



# Dual FireWire Current Limiter and Low-Drop ORing Switch Controller

**MAX5944**

## General Description

The MAX5944 is a dual, current limiter/low-drop ORing, switch controller power-management IC for FireWire® applications. Each independent channel controls two external power MOSFETs to regulate current from the input power supply to the load and performs low-voltage-drop power-supply ORing. The MAX5944 operates over the 7.5V to 37V input range and provides inrush and output current limit in addition to diode ORing functions suitable for FireWire applications.

The MAX5944 allows the safe insertion and removal of FireWire peripherals into a live FireWire port by providing inrush current control and output current-limiting functions. The MAX5944 features a current-limit function that actively limits the current drawn by the load with a 2ms timeout. Its autoretry function then automatically restarts after the 259ms autoretry delay time.

The ORing feature provides a very efficient way to protect the FireWire port when connected to another FireWire peripheral that sources a higher voltage. By turning off the external MOSFETs, the MAX5944 provides a true bidirectional load disconnect. Each channel has an independent ON/OFF control that results in less than 10µA supply current per channel.

The MAX5944 operates over the -40°C to +85°C extended temperature range and is available in a 16-pin SO package.

## Applications

FireWire Desktop/Notebook Port  
FireWire Peripheral Device Current Limit  
FireWire Hub  
Hot Swap

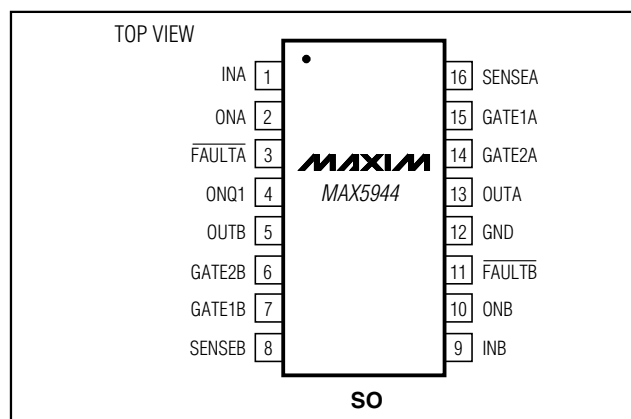
## Features

- ◆ Provides Safe Hot-Swap for 7.5V to 37V Power Supplies
- ◆ Dual-Channel Hot-Swap
- ◆ Low-Drop Power ORing with Ultra-Fast Turn-Off
- ◆ Active Current Limit
- ◆ ±5% Current-Limit Sensing Accuracy
- ◆ 2ms Current-Limit Timeout
- ◆ Fast Current-Limit Response to Output Short-Circuit Conditions
- ◆ Drives External n-Channel Power MOSFETs
- ◆ Independent Overcurrent Fault Status Outputs
- ◆ 259ms Autoretry Period
- ◆ 10µA (Per Channel) Shutdown Current
- ◆ Independent ON/OFF Control Allows Undervoltage Lockout Programming
- ◆ Fast Load Disconnect Control Through ON/OFF Inputs
- ◆ Bidirectional Load Disconnect
- ◆ Power Routing from One Port to Another

## Ordering Information

| PART       | TEMP RANGE     | PIN-PACKAGE |
|------------|----------------|-------------|
| MAX5944ESE | -40°C to +85°C | 16 SO       |

## Pin Configuration



**Typical Operating Circuit appears at end of data sheet.**

FireWire is a registered trademark of Apple Computer, Inc.



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## ABSOLUTE MAXIMUM RATINGS

(Voltages referenced to GND, unless otherwise noted.)

|                  |                    |
|------------------|--------------------|
| IN_              | .....-0.3V to +80V |
| OUT_             | .....-0.3V to +80V |
| SENSE_ to IN_    | .....-1V to +0.3V  |
| GATE1_ to SENSE_ | .....-0.3V to +8V  |
| GATE2_ to OUT_   | .....-0.3V to +8V  |
| FAULT_           | .....-0.3V to +85V |
| ON_ONQ1          | .....-0.3V to +85V |

Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )

16-Pin SO (derate 9.1mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ).....728mW

Operating Temperature Range ..... $-40^\circ\text{C}$  to  $+85^\circ\text{C}$

Maximum Junction Temperature ..... $+150^\circ\text{C}$

Storage Temperature Range ..... $-60^\circ\text{C}$  to  $+150^\circ\text{C}$

ESD Rating (Human Body Model).....2000V

Lead Temperature (soldering, 10s) ..... $+300^\circ\text{C}$

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

( $V_{IN} = 7.5\text{V}$  to  $37\text{V}$ ,  $\text{GND} = 0\text{V}$ , and  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted. Typical values are at  $V_{IN} = 12\text{V}$ ,  $T_A = +25^\circ\text{C}$ .) (Note 1)

| PARAMETER                                              | SYMBOL              | CONDITIONS                                                                                                         |                             | MIN  | TYP  | MAX   | UNITS |
|--------------------------------------------------------|---------------------|--------------------------------------------------------------------------------------------------------------------|-----------------------------|------|------|-------|-------|
| SUPPLIES                                               |                     |                                                                                                                    |                             |      |      |       |       |
| Supply Voltage Range                                   | V <sub>IN_</sub>    |                                                                                                                    |                             | 7.5  |      | 37    | V     |
| Supply Current                                         | I <sub>IN</sub>     | V <sub>ON_</sub> = 3V, no load, per channel                                                                        |                             |      | 1.3  | 2.3   | mA    |
| Shutdown Current                                       | I <sub>SD</sub>     | V <sub>ON_</sub> = 0.4V, per channel                                                                               |                             |      | 5    | 10    | μA    |
| IN_ Default Undervoltage Lockout                       | V <sub>UVLO</sub>   | V <sub>IN_</sub> rising, ON_ = IN_                                                                                 |                             | 6.2  | 6.5  | 6.8   | V     |
| IN_ Default Undervoltage-Lockout Hysteresis            |                     |                                                                                                                    |                             |      | 0.35 |       | V     |
| ON_ Undervoltage-Lockout Threshold                     | V <sub>ON_REF</sub> | V <sub>ON_</sub> rising                                                                                            |                             | 1.20 | 1.24 | 1.275 | V     |
| ON_ Undervoltage-Lockout-Threshold Hysteresis          |                     |                                                                                                                    |                             |      | 70   |       | mV    |
| ON_ Input Bias Current                                 | I <sub>ON</sub>     |                                                                                                                    |                             |      |      | 1     | μA    |
| GATE2_ (Current-Limit Control)                         |                     |                                                                                                                    |                             |      |      |       |       |
| GATE2_ Pullup Current (Note 2)                         | I <sub>G2U</sub>    |                                                                                                                    |                             | 36   | 45   | 54    | μA    |
| GATE2_ High Voltage                                    | V <sub>G2</sub>     | V <sub>GATE2_</sub> - V <sub>OUT_</sub>                                                                            | 7.5V ≤ V <sub>IN</sub> ≤ 8V | 4.25 | 5.5  | 6.50  | V     |
|                                                        |                     |                                                                                                                    | 8V ≤ V <sub>IN</sub> ≤ 37V  | 4.5  | 5.5  | 6.5   |       |
| Current-Limit Threshold Voltage                        | V <sub>TH</sub>     | V <sub>IN_</sub> - V <sub>SENSE_</sub>                                                                             |                             | 47.5 | 50   | 52.5  | mV    |
| Fast Pulldown Current-Limit Threshold Voltage (Note 3) | V <sub>THF</sub>    | V <sub>IN_</sub> - V <sub>SENSE_</sub>                                                                             |                             | 70   | 75   | 80    | mV    |
| GATE2_ Pulldown Current                                | I <sub>G2D</sub>    | V <sub>TH</sub> < (V <sub>IN_</sub> - V <sub>SENSE_</sub> ) < V <sub>THF</sub>                                     |                             | 335  | 435  | 535   | μA    |
| GATE2_ Fast Pulldown Current (Note 3)                  | I <sub>G2DF</sub>   | (V <sub>IN_</sub> - V <sub>SENSE_</sub> ) > V <sub>THF</sub> ,<br>V <sub>GATE2_</sub> = (V <sub>OUT_</sub> + 4.5V) |                             | 80   | 125  | 200   | mA    |

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## ELECTRICAL CHARACTERISTICS (continued)

