General description

The MX74610 is a controller device that can be used with an N-Channel MOSFET in a reverse polarity protection circuitry. It is designed to drive an external MOSFET to emulate an ideal diode rectifier when connected in series with a power source. A unique advantage of this scheme is that it is not referenced to ground and thus has Zero Iq.

The MX74610 controller provides a gate drive for an external N-Channel MOSFET and a fast response internal comparator to discharge the MOSFET Gate in the event of reverse polarity. This fast pull-down feature limits the amount and duration of reverse current flow if opposite polarity is sensed.

Features

♦ Maximum reverse voltage of 60V

♦ No Positive Voltage limitation to Anode Terminal

♦ Charge Pump Gate Driver for External N-Channel MOSFET

♦ Lower Power Dissipation than Schottky Diode / PFET Solutions

♦ Low Reverse Leakage Current

♦ Fast 2µs Response to Reverse Polarity

♦ -40°C to +125°C Operating Ambient Temperature

♦ Can be Used in OR-ing Applications

♦ No Peak Current Limit

♦ 6-Pin SOT23-6L and 8-pin MSOP8

Applications

♦ Infotainment Systems

♦ Power Tools (Industrial)

♦ Transmission Control Unit (TCU)

♦ Battery OR-ing Applications

♦ PV BOX

General information

Ordering information

Part Number	Description
MX74610T	SOT23-6L
MX74610SS	MSOP8
MPQ	3000pcs

Package dissipation rating

Package	RθJA（℃/W）
SOT-23 (6)	108.1

Absolute maximum ratings

| Parameter	Value
Cathode to Anode (for a 2ms time duration)	-3 to 60V
Cathode to Anode (continuous)	-3 to 55V
VCAPH to VCAPL	-0.3 to 7V
Anode to VCAPL	-0.3 to 3V
Gate drive, gate pull down to VCAPL	-0.3 to 7V
Junction temperature	150℃
Storage temperature, Tstg	-50 to 150℃
Leading temperature （soldering, 10s）	260℃
ESD Susceptibility HBM	±2000V

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

Recommended operating condition

Symbol	Range
Cathode To Anode	55V(max)
Operating temperature	-40~125℃

Typical application
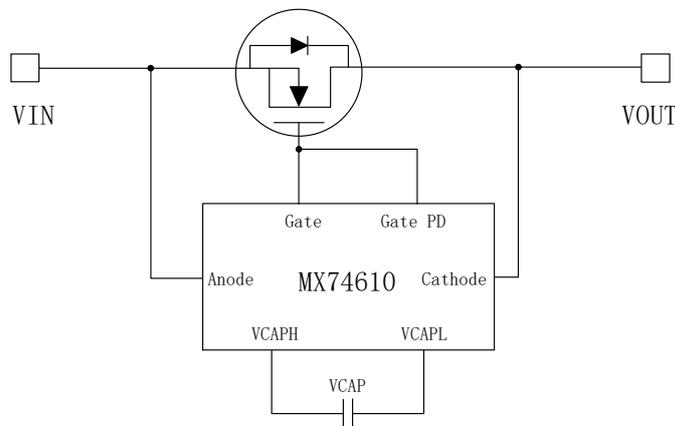
Typical Application

Terminal assignments
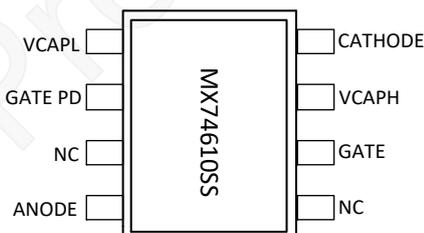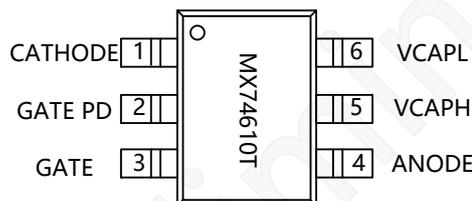
Pin information

| PIN NO.		PIN name	Description
MSOP8	SOT23-6L		
1	6	VCAPL	Charge Pump Output, connect to an external charge pump capacitor.
2	2	GATE PD	Connect to the gate of the external MOSFET for fast turn OFF in the case of reverse polarity.
3		NC	
4	4	ANODE	Anode of the diode, connect to source of the external MOSFET.
5		NC	
6	3	GATE	Gate Drive output, Connect to the Gate of the external MOSFET.
7	5	VCAPH	Charge Pump Output, connect to an external charge pump capacitor.
8	1	CATHODE	Cathode of the diode, connect to Drain of the external MOSFET.

