



+72V SOT23 Simple Swapper Hot-Swap Controllers

MAX5902/MAX5903

General Description

The MAX5902/MAX5903 are SOT23 hot-swap controllers that allow a circuit card to be safely hot plugged into a live backplane without causing a glitch on the power-supply rail. These devices operate from +9V to +72V and provide the simplest hot-swap solution by eliminating all external components except the external P-channel MOSFET.

The MAX5902/MAX5903 limit the inrush current to the load and provide a circuit breaker function for overcurrent protection. During startup the circuit breaker function is disabled and the MAX5902/MAX5903 limit the inrush current by gradually turning on the external MOSFET. Once the external MOSFET is fully enhanced, the circuit breaker function is enabled and the MAX5902/MAX5903 provide overcurrent protection by monitoring the voltage drop across the external MOSFET's on-resistance.

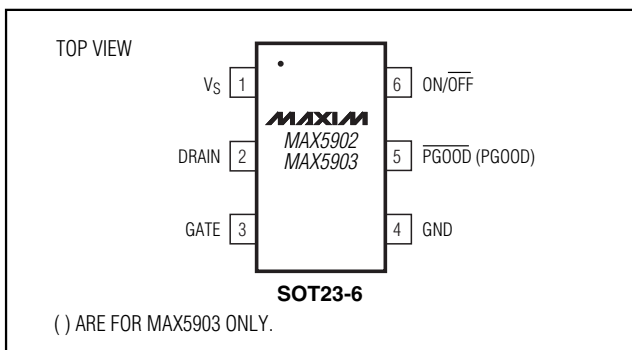
The MAX5902/MAX5903 include an undervoltage lockout (UVLO) function, ON/OFF control input and a power-good status output, PGOOD (MAX5902) or PGOOD (MAX5903). A built in thermal shutdown feature is also included to protect the external MOSFET in case of overheating.

The MAX5902/MAX5903 offer latched or auto-retry fault management and are available with 300mV, 400mV or 500mV circuit breaker thresholds. Both the MAX5902 and MAX5903 are available in a small SOT23 package, and are specified for the extended -40°C to +85°C temperature range. For specific ordering information refer to the selector guide at the end of the data sheet.

Applications

- | | |
|-------------------------|--------------------|
| Network Routers | Servers |
| Network Switches | RAID |
| Base Station Line Cards | Industrial Systems |

Pin Configuration



Features

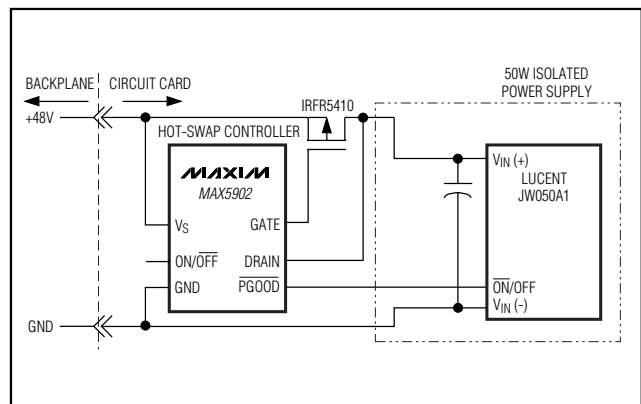
- ◆ Wide +9V to +72V Operation
- ◆ Requires No External Sense Resistor
- ◆ Drives External P-Channel MOSFET
- ◆ Limits Inrush Current
- ◆ Circuit Breaker Function
- ◆ Less than 2mA Quiescent Current
- ◆ ON/OFF Input Permits Load Power-Supply Control and Sequencing
- ◆ Adjustable Undervoltage Lockout
- ◆ Power-Good Output with +72V Rating
- ◆ Latching or Automatic Retry Fault Management
- ◆ Thermal Shutdown Helps Protect the External MOSFET
- ◆ Space-Saving SOT23-6 Package

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX5902_ _EUT*	-40°C to +85°C	6-SOT23
MAX5903_ _EUT*	-40°C to +85°C	6-SOT23

*For specific part numbers see Selector Guide at end of data sheet.

Typical Operating Circuits



Typical Operating Circuits continued at end of data sheet.

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ABSOLUTE MAXIMUM RATINGS

Terminal Voltage (with respect to GND unless otherwise noted)
 V_S , DRAIN, PGOOD, $\overline{\text{PGOOD}}$ -0.3V to +76V
 ON/OFF -0.3V to +4V
 GATE to V_S -12V to +0.3V
 Current into any Pin $\pm 3\text{mA}$

Continuous Power Dissipation at $T_A = +70^\circ\text{C}$
 6-Pin SOT23 (derate 9.1mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$) 727mW
 Maximum Junction Temperature $+150^\circ\text{C}$
 Storage Temperature Range -60°C to $+150^\circ\text{C}$
 Lead Temperature Note 1

Note 1: This device is constructed using a unique set of packaging techniques that impose a limit on the thermal profile the device can be exposed to during board level solder attach and rework. This limit permits only the use of solder profiles recommended in the industry standard specification, JEDEC 020A, paragraph 7.6, Table 3 for IR/VPR and convection reflow. Preheating is required. Hand or wave soldering is not allowed.