( $V_{IN}$  = 7.5V to 37V, GND = 0V, and  $T_A$  = -40°C to +85°C, unless otherwise noted. Typical values are at  $V_{IN}$  = 12V,  $T_A$  = +25°C.) (Note 1)

| PARAMETER                                                             | SYMBOL | CONDITIONS                                                     |                 | MIN  | TYP | MAX  | UNITS |   |
|-----------------------------------------------------------------------|--------|----------------------------------------------------------------|-----------------|------|-----|------|-------|---|
| GATE2_ Peak Pulldown Current                                          | IG2DP  | (VIN_ - VSENSE_) = 1V                                          |                 | 1.0  |     |      | A     |   |
| GATE2_ Pulldown Current During Any GATE2_ Turn-Off Condition (Note 4) | IG2OFF | VGATE2_ = (VOUT_ + 4.5V)                                       |                 | 80   | 125 | 200  | mA    |   |
| GATE1_ (ORing Control)                                                |        |                                                                |                 |      |     |      |       |   |
| ORing Switch Turn-On-Current Threshold Voltage                        | VOR    | (VIN_ - VSENSE_) rising                                        |                 | 3    | 5   | 7    | mV    |   |
| ORing Switch Turn-On-Current Threshold Voltage Hysteresis             |        | (VIN_ - VSENSE_) falling                                       |                 | 0.5  |     |      | mV    |   |
| GATE1_ Pullup Current (Note 5)                                        | IG1U   |                                                                |                 | 36   | 45  | 54   | μA    |   |
| GATE1_ High Voltage                                                   | VG1    | VGATE_ - VSENSE_                                               | 7.5V ≤ VIN ≤ 8V | 4.25 | 5.5 | 6.50 | V     |   |
|                                                                       |        |                                                                | 8V ≤ VIN ≤ 37V  | 4.5  | 5.5 | 6.5  |       |   |
| GATE1_ Turn-Off Switch On-Resistance                                  | RG1PD  | Measured between GATE1_ and SENSE_ when (VIN_ - VSENSE_) < VOR |                 | 2    |     |      | 3     | Ω |
| LOGIC INPUTS                                                          |        |                                                                |                 |      |     |      |       |   |
| ONQ1 Input-Logic Low Voltage                                          | VIL    | VON_ > VON_REF                                                 |                 | 0.7  |     |      | V     |   |
| ONQ1 Input-Logic High Voltage                                         | VIH    | VON_ > VON_REF                                                 |                 | 1.8  |     |      | V     |   |
| ONQ1 Input Current                                                    | IIH    |                                                                |                 | 1    |     |      | μA    |   |
| FAULT_ Output Low Voltage                                             | VOL    | Low-impedance state, IFAULT_ = 5mA                             |                 | 0.12 |     |      | 0.25  | V |
| FAULT_ Output High Leakage Current                                    | IOH    | High-impedance state, VFAULT_ = 37V                            |                 | 1    |     |      | μA    |   |
| OUT_ Input Current                                                    | IOUT   | VON_ = GND                                                     |                 | 1    |     |      | μA    |   |

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## ELECTRICAL CHARACTERISTICS (continued)

( $V_{IN} = 7.5V$  to  $37V$ ,  $GND = 0V$ , and  $T_A = -40^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values are at  $V_{IN} = 12V$ ,  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                                                    | SYMBOL        | CONDITIONS                                                                                                                         | MIN  | TYP  | MAX  | UNITS   |
|--------------------------------------------------------------|---------------|------------------------------------------------------------------------------------------------------------------------------------|------|------|------|---------|
| <b>TIMING</b>                                                |               |                                                                                                                                    |      |      |      |         |
| Current-Limit Timeout                                        | $t_{LIM}$     | Current-limit mode                                                                                                                 | 1.78 | 2.02 | 2.26 | ms      |
| Automatic Restart Delay After Current-Limit Timeout (Note 7) | $t_{OFF}$     |                                                                                                                                    | 240  | 259  | 278  | ms      |
| GATE1_ Turn-Off Time (ORing Response Time)                   | $t_{OR}$      | From $V_{OR}$ trigger until ( $V_{GATE1\_} - V_{IN\_}$ ) < 1V, $C_{GATE1\_} = 10nF$                                                |      | 100  |      | ns      |
| Turn-Off Response Time (Note 7)                              | $t_{ON\_OFF}$ | Time from $V_{ON\_} < (V_{ON\_OFF} - \text{Hysteresis})$ until ( $V_{GATE2\_} - V_{OUT\_}$ ) < 1V, for $C_{GATE2\_} = \text{open}$ |      | 0.34 | 0.6  | $\mu s$ |
| Minimum Delay from ON_ Low to Low-Current Shutdown Mode      | $t_{SD}$      | ON_ step from 1.3V to 0.4V                                                                                                         |      | 50   |      | $\mu s$ |

**Note 1:** All min/max parameters are tested at  $+25^\circ C$  and  $+85^\circ C$ . Limits at  $-40^\circ C$  are guaranteed by design.

**Note 2:** Measured at both  $V_{GATE2} = V_{OUT} = 0V$  and  $V_{GATE2} = V_{OUT} = V_{IN}$ .

**Note 3:** The typical value of parameter  $V_{THF}$  is  $1.5 \times V_{TH}$ .

**Note 4:** Current-Limit Timeout.  $IN_$  or  $ON_$  low.

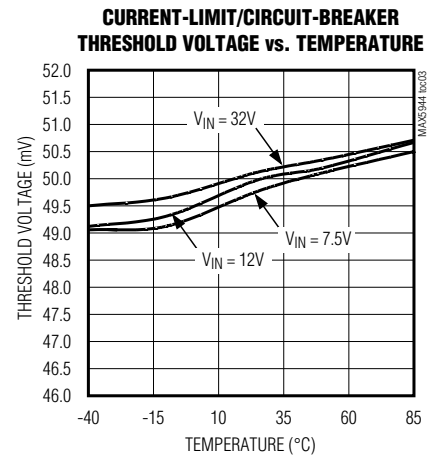
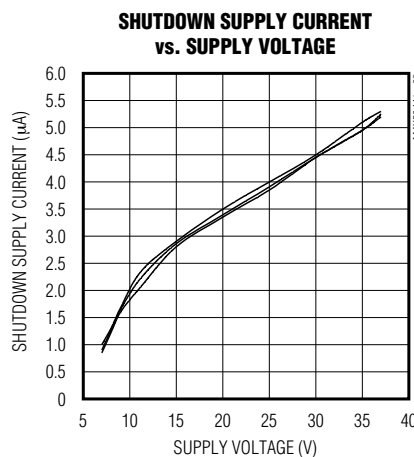
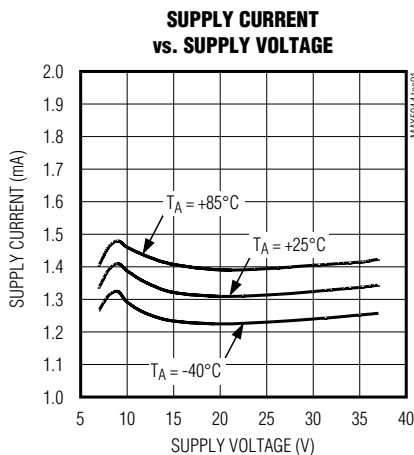
**Note 5:** See the *Typical Operating Circuit*. Measured at  $V_{GATE\_} = V_{SENSE\_}$ .

**Note 6:** The tristate ("floating") logic condition will be entered if the pin current is within these limits.

**Note 7:** If the  $ON_$  voltages go below  $V_{ON\_REF} - \text{Hysteresis}$ , then  $GATE2_$  goes low immediately to disconnect power from the load quickly (within  $t_{ON\_OFF}$ ).