Block diagram
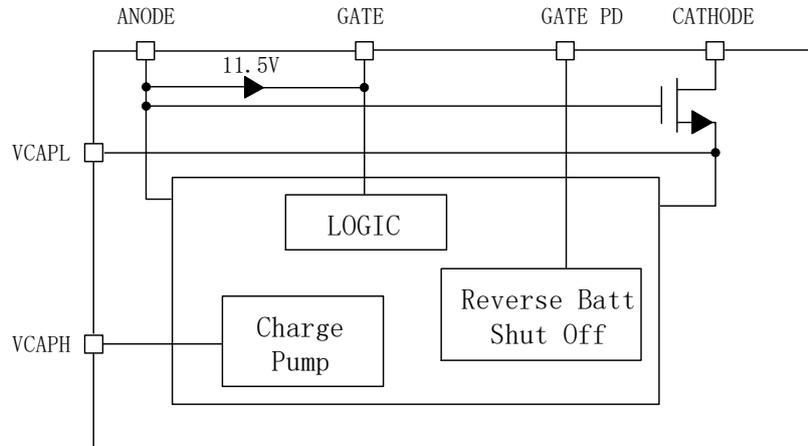
Electrical characteristics

（$V_{Anode - Cathode}$ = 0.55V, T_A = 25°C, unless otherwise noted）

Symbol	Parameter	Test condition	Min	Typ.	Max	Unit
$V_{Anode\ to\ Cathode}$	Minimum startup voltage across external MOSFET's body diode	External MOSFET V_{GS} = 0V	0.48			V
$V_{cap\ Threshold}$	Charge pump capacitor drive thresholds	V_{cap} Upper Threshold		6.3		V
		V_{cap} Lower Threshold		5.15		V
$I_{Gate\ up}$	Gate drive pull up current	$V_{Gate\ to\ Anode}$ = 2V	8.9	9.4		uA
$I_{Gate\ down}$	Gate drive pull down current during forward voltage	$V_{Gate\ to\ Anode}$ = 4V	6.35	6.8		uA
$I_{Gate\ pull\ down}$	Gate drive pull down current when reverse voltage is sensed	$V_{Gate\ Pull\ Down}$ = V_{Anode} + 2V		160		mA
$I_{Charge\ Current}$	Charging current for the charge pump capacitor	$V_{Anode\ to\ Cathode}$ = 0.55V	40	46		uA
$I_{Discharge\ Current}$	V_{cap} current consumption to power the controller when MOSFET is ON	V_{cap} = 6.6V		0.95		uA
$T_{Recovery}$	Time to shut off MOSFET when voltage is reversed (Equivalent to diode reverse recovery time)	$V_{Anode\ to\ Cathode}$ = -20mV C_{gate} = 4nF		2.2	5	us
D	Duty cycle	I_{load} = 3A, T_A = 25°C			98%	
		I_{load} = 3A, T_A = 125°C			92%	
I_{LKG}	Reverse leakage current	$V_{Anode\ to\ Cathode}$ = -13.5V		60	110	uA
I_q	Quiescent current to GND			0		uA
I_{Anode}	Current into Anode pin	Current into Anode pin when $V_{Anode - Cathode}$ = 0.3V		30		uA