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

($V_S = +9\text{V}$ to $+72\text{V}$, GND = 0, ON/OFF open circuit, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, unless otherwise noted. Typical values are at $V_S = +48\text{V}$ and $T_A = +25^\circ\text{C}$.) (Notes 2, 3)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
Supply Voltage	V_S		9		72	V	
Supply Current	I_{GND}	Measured out of GND, PGOOD or $\overline{\text{PGOOD}}$ open circuit, DRAIN = V_S		1	2	mA	
External Gate Drive	V_{GS}	$V_S - V_{\text{GATE}}$	$V_S = +36\text{V}$ to $+72\text{V}$	9	10	11	V
			$V_S = +9\text{V}$	8	8.5		
Load Voltage Slew Rate Magnitude	SR	$I \text{ d}V_{\text{DRAIN}}/\text{d}t$ $C_L = 10\mu\text{F}$	$V_S = +36\text{V}$ to $+72\text{V}$	5	9	18	V/ms
			$V_S = +9\text{V}$	3	6	11	
Default Undervoltage Lockout	V_{UVLO}	V_S increasing	28.5	31.5	34.5	V	
Undervoltage Lockout Hysteresis				3.5		V	
ON/OFF Pin Input Resistance	$R_{\text{ON/OFF}}$		19	32	52	k Ω	
DRAIN to GND Resistance	R_{DGND}			900		k Ω	
DRAIN to V_S Resistance	R_{DS}			650		k Ω	
ON/OFF Reference Threshold	$V_{\text{ON/OFF}}$	$V_{\text{ON/OFF}}$ Increasing	1.14	1.26	1.38	V	
ON/OFF Hysteresis				140		mV	
Start Delay (Note 4)	t_{ON}		80	150	280	ms	
ON/OFF Off Delay (Note 5)	t_{OFF}	$V_S - V_{\text{GATE}} < 1\text{V}$	5	10	18	ms	
Circuit Breaker Threshold	V_{CB}	$V_S - V_{\text{DRAIN}}$	MAX590_ _AEUT	200	300	460	mV
			MAX590_ _BEUT	280	400	540	
			MAX590_ _CEUT	400	500	660	
Circuit Breaker Delay (Note 6)	t_{CB}	$(V_S - V_{\text{DRAIN}}) > V_{\text{CB}}$ until $(V_S - V_{\text{GATE}}) < 1\text{V}$, 200mV overdrive step	$C_{\text{GATE}} = 1\text{nF}$		2	6.5	μs
			$C_{\text{GATE}} = 4.7\text{nF}$		4	11	
			$C_{\text{GATE}} = 10\text{nF}$		7	17	
Restart Delay (Note 4)	t_{RS}	After circuit breaker event, MAX590_ _A_EUT only	80	150	280	ms	
Power Good Output Low Voltage	V_{OL}	$I_{\text{OL}} = 1\text{mA}$		0.3	0.6	V	

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MAX5902/MAX5903

ELECTRICAL CHARACTERISTICS (continued)

($V_S = +9V$ to $+72V$, $GND = 0$, ON/OFF open circuit, $T_A = -40^\circ C$ to $+85^\circ C$, unless otherwise noted. Typical values are at $V_S = +48V$ and $T_A = +25^\circ C$.) (Notes 2, 3)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Power-Good Output Open-Drain Leakage Current	I_{OH}	$V_{PGOOD} = 72V$ (MAX5902) $V_{PGOOD} = 72V$ (MAX5903)			10	μA
Thermal Shutdown Temperature	T_{SD}	Junction temperature		+125		$^\circ C$
Thermal Shutdown Hysteresis	T_{HY}			15		$^\circ C$

Note 2: All currents into device pins are positive, all currents out of device pins are negative, and all voltages are referenced to GND, unless otherwise noted.

Note 3: All specifications are 100% tested at $T_A = +25^\circ C$, unless otherwise noted. Specifications over $-40^\circ C$ to $+85^\circ C$ are guaranteed by characterization.

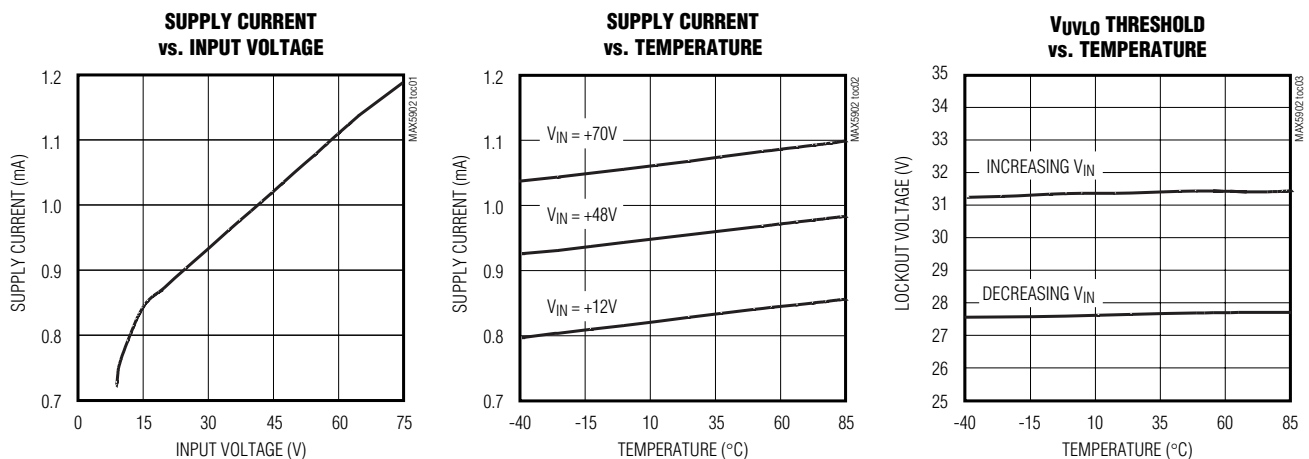
Note 4: This is the delay time from a valid on condition until V_{GS} begins rising. Valid on conditions are: the device is not in undervoltage lockout; ON/OFF is not driven low; and the device is not in thermal shutdown.