## Typical Operating Characteristics

( $V_{IN} = +12V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

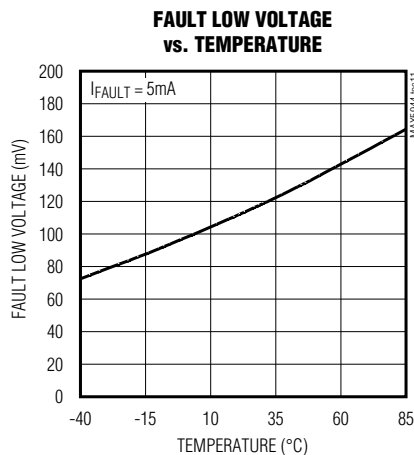
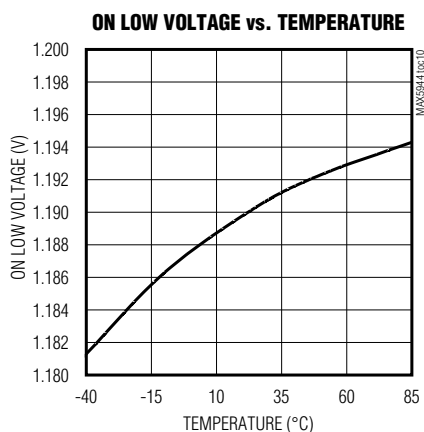
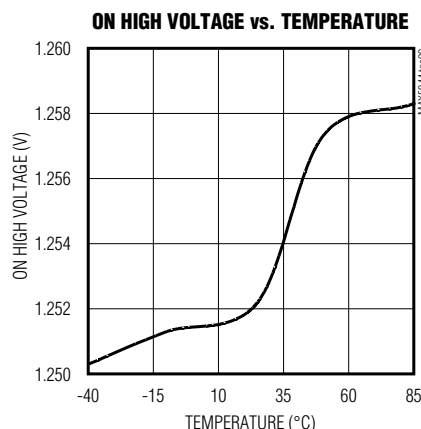
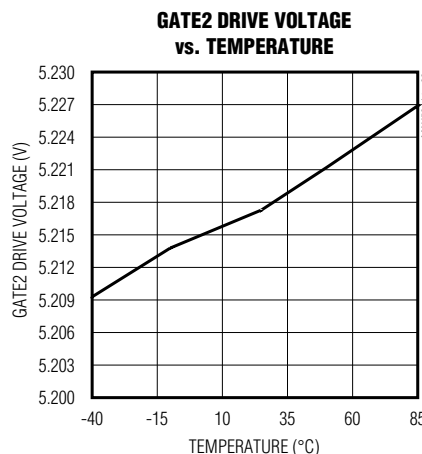
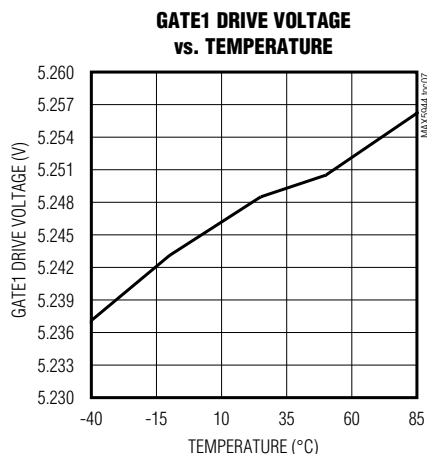
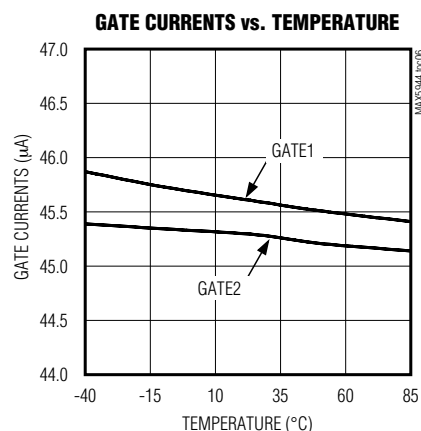
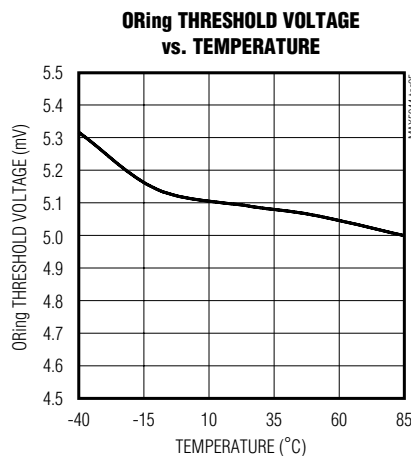
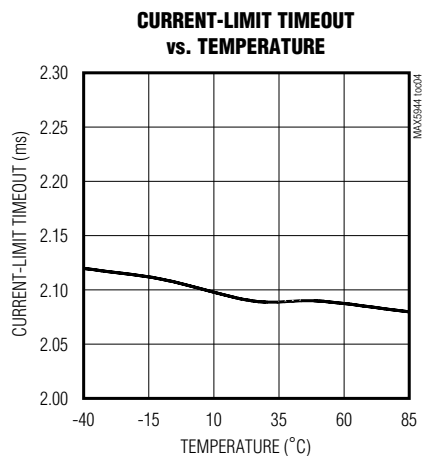


# Dual FireWire Current Limiter and Low-Drop ORing Switch Controller

MAX5944

## Typical Operating Characteristics (continued)

( $V_{IN} = +12V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

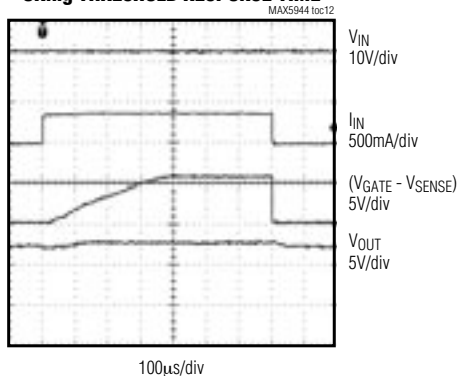


# Dual FireWire Current Limiter and Low-Drop ORing Switch Controller

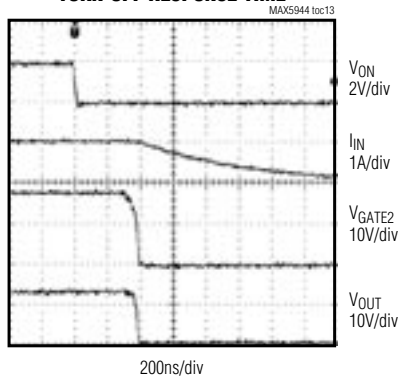
## Typical Operating Characteristics (continued)

( $V_{IN\_} = +12V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

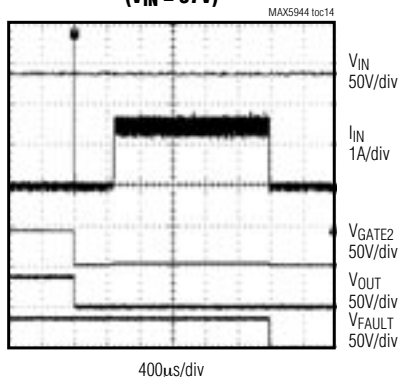
**ORing THRESHOLD RESPONSE TIME**



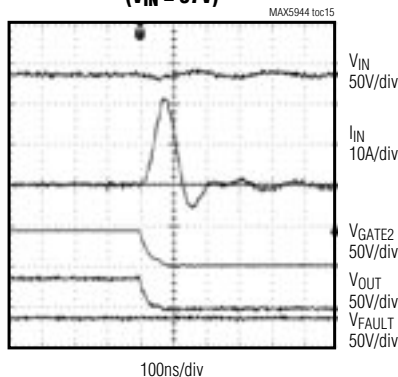
**TURN-OFF RESPONSE TIME**



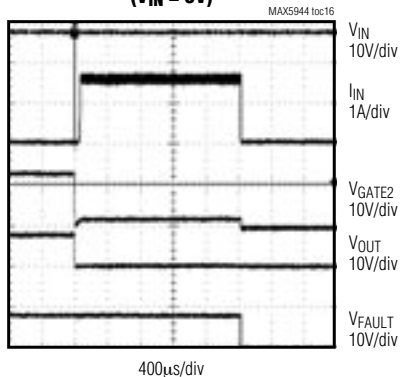
**SHORT-CIRCUIT EVENT  
( $V_{IN} = 37V$ )**



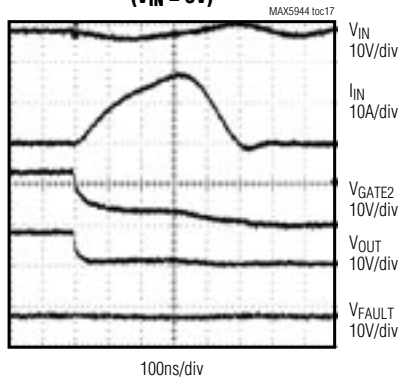
**SHORT-CIRCUIT EVENT  
( $V_{IN} = 37V$ )**



**SHORT-CIRCUIT RESPONSE  
( $V_{IN} = 8V$ )**



**SHORT-CIRCUIT RESPONSE  
( $V_{IN} = 8V$ )**



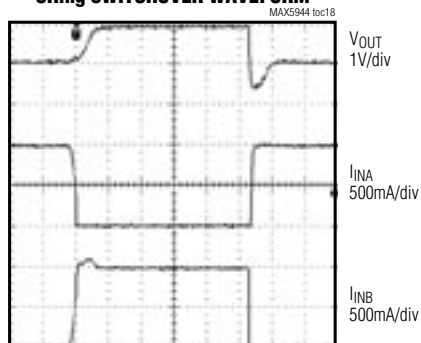
# Dual FireWire Current Limiter and Low-Drop ORing Switch Controller

MAX5944

## Typical Operating Characteristics (continued)

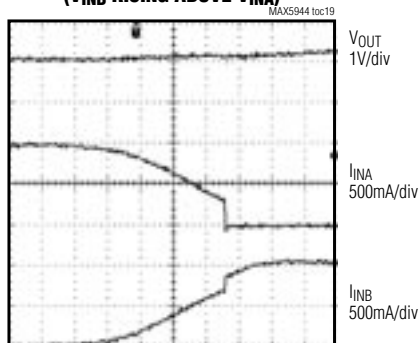
( $V_{IN-} = +12V$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted.)