Characteristic plots
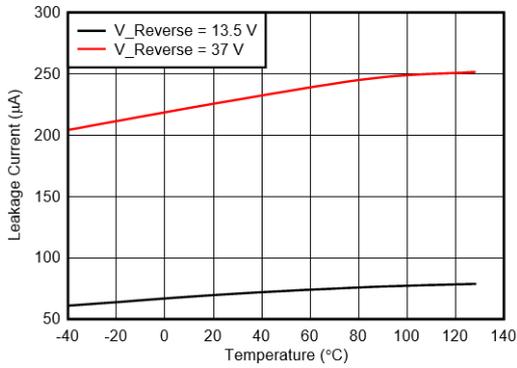
Reverse Leakage at Negative Voltages
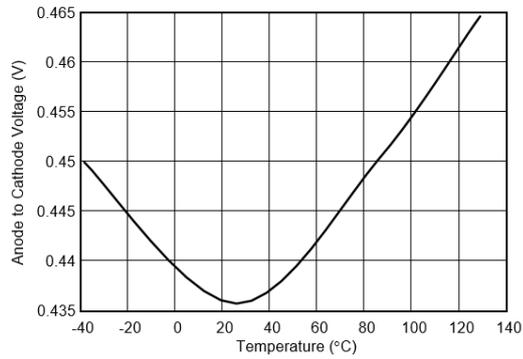
Anode to Cathode Startup Voltage
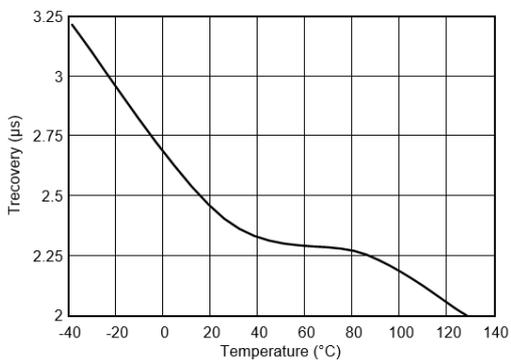
Reverse Recovery Time (T$_{Recovery}$)
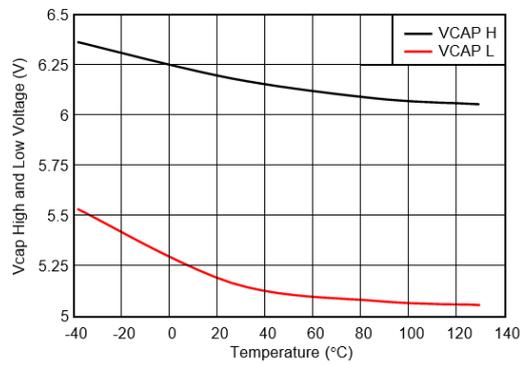
VCAPH and VCAPL Voltage Threshold
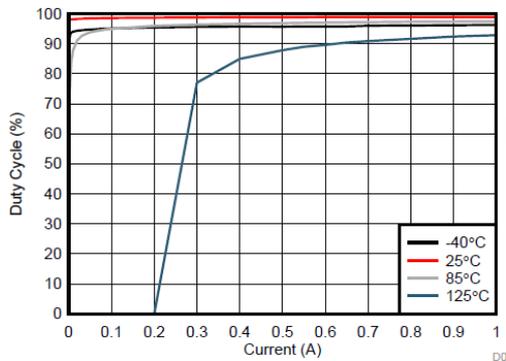
Duty Cycle of the Output Voltage at Startup
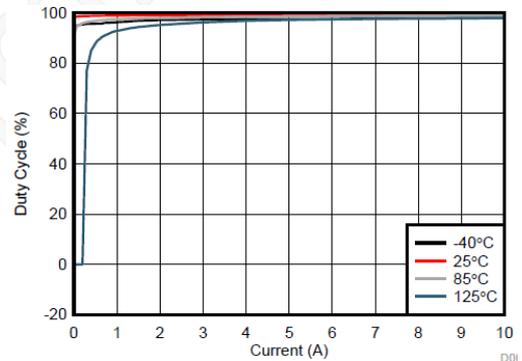
Duty Cycle of the Output Voltage
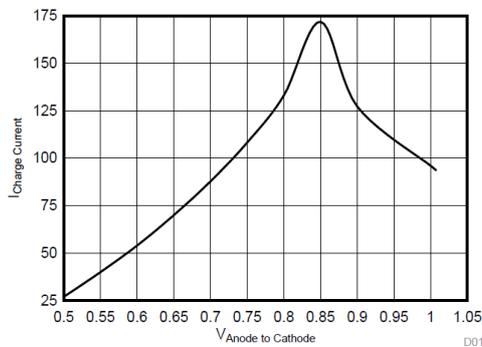
Voltage Across Body Diode vs Vcap Charging Current

Detailed description

Most systems in industrial applications require fast response reverse polarity protection at the input stage. Schottky diodes or P-Channel MOSFETs are typically used in most power systems to protect the load in the case of negative polarity. The main disadvantage of using diodes is voltage drop during forward conduction, which reduces the available voltage and increases the associated power losses. PFET solutions are inefficient for handling high load current at low input voltage.