Note 5: This is the delay from a valid low on ON/OFF until V_{GS} falls. Pulses on ON/OFF less than t_{OFF} are ignored, offering glitch immunity.

Note 6: Guaranteed by characterization, not production tested. C_{GATE} is a capacitor from GATE to V_S .

Typical Operating Characteristics

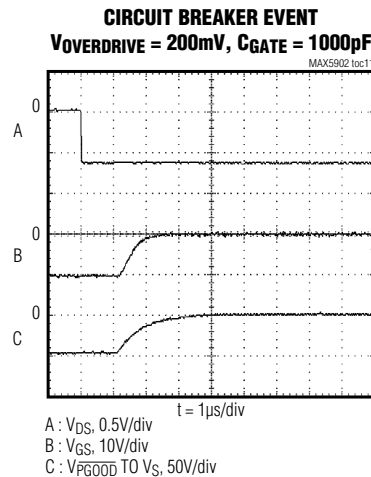
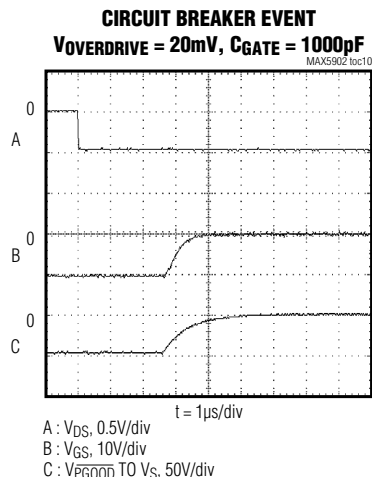
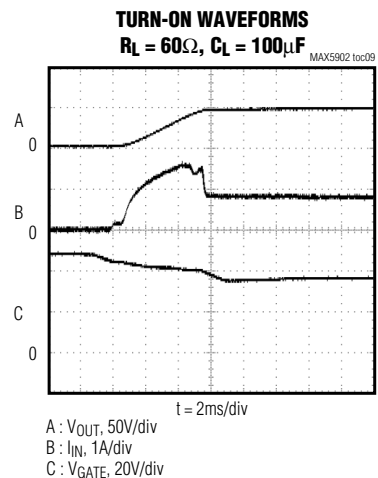
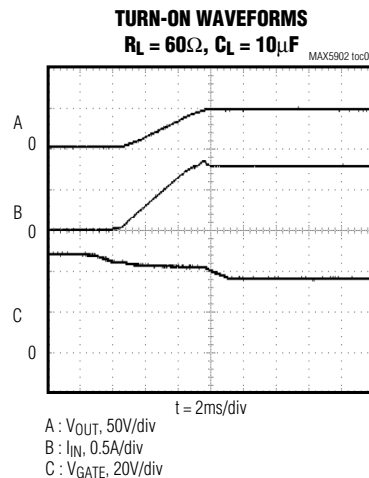
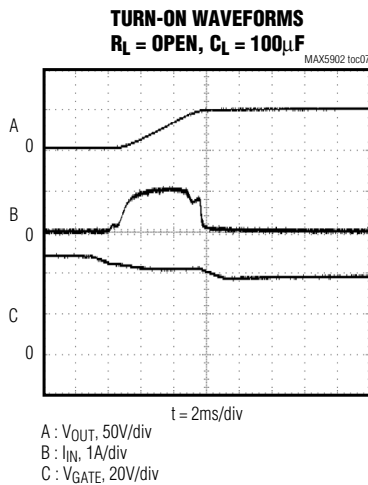
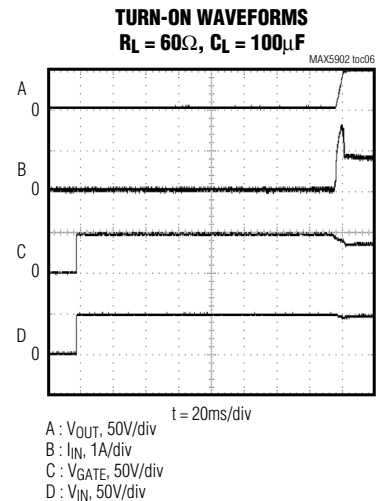
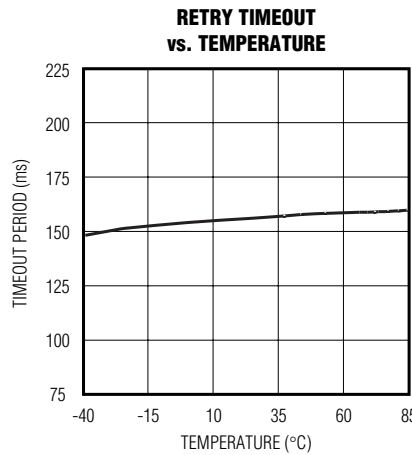
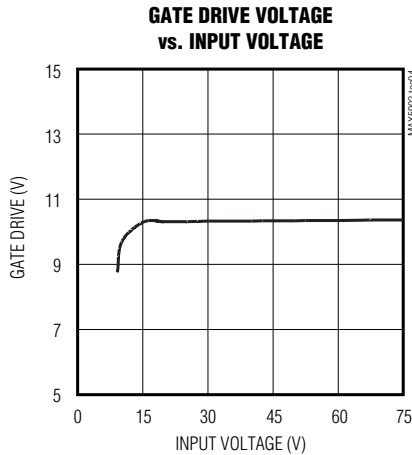
($V_S = +48V$, $GND = 0$, and $T_A = +25^\circ C$, unless otherwise noted. See Figure 2 for test circuits.)