**ORing SWITCHOVER WAVEFORM**



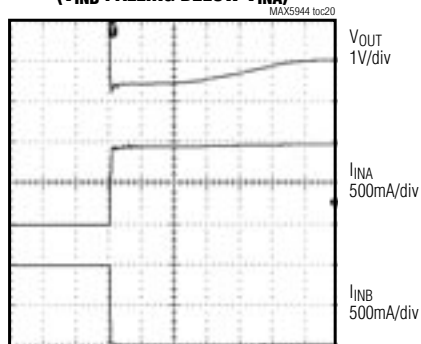
$V_{INA} = 12V$   $V_{ONB} \text{ RISING} = 12V$   
 $V_{INB} = 12.8V$   $C_{OUT} = 0$

**ORing SWITCHOVER WAVEFORM**  
( $V_{INB}$  RISING ABOVE  $V_{INA}$ )



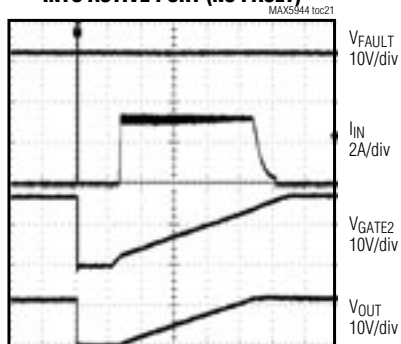
$V_{INA} = 12V$   $V_{ONB} \text{ RISING} = 12V$   
 $V_{INB} = 13V$   $C_{OUT} = 0$

**ORing SWITCHOVER WAVEFORM**  
( $V_{INB}$  FALLING BELOW  $V_{INA}$ )



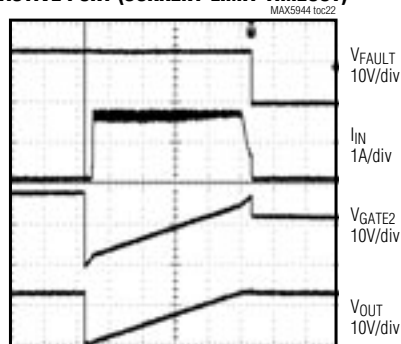
$V_{INA} = 12V$   $V_{ONB} \text{ FALLING} = 12V$   
 $V_{INB} = 13V$   $C_{OUT} = 0$

**HOT PLUG-IN LOAD CAPACITANCE**  
INTO ACTIVE PORT (NO FAULT)



$C_{LOAD} = 220\mu F$

**HOT PLUG-IN LOAD CAPACITANCE INTO**  
ACTIVE PORT (CURRENT-LIMIT TIMEOUT)



$C_{LOAD} = 470\mu F$

# Dual FireWire Current Limiter and Low-Drop ORing Switch Controller

## Pin Description

| PIN | NAME                       | FUNCTION                                                                                                                                                                                                                                                                                                                                                                       |
|-----|----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | INA                        | Channel A Input Power and Current-Sense Positive Input. Connect INA to the other end of the current-sense resistor and to the power source (see the <i>Typical Operating Circuit</i> ).                                                                                                                                                                                        |
| 2   | ONA                        | Channel A On/Off Control Input. ONA sets the undervoltage lockout threshold and resets the part after a fault latch. Drive ONA high to enable the device. Drive ON_ low to disable the device. Connect ONA to INA for the default undervoltage lockout threshold. Connect a resistor-divider from INA to ONA and to GND to program the desired undervoltage lockout threshold. |
| 3   | $\overline{\text{FAULTA}}$ | Channel A Current-Fault Status Output. $\overline{\text{FAULTA}}$ is an open-drain output. $\overline{\text{FAULTA}}$ goes low after a current-limit fault has exceeded the 2ms (typ) current-limit timeout period (see the <i>FAULT_</i> section).                                                                                                                            |
| 4   | ONQ1                       | ORing Switch Manual Turn-On Input. Drive ONQ1 low to enable power-supply ORing for channels A and B. Drive ONQ1 high to set GATE1A to GATE1B high to allow reverse-current flow. ONQ1 is disabled for the respective channel when $V_{\text{IN}}$ is below the UVLO threshold, $V_{\text{ON_}}$ is below the undervoltage lockout threshold and after a current-limit fault.   |
| 5   | OUTB                       | Channel B Output-Voltage Sense. Connect to the output.                                                                                                                                                                                                                                                                                                                         |
| 6   | GATE2B                     | Channel B Current-Limiter Switch Gate-Drive Output. Referenced to OUTB. Connect GATE2B to the gate of the 2nd n-channel MOSFET. GATE2B is a charge pump with a 50 $\mu$ A pullup current to 5.5V (typ) above OUTB when active (see the <i>Typical Operating Circuit</i> ).                                                                                                     |
| 7   | GATE1B                     | Channel B ORing Switch Gate-Drive Output. Referenced to SENSEB. Connect GATE1B to the gate of the 1st n-channel MOSFET. GATE1B is a charge pump with a 50 $\mu$ A pullup current to 5.5V (typ) above SENSEB when active (see the <i>Typical Operating Circuit</i> ).                                                                                                           |
| 8   | SENSEB                     | Channel B Current-Sense Negative Input. Connect current-sense resistor, $R_{\text{SENSE}}$ , from INB to SENSEB.                                                                                                                                                                                                                                                               |
| 9   | INB                        | Channel B Input Power and Current-Sense Positive Input. Connect INB to the other end of the current-sense resistor and to the power source.                                                                                                                                                                                                                                    |
| 10  | ONB                        | Channel B On/Off Control Input. ONB sets the undervoltage lockout threshold and resets the part after a fault latch. Drive ONB high to enable the device. Drive ON_ low to disable the device. Connect ONB to INB for the default undervoltage lockout threshold. Connect a resistor-divider from INB to ONB and to GND to program the desired undervoltage lockout threshold. |
| 11  | $\overline{\text{FAULTB}}$ | Channel B Current-Fault Status Output. $\overline{\text{FAULTB}}$ is an open-drain output. $\overline{\text{FAULTB}}$ goes low after a current-limit fault has exceeded the 2ms (typ) current-limit timeout period (see the <i>FAULT_</i> section).                                                                                                                            |
| 12  | GND                        | Ground                                                                                                                                                                                                                                                                                                                                                                         |
| 13  | OUTA                       | Channel A Output-Voltage Sense. Connect to the output.                                                                                                                                                                                                                                                                                                                         |
| 14  | GATE2A                     | Channel A Current-Limiter Switch Gate-Drive Output. Referenced to OUTA. Connect GATE2A to the gate of the 2nd n-channel MOSFET. GATE2A is a charge pump with a 50 $\mu$ A pullup current to 5.5V (typ) above OUTA when active.                                                                                                                                                 |
| 15  | GATE1A                     | Channel A ORing Switch Gate-Drive Output. Referenced to SENSEA. Connect GATE1A to the gate of the 1st n-channel MOSFET. GATE1A is a charge pump with a 50 $\mu$ A pullup current to 5.5V (typ) above SENSEA when active.                                                                                                                                                       |
| 16  | SENSEA                     | Channel A Current-Sense Negative Input. Connect current-sense resistor, $R_{\text{SENSE}}$ , from INA to SENSEA (see the <i>Typical Operating Circuit</i> ).                                                                                                                                                                                                                   |



