution involves setting and resetting the watchdog input at different points in the program, rather than "pulsing" the watchdog input high-low-high or low-high-low. This technique avoids a "stuck" loop where the watchdog timer continues to be reset within the loop, keeping the watchdog from timing out.

Figure 17 shows an example flow diagram where the I/O driving the watchdog input is set high at the beginning of the program, set low at the beginning of every subroutine or loop, then set high again when the program returns to the beginning. If the program should "hang" in any subroutine, the I/O is continually set low and the watchdog timer is allowed to time out, causing a reset or interrupt to be issued.

### Maximum VCC Fall Time

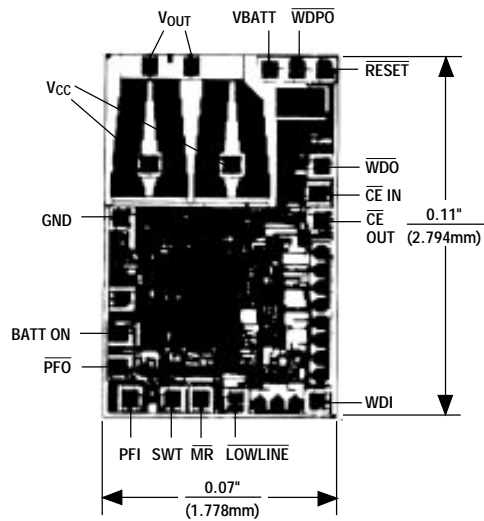
The VCC fall time is limited by the propagation delay of the battery switchover comparator and should not exceed 0.03V/μs. A standard rule of thumb for filter capacitance on most regulators is on the order of 100μF per amp of current. When the power supply is shut off or the main battery is disconnected, the associated initial VCC fall rate is just the inverse or  $1A / 100\mu F = 0.01V/\mu s$ . The VCC fall rate decreases with time as VCC falls exponentially, which more than satisfies the maximum fall-time requirement.

MAX791

## Microprocessor Supervisory Circuit

MAX791

Chip Topography

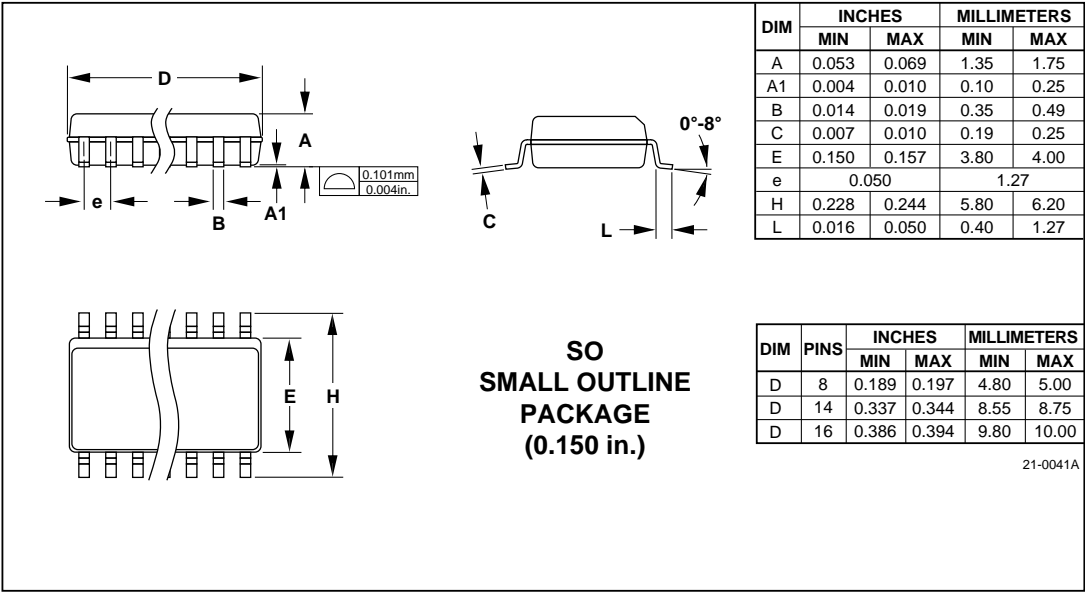
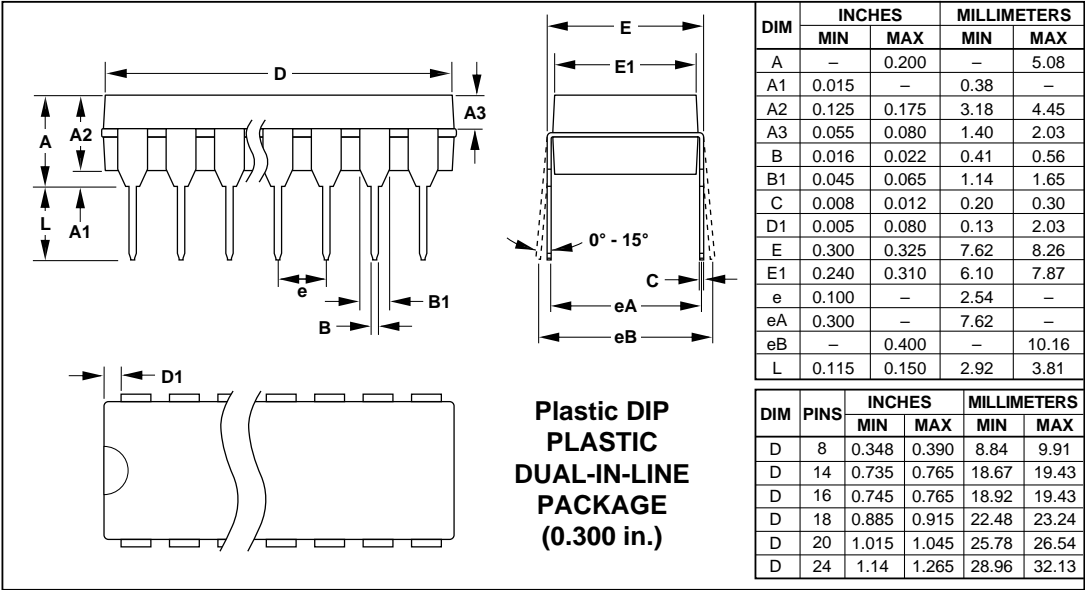