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Typical Operating Characteristics (continued)

($V_S = +48V$, $GND = 0$, and $T_A = +25^\circ C$, unless otherwise noted. See Figure 2 for test circuits.)



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necting the load immediately. If no circuit breaker fault exists, the MAX5902/MAX5903 assert the power-good output. Then, if any of four conditions exist, the power good output deasserts and the MAX5902/MAX5903 turn off the MOSFET. The four conditions are: the voltage across the MOSFET exceeds the circuit breaker threshold; the supply voltage falls below the undervoltage lockout level; the die temperature exceeds +125°C; or ON/OFF is forced low. After a circuit breaker fault, the MAX5902L/MAX5903L keep the MOSFET off until the power is cycled, or the part is reset by toggling ON/OFF low for 10ms (typ). After a circuit breaker fault, the MAX5902A/MAX5903A automatically restarts in 150ms (typ). All versions automatically restart after a

thermal fault, or an undervoltage shutdown, if the fault condition goes away for at least 150ms (typ).

ON/OFF offers external control of the MAX5902/MAX5903, facilitating power-supply sequencing, and may also be used to change the undervoltage lockout (UVL) level. UVLO keeps the external MOSFET switched off as long as the input voltage is below the desired level.

A power good output, PGOOD (MAX5902) or PGOOD (MAX5903), asserts when the external MOSFET is fully enhanced and the source-drain voltage is below the circuit breaker threshold. PGOOD and PGOOD are open-drain outputs referenced to GND, and can withstand up to +72V.