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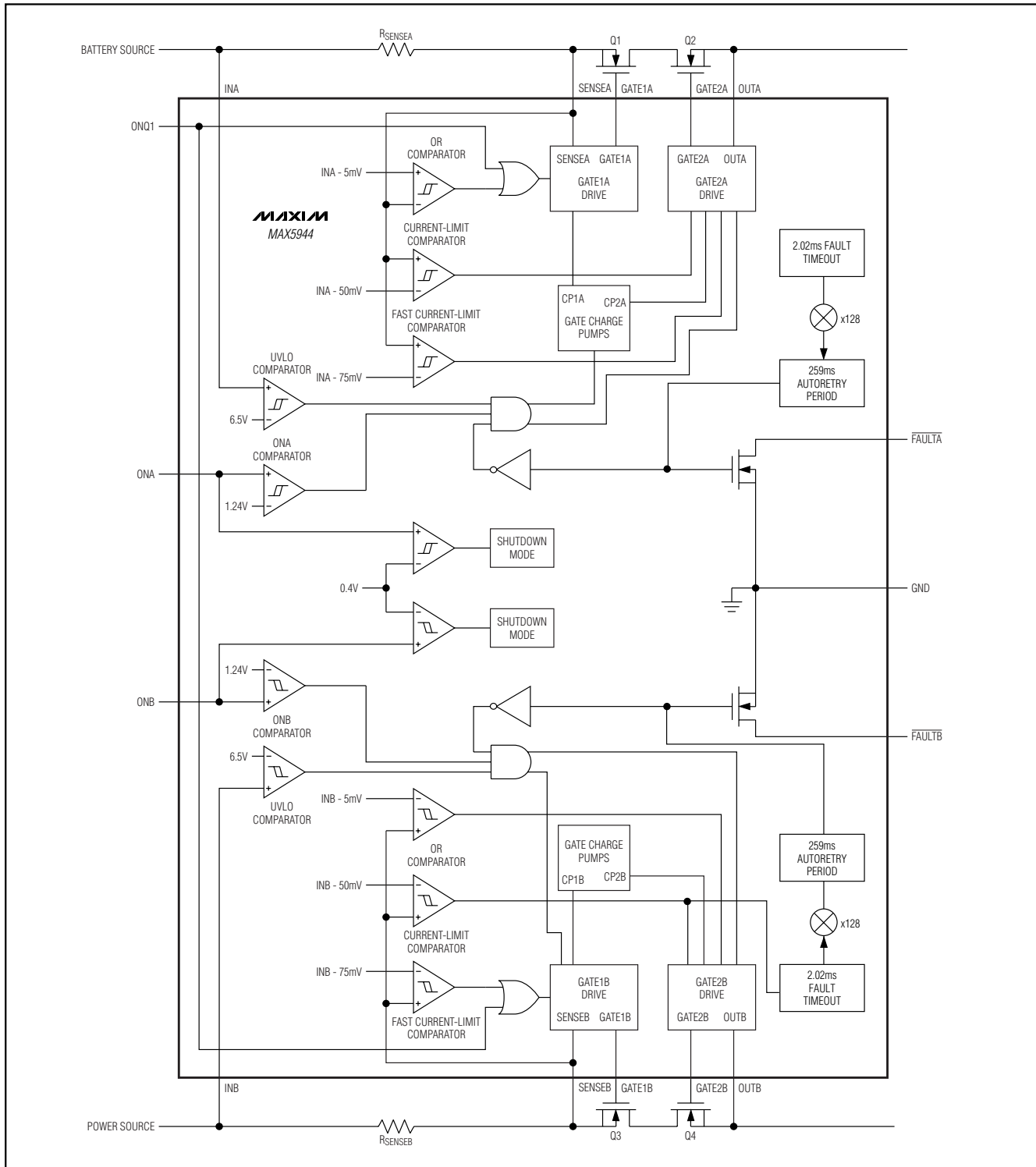


Figure 1. MAX5944 Functional Diagram

# Dual FireWire Current Limiter and Low-Drop ORing Switch Controller

## Detailed Description

The MAX5944 dual-channel controller IC performs hot-swapping, power-supply ORing, and current limiting for FireWire power-supply applications. The MAX5944 incorporates four MOSFET drivers (GATE1\_ and GATE2\_) to control external n-channel power MOSFETs to perform low-voltage-drop power-supply ORing (GATE1\_), hot-swapping, and current limiting (GATE2\_) from the input power supply to the load. A sense resistor provides accurate current limiting. GATE1\_ and GATE2\_ provide true load disconnect to prevent current flowing from either direction between IN\_ and OUT\_.

The MAX5944 independent channels remain in low-current shutdown mode when VON\_ is below the 0.4V threshold. Low-current shutdown mode disables the MAX5944 channels resulting in less than 10µA supply current per channel. Shutdown places all logic inputs in a high-impedance state, which allows the inputs to be connected to IN\_ without drawing additional current from the supply.

When either input supply voltage (VIN\_) is above 7.5V and VON\_ is above the VON\_REF threshold, the MAX5944 channel turns on, sourcing 50µA current from GATE2\_ (current regulation), to enhance Q2\_ slowly. If the voltage across the current-sense resistor, V<sub>IS</sub>, is greater than the current-limit threshold, the MAX5944 regulates the GATE2\_ voltage to limit the load current at the current-limit level so that V<sub>IS</sub> is equal to V<sub>TH</sub>. In normal operation, V<sub>IS</sub> drops below V<sub>TH</sub> and GATE2\_ rises to approximately 5.5V above OUT\_.

GATE1\_ controls the MAX5944 ORing function. Initially, GATE1\_ is off (ONQ1 = low) and the load current conducts through the body diode of Q1\_. GATE1\_ rises to 5.5V above IN\_ when V<sub>IS</sub> exceeds V<sub>OR</sub>, thereby enhancing Q1\_ and reducing the voltage drop, power dissipation, and heat generation in the power-supply pathway. When a voltage greater than VIN\_ is connected at OUT\_, the higher voltage source commences providing current to the load. The MAX5944 turns off GATE1\_ rapidly upon V<sub>IS</sub> falling below the V<sub>OR</sub> hysteresis, thus blocking the higher voltage from backdriving VIN\_. GATE1\_ also turns off when the load current drops, causing V<sub>IS</sub> to fall below V<sub>OR</sub> hysteresis.

## Current Limiting

The MAX5944 limits the load current by monitoring the voltage across RSENSE\_ at all times and regulating the current to the load as necessary to keep V<sub>IS</sub> to its current-limit threshold voltage (V<sub>TH</sub>). Set the maximum current limit (I<sub>LIMIT</sub>) by placing the appropriate sense resistor between IN\_ and SENSE\_, where  $I_{LIMIT} = V_{TH} / R_{SENSE\_}$ . When the load current is less than I<sub>LIMIT</sub>,

GATE2\_ rises to V<sub>G2</sub> (5.5V) to fully enhance MOSFET Q2\_ (see the *Typical Operating Circuit*).

When the load attempts to draw more current than I<sub>LIMIT</sub>, the MAX5944's GATE2\_ pulldown current (I<sub>G2D</sub>) regulates the current through Q2\_, causing OUT\_ to act as a constant current source. The output current is limited to I<sub>LIMIT</sub>. If the current-limit condition persists after the 2ms current-limit timeout period (t<sub>LIM</sub>) has expired, the GATE2\_ strong pulldown current (I<sub>G2OFF</sub>) quickly turns off GATE2\_ to disconnect the load from the power supply and FAULT\_ asserts low (Figure 2a). If the current-limit duration is less than t<sub>LIM</sub>, GATE2\_ pulls to V<sub>GS2</sub> (Figure 2b). During an output short circuit or a gross overload, the load current overshoots and causes V<sub>IS</sub> to exceed the fast pulldown current-limit threshold voltage (V<sub>THF</sub>). The MAX5944 responds with much stronger GATE2\_ pulldown currents (I<sub>G2DP</sub> and/or I<sub>G2DF</sub>) to quickly bring the load current back down to the programmed current limit.

## Current-Limit Threshold

The MAX5944 current limit has internal 50mV trip threshold voltages (V<sub>TH</sub>). Use the following formula to calculate the maximum current:

$$I_{LIMIT} = V_{TH} / R_{SENSE\_}$$

where V<sub>TH</sub> is the 50mV (typ) threshold voltage across RSENSE\_, and RSENSE\_ is the sense resistor connected between IN\_ and SENSE\_.

## Power-Supply ORing, GATE1\_

GATE1\_ controls the MAX5944 ORing function. The MAX5944 accomplishes a very low voltage-drop diode ORing function using n-channel power MOSFETs. Initially, GATE1\_ is off (ONQ1 = low) and the load current conducts through the body diode of Q1\_, Figure 3. GATE1\_ rises to 5.5V above SENSE\_ when V<sub>IS</sub> exceeds the 5mV V<sub>OR</sub> threshold, enhancing Q1\_. Q1\_'s low R<sub>DS(ON)</sub> provides a very low voltage drop across its source to drain, which results in less power dissipation and heat generation in the power-supply path than a traditional diode.

The MAX5944 continuously monitors the load currents through the voltage drops, V<sub>IS</sub>, across the current-sensing resistors. Q1\_ turns off rapidly when V<sub>IS</sub> decreases below the V<sub>OR</sub> minus its hysteresis.

Connect ONQ1 to GND for a normal ORing function. Drive ONQ1 high to force Q1 on, regardless of the load-current condition, as long as voltages at IN\_ and ON\_ exceed V<sub>UVLO</sub> and V<sub>ON-REF</sub>, respectively, and the device is not in a current-fault shutdown.