The MX74610 is a zero Iq controller that is combined with an external N-channel MOSFET to replace a diode or PFET reverse polarity solution in power systems. The voltage across the MOSFET source and drain is constantly monitored by the MX74610 ANODE and CATHODE pins. An internal charge pump is used to provide the GATE drive for the external MOSFET. This stored energy is used to drive the gate of MOSFET. The voltage drop depends on the R_{DSON} of a particular MOSFET in use, which is significantly smaller than a PFET. The MX74610 has no ground reference which makes it identical to a diode.

Feature Description

During T_0

When power is initially applied, the load current I_D will flow through the body diode of the MOSFET and produce a voltage drop V_f during T_0 in the following figure. This forward voltage drop V_f across the body diode of the MOSFET is used to charge up the charge pump capacitor V_{cap}. During this time, the charge pump capacitor V_{cap} is charged to a higher threshold of 6.3V (typical).

During T_1

Once the voltage on the capacitor reaches the higher voltage level of 6.3V (typical), the charge pump is disabled and the MOSFET turns ON. The energy stored in the capacitor is used to provide the gate drive for the MOSFET (T_1 in the following figure). When the MOSFET is ON, it provides a low resistive path for the drain current to flow and minimizes the power dissipation associated with forward conduction. The power losses during the MOSFET ON state depend primarily on the R_{DSON} of the selected MOSFET and load current. At the time when the capacitor voltage reaches its lower threshold V_{CAPL} 5.15V (typical), the MOSFET gate turns OFF. The drain current I_D will then begin to flow through the body diode of the MOSFET, causing the MOSFET body diode voltage drop to appear across Anode and Cathode pins. The charge pump circuitry is re-activated and begins charging the charge pump capacitor. The MX74610 operation keeps the MOSFET ON at approximately 98% duty cycle (typical) regardless of the external charge pump capacitor value. This is the key factor to minimizing the power losses. The forward voltage drop during this time is determined by the R_{DSON} of the MOSFET.
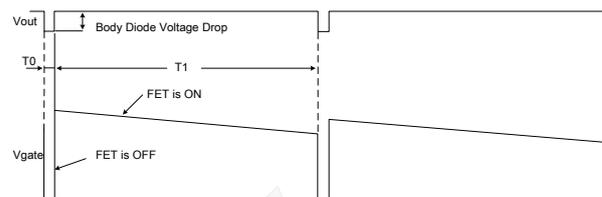

Output Voltage and V_{gate} Operation at 1A Output Current

Pin Operation

Anode and Cathode Pins

The MX74610 Anode and Cathode pins are connected to the source and drain of the external MOSFET. The current into the Anode pin is 30μA (typical). When power is initially applied, the load current flows through the body diode of the external MOSFET, the voltage across Anode and Cathode pins is equal to the forward diode drop V_f. The minimum value of V_f required to enable the charge pump circuitry is 0.48V. Once the MOSFET is turned ON, the Anode and Cathode pins constantly sense the voltage difference across the MOSFET to determine the magnitude and polarity of the voltage across it. When the MOSFET is on, the voltage difference across Anode and Cathode pins depends on the R_{DSON} and load current. If voltage difference across source and drain of the external MOSFET becomes negative, this is sensed as a fault condition by Anode and Cathode pins and gate is turned off by Gate Pull Down pin as shown in the following figure. The reverse voltage threshold across Anode and Cathode to detect the fault condition is -20mV. The consistent sensing of voltage polarity across the MOSFET enables the MX74610 to provide a fast response to the power source failure and limit the amount and duration of the reverse current flow.
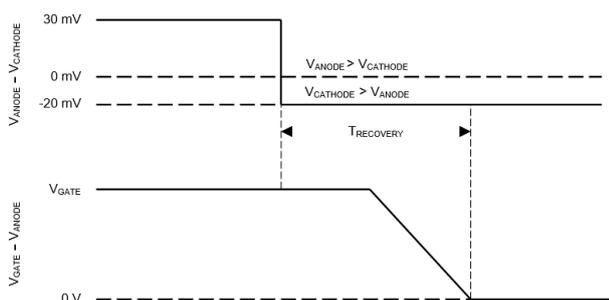
Gate Shut Down Timing in the Event of Reverse Polarity