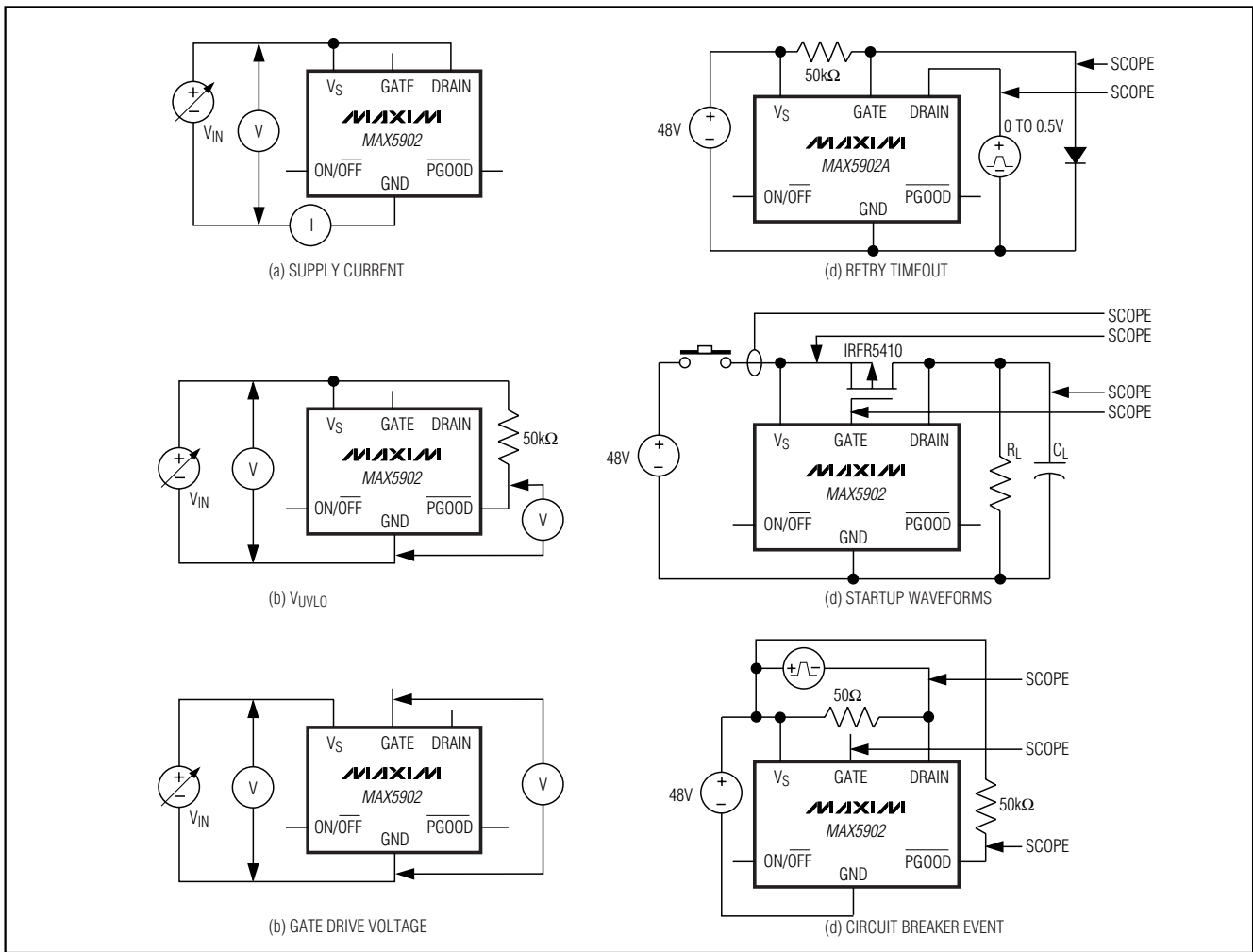


Figure 2. Test Circuits

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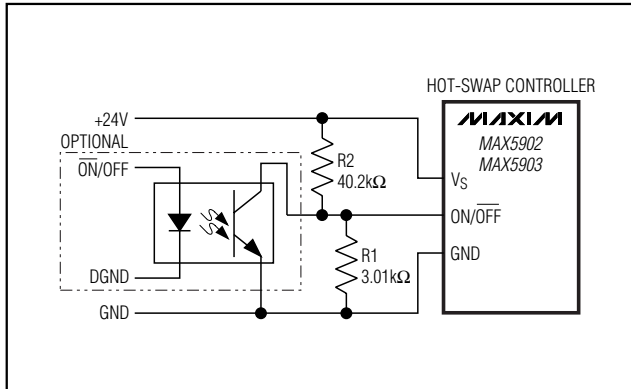


Figure 3. Programmed +18V Lockout, with Optional Optocoupler On/Off Control.

A thermal shutdown feature protects the external MOSFET by turning it off if the die temperature of the MAX5902/MAX5903 exceeds +125°C. The MAX5902/MAX5903 must be in good thermal contact with the external MOSFET. See *Layout Guidelines* in the *Applications* section of the data sheet.

A circuit breaker function monitors the voltage across the external MOSFET, V_{SD} , and turns off the MOSFET if V_{SD} exceeds the circuit breaker threshold, V_{CB} . The circuit breaker function is enabled after the MOSFET is fully enhanced. Three threshold voltage options are available—300mV, 400mV, and 500mV. One version is available with no circuit breaker function. Fault management for the MAX5902/MAX5903 is offered with two different configurations; latched and automatic retry.

Latched Circuit Breaker

After a circuit breaker trip event the latched versions (MAX5902L/MAX5903L) drive GATE to V_S , turning off the external MOSFET, and PGOOD (PGOOD) is deasserted. A latched off condition needs to be reset by toggling ON/OFF low for at least 10ms, or by cycling the power supply, V_S .

Automatic Retry Circuit Breaker

After a circuit breaker trip event the automatic retry versions (MAX5902A/MAX5903A) drive GATE to V_S , turning off the external MOSFET, and PGOOD (PGOOD) is deasserted. If the start conditions are met for a full 150ms (t_{RS}) the start sequence is re-initiated. The start conditions are: the device is not in UVLO; ON/OFF is not driven low; and the device is not in thermal shutdown.

No Circuit Breaker

For the versions without a circuit breaker, MAX5902N (MAX5903N), PGOOD (PGOOD) are asserted when the MOSFET is fully enhanced. Once powered up the MAX5902N/MAX5903N ignore the MOSFET drain-to-source voltage for applications where a circuit breaker function is not desired.

Applications Information

ON/OFF Control Input

The ON/OFF control input provides three functions: external ON/OFF control; setting of the UVLO level; and resetting after a circuit breaker event has caused the MAX5902L/MAX5903L to turn off the external MOSFET. Pulling ON/OFF to GND for at least 10ms (t_{OFF}) forces the MAX5902/MAX5903 to turn off the external MOSFET (see Figure 3 for a circuit example). To reset the MAX5902L/MAX5903L after a circuit breaker event, toggle ON/OFF to GND for at least 10ms (t_{OFF}).

ON/OFF can be used to sequence power supplies. Connecting a capacitor from ON/OFF to GND will delay the rise of ON/OFF proportional to the capacitance and input impedance of ON/OFF, typically 33kΩ (Figure 4).

The MAX5902/MAX5903 can be controlled by logic level signals. Logic level signals of 3.3V or 1.8V may be directly connected to ON/OFF. For 5V logic level control, insert a series 47kΩ resistor as shown in Figure 5.