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MAX5944

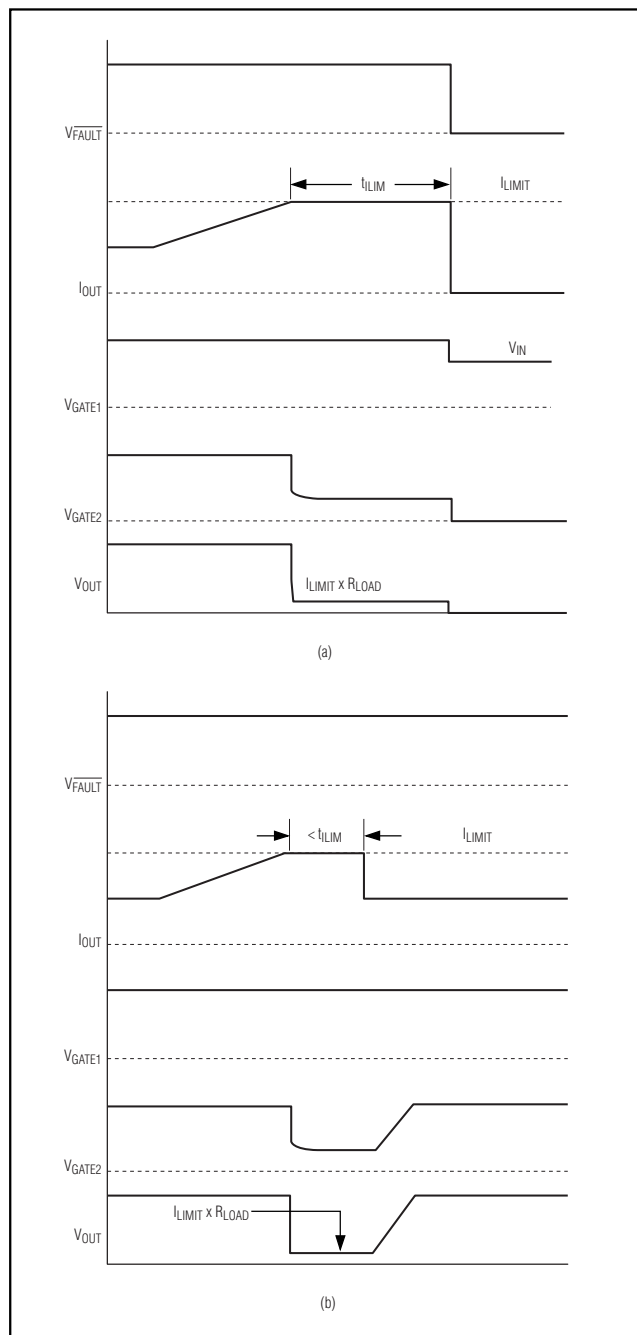


Figure 2. MAX5944 Current-Limit Timing Diagram

When a higher voltage supply is connected at OUTA (Figure 4),  $V_{IS}$  drops below the ORing threshold. The MAX5944 immediately turns off Q1A, blocking reverse-current flow from OUTA to INA. Power is then routed

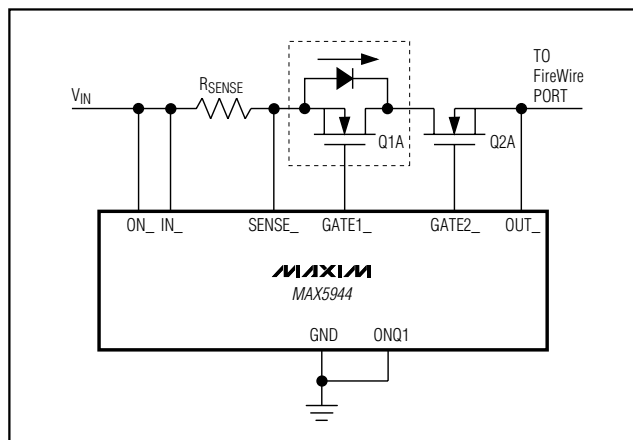


Figure 3. Q1 Current Path During Initial Startup

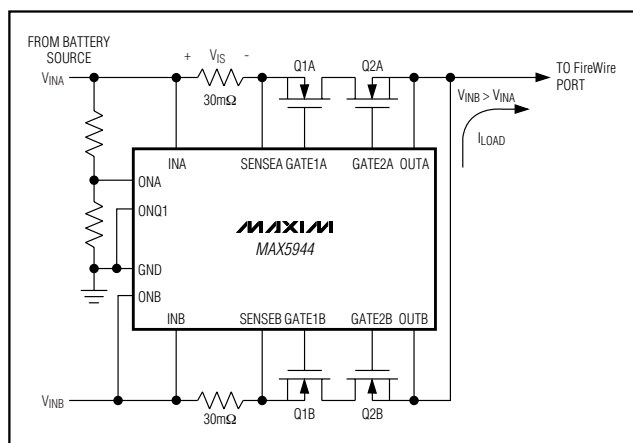


Figure 4. MAX5944 ORing Controller Rerouting Load Current

from the higher supply input (INB) to OUTB, and then to the load (Figure 5).

## Reverse-Current Override (ONQ1 = HIGH)

Drive  $ONQ1$  high to disable the MAX5944 power-supply ORing. Disabling the MAX5944 ORing function allows reverse-current flow through the power-supply system. When  $ONQ1$  is high,  $GATE1A$  and  $GATE1B$  remain fully enhanced as long as their respective  $V_{IN\_}$  is greater than 7.5V,  $V_{ON\_}$  is above the 1.24V threshold, and the channels are not in a current-limit fault condition. The MAX5944 reverse-current flow feature permits a higher voltage source connected at Port 1 to be routed to Port 2, as long as the voltage at both inputs ( $IN\_$ ) is initially above the minimum 7.5V operating range, see Figure 6.

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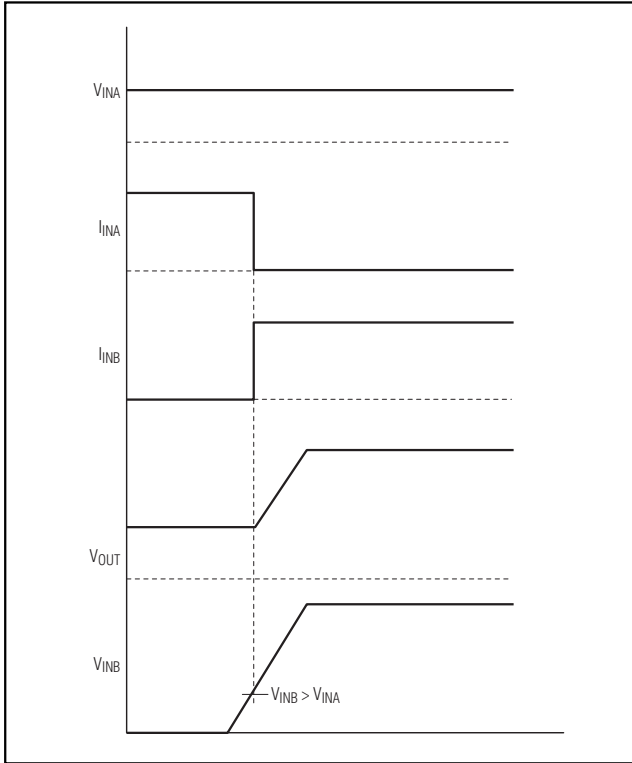


Figure 5. MAX5944 Power Switch Over ORing Timing Diagram

## Undervoltage Lockout

The MAX5944 dual-channel, independent current-limit switches have independent ON/OFF control. Both channels operate from 7.5V to 37V and have default 6.5V undervoltage lockout thresholds. The external MOSFETs remain off as long as  $V_{IN\_} < 6.5V$  and/or  $V_{ON\_} < V_{ON\_REF}$ . The UVLO thresholds are programmable by connecting a resistor-divider at  $ON\_$ . When  $V_{ON\_} > 1.24V$  and  $V_{IN\_} > 7.5V$ ,  $GATE2\_$  enhances to 5.5V, with respect to  $OUT\_$  and the MAX5944 switch goes into normal operation.

Program the switches' individual turn-on threshold voltages using the following formula:

$$R1 = \left( \frac{V_{TURN-ON}}{1.24} - 1 \right) \times R2$$

where  $V_{TURN-ON}$  is the desired turn-on voltage of channel A and/or B. Choose an  $R2$  value in the  $1k\Omega$  range to minimize error due to  $ON$  input bias current.