SUBSTRATE CONNECTED TO V<sub>OUT</sub>  
TRANSISTOR COUNT: 729

Microprocessor Supervisory Circuit

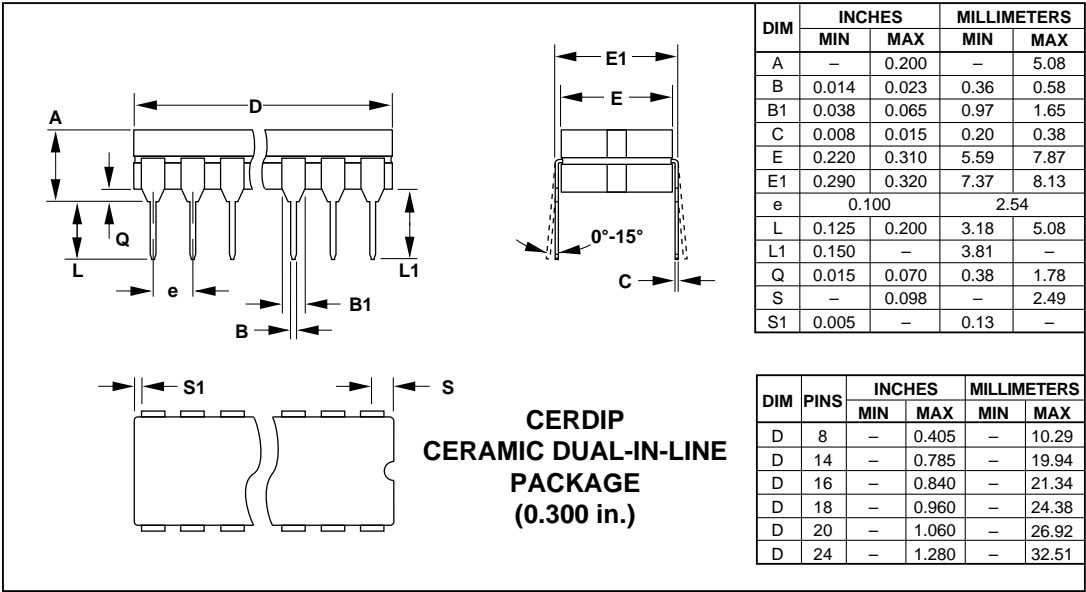
Package Information

MAX791



# Microprocessor Supervisory Circuits

## Package Information (continued)



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