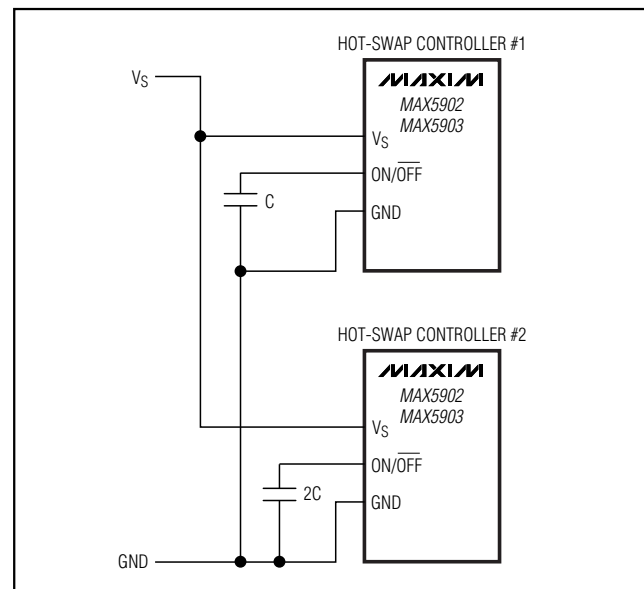


Figure 4. Power-Supply Sequencing

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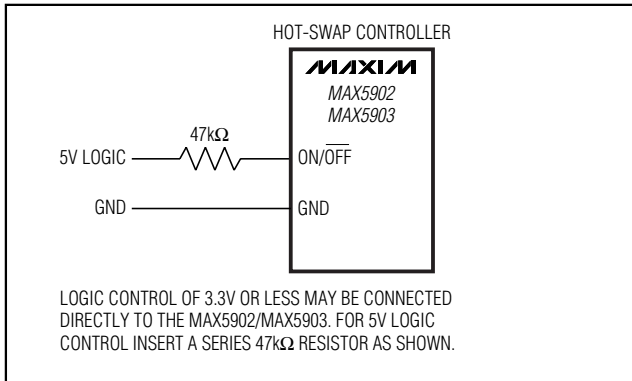


Figure 5. Logic Control

Turn-On and Turn-Off Delays

After power is applied, or ON/OFF is released, there is a 150ms delay (t_{ON}) before the gate ramp is started. This delay is also the automatic restart time delay.

In the event of a circuit breaker condition or an over-temperature fault condition, the turn-off delay is less than 4μs. An undervoltage condition must exist for at least 10ms (t_{OFF}) before the MAX5902/MAX5903 turns off the external MOSFET. ON/OFF must be held low for at least 10ms (t_{OFF}) before the MAX5902/MAX5903 turns off the external MOSFET. Turn-off delay minimizes spurious shutdowns due to noisy signals or momentary voltage spikes, as well as preventing accidental resetting of the circuit breaker latch (MAX5902L/MAX5903L).

Thermal Shutdown

A thermal shutdown feature helps protect the external MOSFET. If the die temperature of the MAX5902/MAX5903 exceeds +125°C, the MOSFET is turned off. For accurate performance the MAX5902/MAX5903 must be in close thermal contact with the external MOSFET. See *Layout Guidelines* for information. Due to the low power dissipation of the MAX5902/MAX5903, its junction temperature will typically be within a few degrees of the MOSFET. All versions of the MAX5902/MAX5903 automatically restart from a temperature fault when the junction temperature drops below +110°C.

Undervoltage Lockout

The MAX5902/MAX5903 turns off the external MOSFET if the magnitude of the input voltage is below the level set by ON/OFF for longer than 10ms (t_{OFF}). If ON/OFF is left unconnected, the lockout voltage (V_{UVLO}) defaults to 31.5V. V_{UVLO} may also be set to any value within the power-supply range by using external resis-

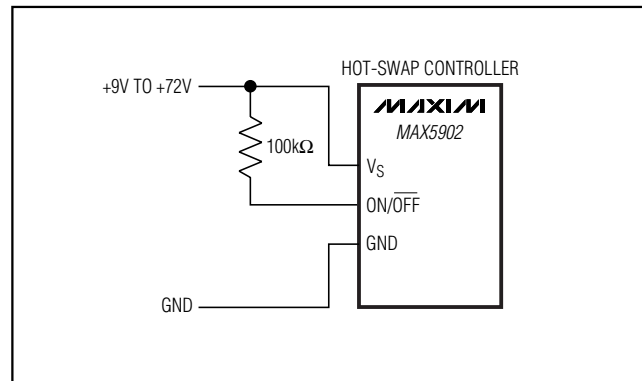


Figure 6. Defeating Undervoltage Lockout

tors. To set the lockout voltage to a value between +9V and +72V use a resistor divider connected between V_S and GND, with the center node of the divider connected to ON/OFF. For example, use a 3kΩ resistor (R1 in Figure 3) from ON/OFF to GND and calculate the other resistor, R2, using:

$$R2 = R1 \times \left(\frac{V_{UVLO}}{V_{ON/OFF}} - 1 \right)$$

where V_{UVLO} is the desired lockout voltage, and $V_{ON/OFF}$ is the ON/OFF reference threshold specified in the *Electrical Characteristics* table (typically 1.26V).

Figure 3 shows an example circuit with V_{UVLO} set for +18V. To defeat the UVLO simply connect a single 100kΩ resistor between ON/OFF and V_S , as shown in Figure 6.

The Power Good Output

The power good output, \overline{PGOOD} (PGOOD), is open-drain and asserts when the external MOSFET is fully enhanced and V_{SD} is less than the circuit breaker threshold (V_{CB}). For versions without the circuit breaker function (MAX5902N/MAX5903N), \overline{PGOOD} (PGOOD) asserts when the external MOSFET is fully enhanced.

\overline{PGOOD} (PGOOD) deasserts within 4μs when a circuit breaker event occurs or if the die temperature exceeds +125°C. \overline{PGOOD} (PGOOD) deasserts if $V_S < V_{UVLO}$ for longer than 10ms or ON/OFF is held low for longer than 10ms.

The MAX5902 \overline{PGOOD} is active-low and the MAX5903 PGOOD is active-high. Both are open-drain N-channel MOSFETs with their sources connected to GND, and can withstand up to +72V.