When operating the MAX5944,  $ON\_$  must remain above its 1.24V threshold. If  $V_{ON\_}$  falls below its 1.24V thresh-

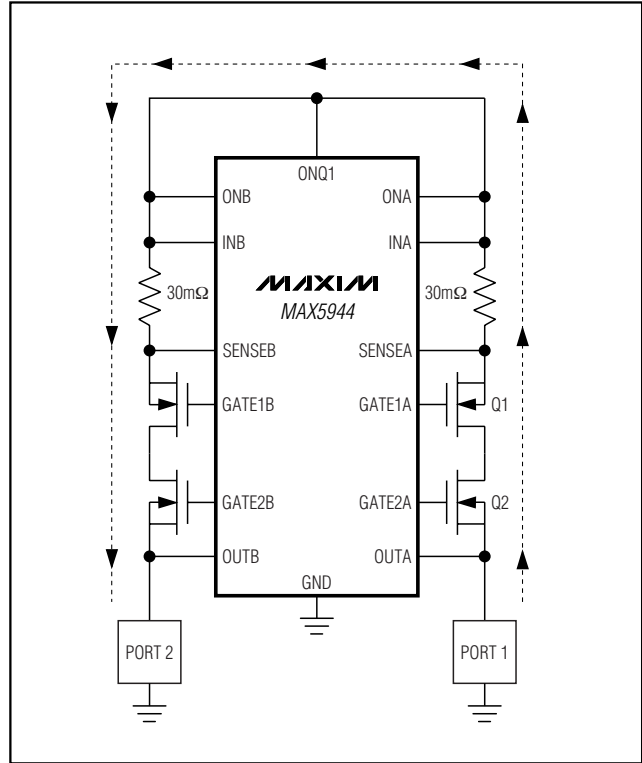


Figure 6. MAX5944 Operating in Reverse-Current Mode (Routing Power from Port 1 to Port 2)

old, the power-supply MOSFETs turn off immediately (less than  $1\mu s$ ). This allows the power supply to disconnect in the event of a fault condition detected by the system, such as shorting of the output to a different power-supply voltage or a FireWire signal pin. If possible transient conditions exist at the main power-supply line ( $IN\_$ ), place an RC filter at  $ON\_$  to reject transient voltage dips to prevent unnecessary power-supply interruptions.

The MAX5944 remain in low-current shutdown mode when  $V_{ON\_}$  is below the 0.4V threshold. Low-current shutdown mode disables the channel resulting in less than  $10\mu A$  supply current.

## Current-Fault Status Outputs ( $\overline{FAULT\_}$ )

$\overline{FAULT\_}$  are high-voltage, open-drain outputs that pull low when a current-limit fault shutdown has occurred.  $\overline{FAULT\_}$  remain low until the next startup cycle.

## Autoretry Fault Management

The MAX5944 autoretry feature attempts to restart after a  $t_{OFF}$  of 259ms, limiting the duty cycle of the MOSFETs

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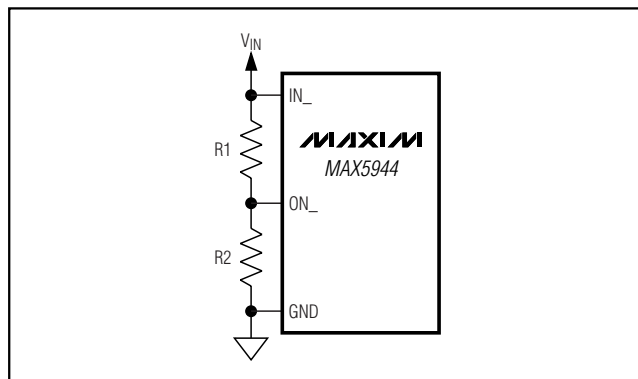


Figure 7. Setting the MAX5944 Turn-On Voltage

to 1/129 under continuous fault conditions.  $\overline{\text{FAULT\_}}$  deasserts every time a restart attempt is made.

## Applications Information

### Startup Considerations

Set the appropriate current-limit threshold for a successful MAX5944 startup. A successful startup is dependent on the MAX5944 current-limit threshold and timeout period. A large capacitor at OUT will result in a charging current equivalent to the current-limit threshold and may cause the MAX5944 to exceed its 2ms timeout period, if the current-limit threshold is set too low. Use the following formula to compute the minimum current-limit setting:

$$I_{\text{LIMIT}} > \frac{C_{\text{OUT}} \times V_{\text{IN}}}{t_{\text{LIM}}} + I_{\text{LOAD}}$$

where  $I_{\text{LIMIT}}$  is the programmed current limit,  $C_{\text{OUT}}$  is the capacitor at OUT,  $V_{\text{IN}}$  is the supply voltage,  $t_{\text{LIM}}$  is the 2ms current-limit timeout period, and  $I_{\text{LOAD}}$  is the load current during startup. With  $V_{\text{IN}} = 12\text{V}$ ,  $C_{\text{OUT}} = 220\mu\text{F}$ , and  $I_{\text{LOAD}} = 0$ , set the MAX5944 current limit greater than 1.3A. This calculation does not include tolerances.

### Choosing RSENSE

Select a sense resistor that causes the current-limit voltage drop at a current-limit level above the maximum normal operating current. Typically, set the current limit at 1.2 to 1.5 times the nominal load current.

Choose the sense-resistor power rating to accommodate a current-limit condition:

$$P_{\text{SENSE}} = (V_{\text{TH}})^2 / R_{\text{SENSE}}$$

where  $P_{\text{SENSE}}$  is the power dissipated across  $R_{\text{SENSE}}$  during a current-limit fault.

### MOSFET Selection

Select external MOSFETs according to the application current level. The MOSFETs' on-resistance ( $R_{\text{DS(ON)}}$ ) should be chosen low enough to have minimum voltage drop at full load to limit the MOSFET power dissipation. High  $R_{\text{DS(ON)}}$  also causes large output ripple if there is a pulsating load. Determine the device power rating to accommodate a short-circuit condition on the board, at startup, and when the device is in autoretry mode.

During normal operation, the external MOSFETs dissipate little power. The power dissipated in normal operation is:

$$P = I_{\text{LOAD2}} \times R_{\text{DS(ON)}}$$

The most power dissipation will occur during a short-circuit event, resulting in high power dissipated in Q2 (Figure 8) during the timeout period for the MAX5944, where the power dissipated across Q2 is:

$$P_{\text{Q2}} = (V_{\text{IN}} - V_{\text{IS}} - V_{\text{Q1}}) \times I_{\text{LIMIT}}$$

### Transient Protection

If  $\text{IN\_}$  or  $\text{OUT\_}$  experiences a fast transient rise in voltage, the drain-to-gate overlap capacitance of  $\text{GATE1\_}$  and/or  $\text{GATE2\_}$  FETs may be sufficient to enhance one of the transistors, allowing current to flow. If the circuit is subjected to large transients, connect capacitors from the gate to source across the appropriate MOSFET to prevent the overlap capacitance from turning on the device. This results in the turn-off time of the FETs to increase due to the additional discharge of the capacitor. Use the minimum capacitor value that will prevent reverse currents from flowing in hot-plug situations.

### FireWire Power Management

The MAX5944 serves to regulate and protect FireWire power over a system interface. The MAX5944 programmable features that make it suitable for both power-provider and power-receiver applications. Figure 9 shows a high-end two-port FireWire power-management system using two MAX5944 dual-channel FireWire current-limiting ICs.