VCAPH and VCAPL Pins

VCAPH and VCAPL are high and low voltage thresholds respectively that the MX74610 uses to detect when to turn the charge pump circuitry ON and OFF. The capacitor charging and discharging time can be correlated to the duty cycle of the MOSFET gate. The following figure shows the voltage behavior across the Vcap. During the period T_0, the capacitor is storing energy from the charge pump. The MOSFET is turned off and current flow is only through the body diode during this period. The conduction through body diode of the MOSFET is for a very small period (2% typical) which rules out the chances of overheating the MOSFET, regardless of the output current. Once the capacitor voltage reaches its high threshold, the MOSFET is turned ON and charge pump circuity is deactivated until the Vcap reaches its lower voltage threshold again T_1. The voltage difference between Vcap high and low threshold is typically 1.15V. The MX74610 charge pump has 46µA charging capability with 5-8MHz frequency.
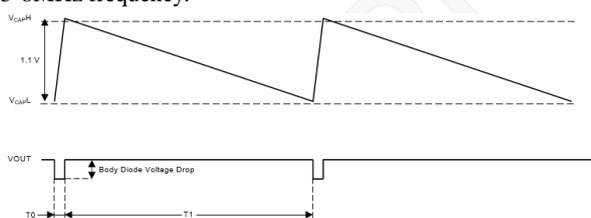
Vcap Charging and Discarding by the Charge Pump

The Vcap current consumption is 1µA (typical) to drive the gate. The MOSFET OFF time (T_0) and ON time (T_1) can be calculated using the following expression.

$$\Delta T = C \times dV / dT$$

Where:

- C = Vcap Capacitance
- dV = 1.15V
- dI = 46µA for charging
- dI = 0.95µA for discharging

Note: Temperature dependence of these parameters – The duty cycle is dependent on temperature since the capacitance variation over temperature has a direct correlation to the MOSFET OFF and ON periods and the frequency. If the capacitor varies 20% the periods and the frequency will also vary by 20% so it is recommended to use a quality X7R/COG cap and not to place the cap near high temperature devices. The variation of the capacitor does not have a thermal impact in the application as the duty cycle does not change.

Gate Drive Pin

When the charge pump capacitor is charged to the high voltage level of 6.3V (typical), the Gate Drive pin provides a 6.8µA (typical) of drive current. When the charge pump capacitor reaches its lower voltage threshold of 5.15V (typical), Gate is pulled down to the Anode voltage V_{IN}. During normal operation, the gate turns ON and OFF with a slow 2ms slew rate to avoid switching noise and EMI issues. To protect the gate of the MOSFET, a built-in internal 11.5V Zener clamp the maximum gate to source voltage $V_{GS(MAX)}$.

Gate Pull Down Pin

The Gate Pull Down pin is connected to the Gate Drive pin in a typical application circuit. When the controller detects negative polarity, possibly due to failure of the input supply or voltage ripple, the Pull-Down quickly discharges the MOSFET gate through a discharge transistor. The Gate Pull Down pin can discharge the MOSFET gate capacitance with 160mA pull down current to speed up the MOSFET turn OFF time. This fast pull down reacts regardless of the Vcap charge level. If the input supply abruptly fails, as would happen if the supply gets shorted to ground, a reverse current will temporarily flow through the MOSFET. This reverse current can be due to parallel connected supplies and load capacitance and is dependent upon the R_{DSON} of the MOSFET.

When the negative voltage across the Anode and Cathode pins reaches -20mV (typical), the MX74610 immediately reacts and discharges the MOSFET gate capacitance. A MOSFET with 5nF of effective gate capacitance can be turned off by the MX74610 within 2µs (typical). The fast turnoff time minimizes the reverse current flow from MOSFET drain by opening the circuit. The reverse leakage current does not exceed 110µA for a constant 13.5V reverse

voltage across Anode and Cathode pins. The reverse leakage current for a Schottky diode is 15mA under the same voltage and temperature conditions.