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Selecting a Circuit Breaker Threshold

The MAX5902A/MAX5903A and the MAX5902L/MAX5903L offer a circuit breaker function to protect the external MOSFET and the load from the potentially damaging effects of excessive current. As load current flows through the external MOSFET, a voltage, V_{SD} , is generated from source to drain due to the MOSFET's on-resistance, $R_{DS(ON)}$. The MAX5902A/MAX5903A and MAX5902L/MAX5903L monitor V_{SD} when the external MOSFET is fully enhanced. If V_{SD} exceeds the circuit breaker threshold the external MOSFET is turned off, and PGOOD (PGOOD) is deasserted. To accommodate different MOSFETs and different load currents the MAX5902/MAX5903 are available with circuit breaker threshold voltages of 300mV, 400mV, and 500mV. To determine the proper circuit breaker threshold for an application use:

$$V_{CB} > (R_{DS(ON)}) \times (I_{OUT(MAX)})$$

where $R_{DS(ON)}$ is the on-resistance of the MOSFET and $I_{OUT(MAX)}$ is the maximum expected output current.

The MAX5902N/MAX5903N have no circuit breaker function. For these parts choose an external MOSFET which meets the load requirements.

The circuit breaker function is intended to protect against gross overcurrent or short-circuit conditions. During a gross overcurrent or short-circuit condition, the MAX5902/MAX5903 disconnect the load by disabling the external MOSFET. For calculating the circuit breaker threshold use the MOSFET's R_{ON} at the worst possible operating condition, and add a 20% overcurrent margin to the maximum circuit current. For instance, if a MOSFET has an R_{ON} of 0.06Ω at $T_A = +25^\circ\text{C}$, and a normalized on-resistance factor of 1.75 at $T_A = +130^\circ\text{C}$ (from the MOSFET data sheet), the R_{ON} used for calculation is the product of these two numbers, or $(0.06\Omega) \times (1.75) = 0.105\Omega$. Then, if the maximum current is expected to be 2A, using a 20% margin, the current for calculation is $(2A) \times (1.2) = 2.4A$. The resulting minimum circuit breaker threshold is then a product of these two results, or $(0.105\Omega) \times (2.4A) = 0.252V$. The next highest minimum available threshold is 0.280V of the MAX5902ABEUT, which is an ideal choice given these parameters. Using this method to choose a circuit breaker threshold allows the circuit to operate under worst case conditions without causing a circuit breaker fault, but the circuit breaker function will still operate if a short circuit, or a gross overcurrent condition exists.

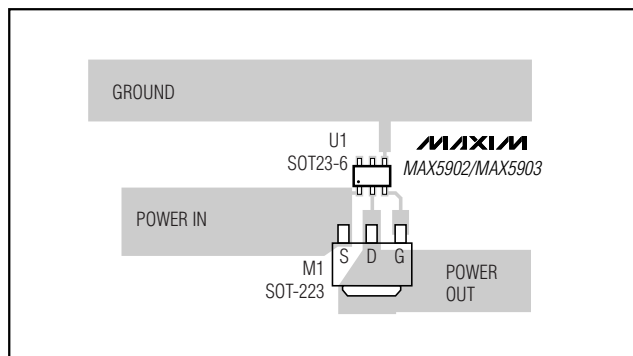


Figure 7. Circuit Board Layout Example.

Determining Inrush Current

Determining a circuit's inrush current is necessary to help choose the proper MOSFET. The MAX5902/MAX5903 regulate the inrush current by means of controlling the load voltage slew rate, but inrush current is also a function of load capacitance. Determine inrush current using:

$$I = C \frac{dV}{dt} = C \times SR$$

where C is the load capacitance, and SR is the MAX5902/MAX5903 Load Voltage Slew Rate Magnitude from the *Electrical Characteristics* table. For example, assuming a load capacitance of $100\mu\text{F}$, and using the typical value of $9V/ms$ for the slew rate, the inrush current is 0.9A typical.

If the maximum possible Load Voltage Slew Rate is used, the maximum inrush current calculates to 1.8A. Choose a MOSFET with a maximum pulsed current specification that exceeds the maximum inrush current.

Suggested External MOSFETs

MAXIMUM LOAD (A)	SUGGESTED EXTERNAL MOSFET	SUGGESTED MAXIM PART
0.5	IRF9540NS	MAX5902AAEUT
1	IRF9540NS	MAX5902ABEUT
2	IRF5210S	MAX5902ABEUT
3	IRF5210S	MAX5902ACEUT

$V_{IN} = +9V \text{ to } +72V$

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Layout Guidelines

Good thermal contact between the MAX5902/MAX5903 and the external MOSFET is essential for the thermal shutdown feature to operate effectively. Place the MAX5902/MAX5903 as close as possible to the drain of the external MOSFET, and use wide circuit board traces for good heat transfer. See Figure 7 for an example of a PC board layout.