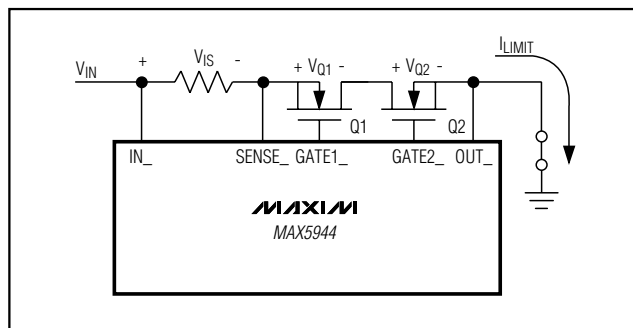


Figure 8. Power Dissipated Across MOSFET Q2 During a Short-Circuit Fault

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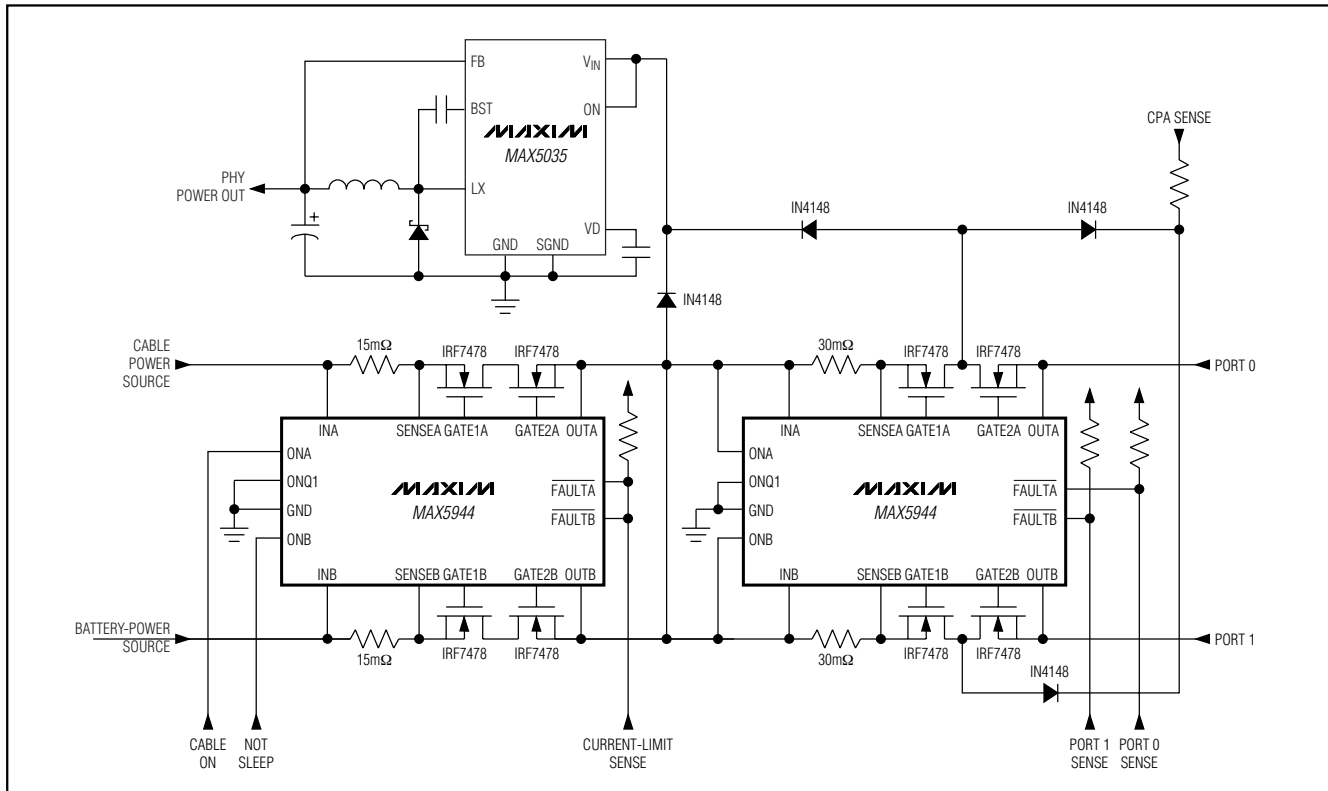
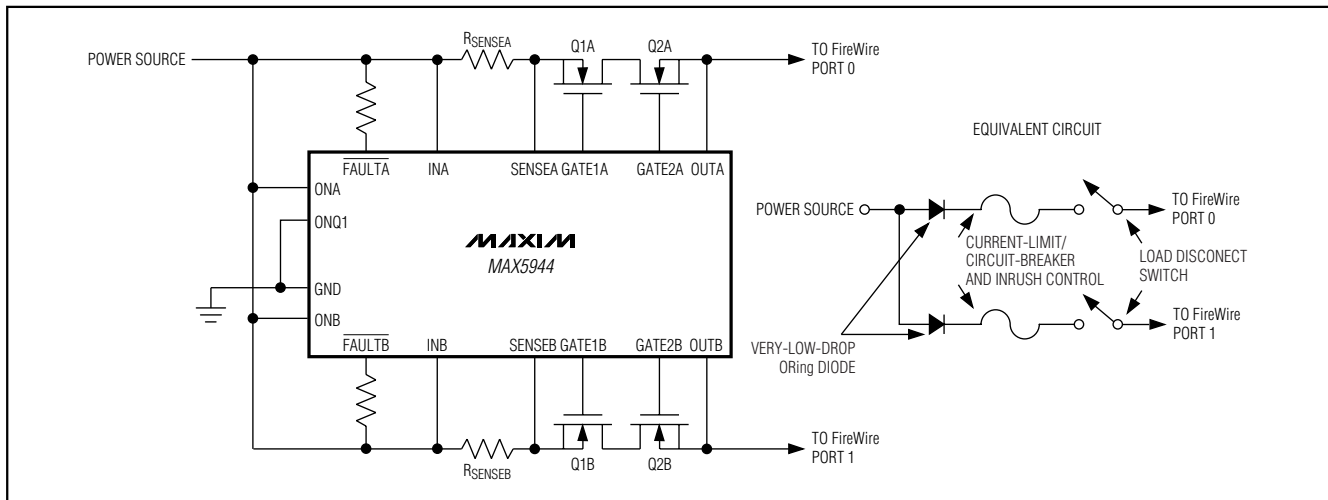


Figure 9. Two-Port FireWire Power Provider

## Typical Operating Circuit



## Chip Information

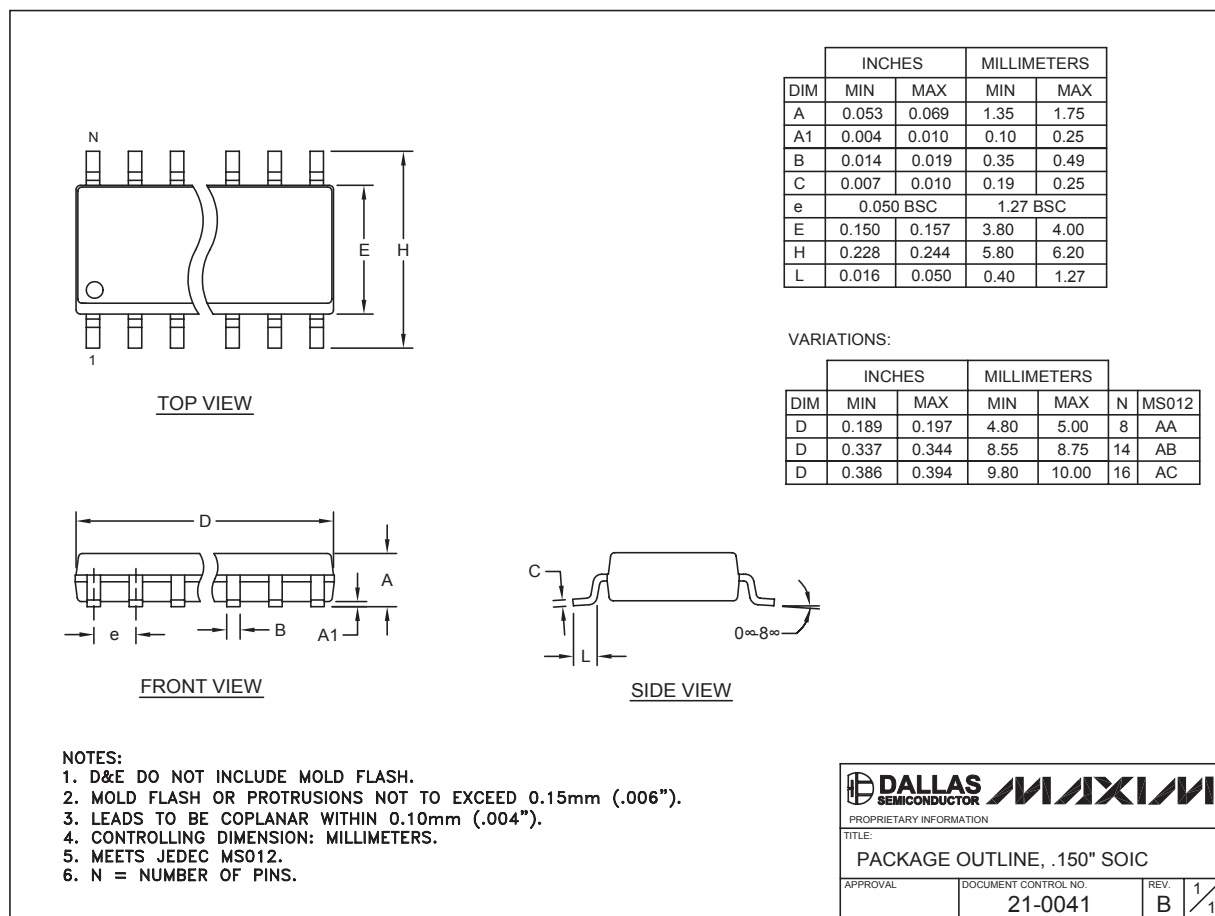
TRANSISTOR COUNT: 4,648

PROCESS: BiCMOS

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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](http://www.maxim-ic.com/packages).)



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