Device Functional Modes

Body Diode Conduction Mode

The MX74610 solution works like a conventional diode during this time with higher forward voltage drop. The power dissipation during this time can be given as:

$$P_{Dissipation} = (V_{Forward\ Drop}) \times (I_{Drain\ Current})$$

However, the current only flows through the body diode while the MOSFET gate is being charged to $V_{GS(TH)}$. This conduction is only for 2% duty cycle; therefore, it does not cause any thermal issues.

Body Diode ON Time = $C \times (V_{CAPH} - V_{CAPL}) / I_{Charge\ Current}$

The MOSFET Conduction Mode

The MOSFET is turned on during this time and current flow is only through the MOSFET. The forward voltage drops, and power losses are limited by the R_{DSON} of the specific MOSFET used in the solution. The MX74610 solution output is comprised of the MOSFET conduction mode for 98% of its duty cycle. This period is given by the following expression:

MOSFET ON Time = $C \times (V_{CAPH} - V_{CAPL}) / I_{Discharge\ Current}$

Duty Cycle Calculation

The MX74610 has an operating duty cycle of 98% at 25℃ and >90% at 125℃. The duty cycle doesn't depend on the Vcap capacitance value. However, the variation in capacitance value over temperature has direct correlation to the switching frequency between the MOSFET and body diode. If the capacitance value decreases, the charging and discharging time will also decrease, causing more frequent switching between body diode and the MOSFET condition. The following expression can be used to calculate the duty cycle of the MX74610:

Duty Cycle (%) = (MOSFET ON Time) $\times$ 100 / (MOSFET ON Time + Body Diode ON Time)

Application and Implementation

Application Information

The MX74610 is used with N-Channel MOSFET controller in a typical reverse polarity protection application. The schematic for the typical application is shown in the following figure where the MX74610 is used in series with a battery to drive the MOSFET Q1. The TVS+ and TVS- are not required for the MX74610. However, they are typically used to clamp the positive and negative voltage surges respectively. The output capacitor Cout is recommended to protect the immediate output voltage collapse because of line disturbance.
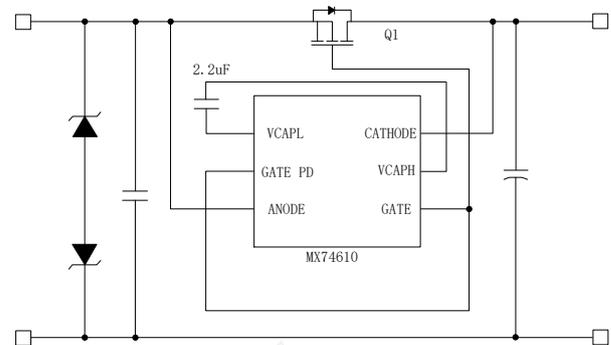
Typical Application Schematic

Capacitor Selection

A ceramic capacitor should be placed between VCAPL and VCAPH. The capacitor acts as a holding tank to power up the control circuitry when the MOSFET is on.

When the MOSFET is off, this capacitor is charged up to higher voltage threshold of ~6.3V. Once this voltage is reached, the Gate Drive of MX74610 will provide drive for the external MOSFET. When the MOSFET is ON, the voltage across its body diode is collapsed because the forward conduction is through the MOSFET. During this time, the capacitor acts as a supply for the Gate Drive to keep the MOSFET ON.

The capacitor voltage will gradually decay when the MOSFET is ON. Once the capacitor voltage reaches a lower voltage threshold of 5.15V, the MOSFET is turned off and the capacitor gets recharged again for the next cycle.

A capacitor value of 220nF to 4.7uF with X7R/COG characteristic and 16V rating or higher is recommended for this application. A higher value capacitor sets longer MOSFET ON time and OFF time, however, the duty cycle remains at ~98% for MOSFET ON time irrespective of capacitor value.

If the Vcap value is 2.2μF, the MOSFET ON time and OFF time can be calculated using the following equation:

MOSFET ON Time = (2.2μF × 1.15V)/0.95μA = 2.66s

Body Diode ON Time = (2.2μF × 1.15V)/46μA = 55ms

The duty cycle can be calculated using the following

equation:

Duty Cycle = 2.66s / (2.66s + 0.055s) = 98%

MOSFET Selection

The MX74610 can provide up to 5V of gate to source voltage (V_{GS}). The important MOSFET electrical parameters are the maximum continuous Drain current I_D, the maximum drain-to-source voltage $V_{DS(MAX)}$, and the drain-to-source ON resistance R_{DSON}. The maximum continuous drain current, I_D, rating must exceed the maximum continuous load current. The rating for the maximum current through the body diode, I_S, is typically rated the same as, or slightly higher than the drain current, but body diode current only flows for a small period when the charge pump capacitor is being charged.