Chip Information

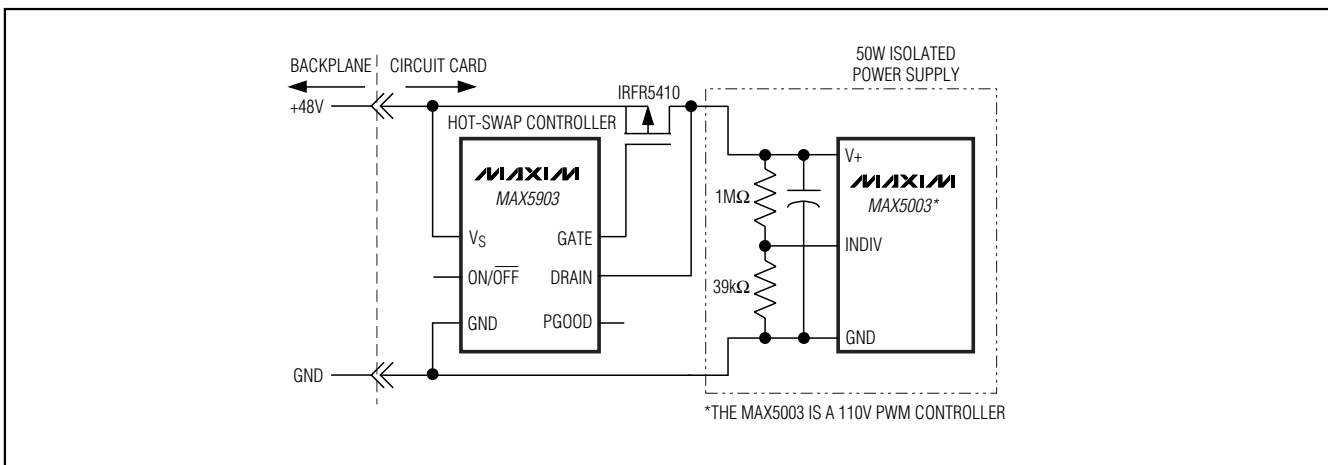
TRANSISTOR COUNT: 658
PROCESS TECHNOLOGY: BiCMOS

Selector Guide

PART	CIRCUIT BREAKER FUNCTION	CIRCUIT BREAKER THRESHOLD	POWER GOOD OUTPUT LOGIC	TOP MARK
MAX5902NNEUT*	None	None	Active-Low	AASM
MAX5902AAEUT*	Auto Retry	300mV	Active-Low	AASA
MAX5902ABEUT*	Auto Retry	400mV	Active-Low	AASB
MAX5902ACEUT*	Auto Retry	500mV	Active-Low	AASC
MAX5902LAEUT*	Latched	300mV	Active-Low	AASD
MAX5902LBEUT*	Latched	400mV	Active-Low	AASE
MAX5902LCEUT*	Latched	500mV	Active-Low	AASF
MAX5903NNEUT*	None	None	Active-High	AASN
MAX5903AAEUT*	Auto Retry	300mV	Active-High	AASG
MAX5903ABEUT*	Auto Retry	400mV	Active-High	AASH
MAX5903ACEUT*	Auto Retry	500mV	Active-High	AASI
MAX5903LAEUT*	Latched	300mV	Active-High	AASJ
MAX5903LBEUT*	Latched	400mV	Active-High	AASK
MAX5903LCEUT*	Latched	500mV	Active-High	AASL

*Requires special solder temperature profile described in the Absolute Maximum Ratings section.

Typical Operating Circuits (continued)



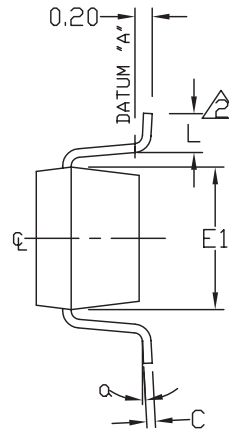
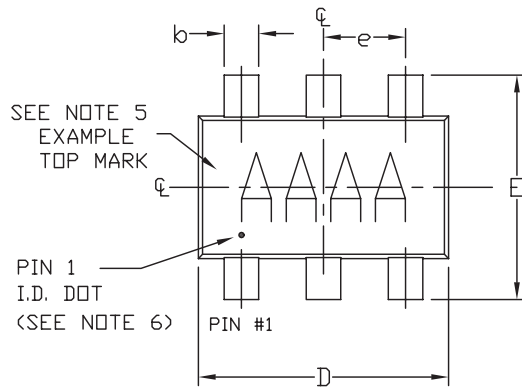
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Package Information

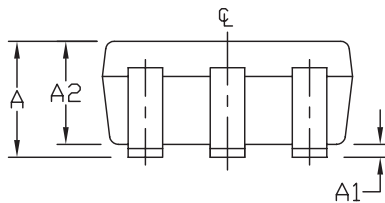
(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information go to www.maxim-ic.com/packages.)

MAX5902/MAX5903

6LSOT1EPS



SYMBOL	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
b	0.35	0.50
C	0.08	0.20
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.75
L	0.35	0.55
e	0.95 REF	
α	0°	10°



NOTES:

- ALL DIMENSIONS ARE IN MILLIMETERS.
- FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM A & LEAD SURFACE.
- PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.
- PACKAGE OUTLINE INCLUSIVE OF SOLDER PLATING.
- PIN 1 IS LOWER LEFT PIN WHEN READING TOP MARK FROM LEFT TO RIGHT. (SEE EXAMPLE TOP MARK)
- PIN 1 I.D. DOT IS 0.3 MM ϕ MIN. LOCATED ABOVE PIN 1.
- MEETS JEDEC MO178.

MAXIM			
PROPRIETARY INFORMATION			
TITLE:			
PACKAGE OUTLINE, SOT-23, 6L			
APPROVAL	DOCUMENT CONTROL NO.	REV	1/1
	21-0058	E	

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Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600 11