The voltage across the MOSFET's body diode must be higher than 0.48V at low current. The body diode voltage for a MOSFET typically decreases as the ambient temperature increases. This will increase the source current requirement to achieve the minimum body diode drain-to-source voltage for the charge pump to initiate. The maximum drain-to-source voltage, $V_{DS(MAX)}$, must be high enough to withstand the highest differential voltage seen in the application. This would include any anticipated fault conditions. The MX74610 does not have positive voltage limitation.

OR-ing Application Configuration

Basic redundant power architecture comprises of two or more voltage or power supply sources driving a single load. In its simplest form, the OR-ing solution for redundant power supplies consists of Schottky OR-ing diodes that protect the system against an input power supply fault condition. A diode OR-ing device provides effective and low-cost solution with few components. However, the diodes forward voltage drops affects the efficiency of the system permanently, since each diode in an OR-ing application spends most of its time in forward conduction mode. These power losses increase the requirements for thermal management and allocated board space.

The MX74610 combined with external N-Channel MOSFETs can be used to in OR-ing Solution as shown in the following figure. The source to drain voltage V_{DS} for each MOSFET is monitored by the Anode and Cathode pins of the MX74610. The forward conduction is through MOSFETs 98% of the time which avoids the diode forward voltage drop. The body diode of each MOSFET only conducts the remaining 2% of

the time to allow the charge pump capacitor to be fully charged.

This is essential for an OR-ing device to quickly detect the reverse current and instantly pull-down the MOSFET gate to block the reverse current flow. An effective OR-ing solution needs to be extremely fast to limit the reverse current amount and duration. The MX74610 devices in OR-ing configuration constantly sense the voltage difference between Anode and Cathode pins, which are the voltage levels at the power sources (PS1, PS2) and the common load point respectively. When either of the power sources operates at lower voltage, the MX74610 detects a negative polarity and shuts down the Gate Drive through a fast Pull-Down within 2μs (typical).
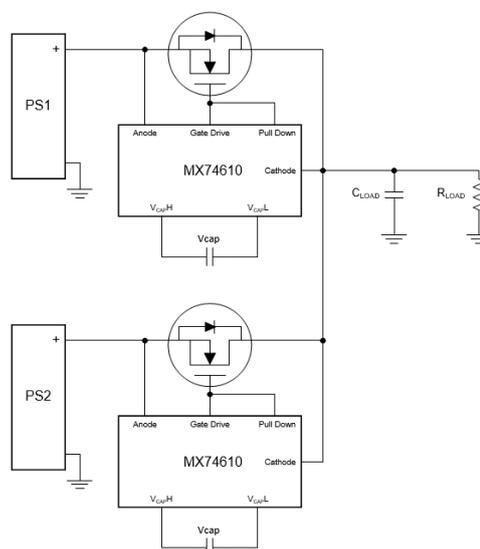
Typical OR-ing Application

Power Supply Recommendations

While testing the MX74610 solution, it is important to use low impedance power supply which allows current sinking. If the power supply does not allow current sinking, it would prevent the current flow in the reverse direction in the event of reverse polarity. The MOSFET gate won't get pulled down immediately due to the absence of reverse current flow.

Layout Guidelines

♦ The V_{IN} terminal is recommended to have a low-ESR ceramic bypass-capacitor. The typical recommended bypass capacitance is a 10μF ceramic capacitor with a X5R or X7R dielectric.

♦ The V_{IN} terminal must be tied to the source of the MOSFET using a thick trace or polygon.

♦ The Anode pin of the MX74610 is connected to the

Source of the MOSFET for sensing.

♦ The Cathode pin of the MX74610 is connected to the drain of the MOSFET for sensing.

♦ The high current path of for this solution is through the MOSFET, therefor it is important to use thick traces for source and drain of the MOSFET.

♦ The charge pump capacitor Vcap must be kept away from the MOSFET to lower the thermal effects on the capacitance value.

♦ The Gate Drive and Gate pull down pins of the MX74610 must be connected to the MOSFET gate without using vias. Avoid excessively thin traces to the Gate Drive.

♦ Obtaining acceptable performance with alternate layout schemes is possible.

♦ Keep the Drive pin close to the MOSFET to avoid further reduce MOSFET turn-on delay.

Package information
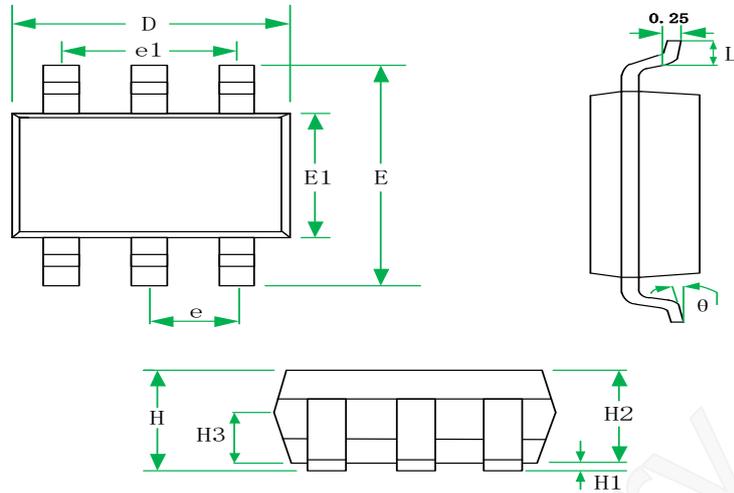
SYMBOL	MILLIMETERS			INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
H			1.45			0.057
H1	0.04		0.15	0.0016		0.0059
H2	1.00	1.10	1.20	0.039	0.043	0.047
H3	0.55	0.65	0.75	0.022	0.026	0.029
D	2.72	2.92	3.12	0.107	0.115	0.123
E	2.60	2.80	3.00	0.102	0.110	0.118
E1	1.40	1.60	1.80	0.055	0.063	0.071
e	0.95BSC			0.037BSC		
e1	1.90BSC			0.074BSC		
L	0.30		0.60	0.012		0.024
θ	0		8°	0		8°

SOT23-6 for MX74610T
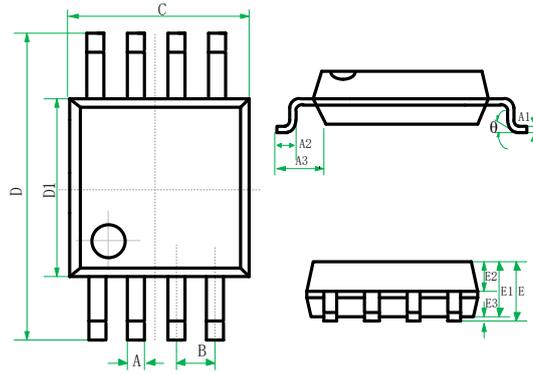
SYMBOL	MILLIMETERS			INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	0.28	0.33	0.38	0.011	0.013	0.015
A1	0.13		0.2	0.005		0.008
A2	0.445	0.546	0.648	0.018	0.021	0.026
A3	0.95BSC			0.037BSC		
B	0.65BSC			0.026BSC		
C	2.9	3.0	3.1	0.114	0.118	0.122
D	4.8	4.9	5.0	0.189	0.193	0.197
D1	2.9	3.0	3.1	0.114	0.118	0.122
E	0.86		1.04	0.034		0.041
E1	0.81		0.91	0.032		0.036
θ	0	-	8°	0		8°

MX74610SS

Restrictions on Product Use

◆ MAXIN micro is continually working to improve the quality and reliability of its products. Nevertheless, semiconductor devices in general can malfunction or fail due to their inherent electrical sensitivity and vulnerability to physical stress. It is the responsibility of the buyer, when utilizing MAXIN products, to comply with the standards of safety in making a safe design for the entire system, and to avoid situations in which a malfunction or failure of such MAXIN products could cause loss of human life, bodily injury or damage to property.

◆ In developing your designs, please ensure that MAXIN products are used within specified operating ranges as set forth in the most recent MAXIN products specifications.

◆ The information contained herein is subject to change without notice.

Version update record:

V10 The original version （preliminary）