

LM9061

Power MOSFET Driver with Lossless Protection

General Description

The LM9061 is a charge-pump device which provides the gate drive to any size external power MOSFET configured as a high side driver or switch. A CMOS logic compatible ON/OFF input controls the output gate drive voltage. In the ON state, the charge pump voltage, which is well above the available V_{CC} supply, is directly applied to the gate of the MOSFET. A built-in 15V zener clamps the maximum gate to source voltage of the MOSFET. When commanded OFF a 110 μA current sink discharges the gate capacitances of the MOSFET for a gradual turn-OFF characteristic to minimize the duration of inductive load transient voltages and further protect the power MOSFET.

Lossless protection of the power MOSFET is a key feature of the LM9061. The voltage drop (V_{DS}) across the power device is continually monitored and compared against an externally programmable threshold voltage. A small current sensing resistor in series with the load, which causes a loss of available energy, is not required for the protection circuitry. Should the V_{DS} voltage, due to excessive load current, exceed the threshold voltage, the output is latched OFF in a more gradual fashion (through a 10 μA output current sink) after programmable delay time interval.

Designed for the automotive application environment the LM9061 has a wide operating temperature range of -40°C to $+125^{\circ}\text{C}$, remains operational with V_{CC} up to 26V, and can

withstand 60V power supply transients. The LM9061 is available in an 8-pin small outline surface mount package.

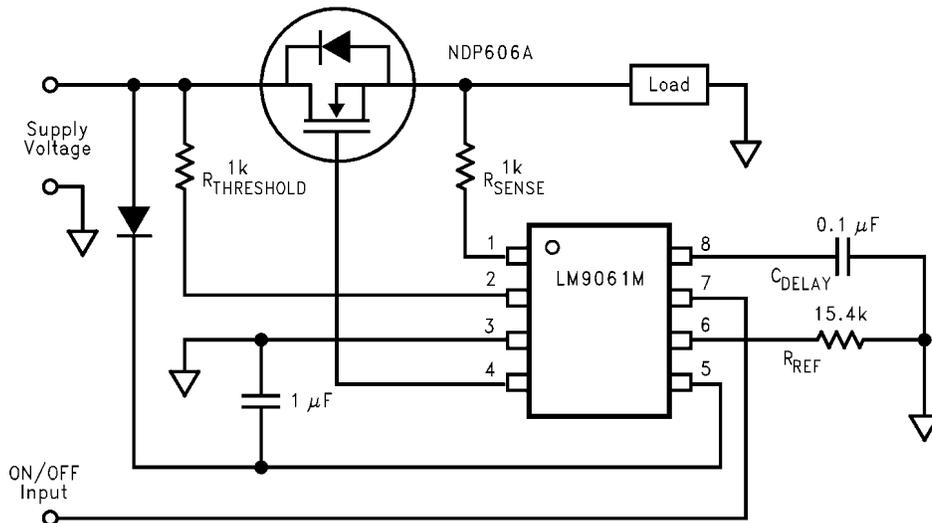
Features

- Built-in charge pump for gate overdrive of high side drive applications
- Lossless protection of the power MOSFET
- Programmable MOSFET protection voltage
- Programmable delay of protection latch-OFF
- Fast turn-ON (1.5 ms max with gate capacitance of 25000 pF)
- Overvoltage shut OFF with $V_{CC} > 26\text{V}$
- Withstands 60V supply transients
- CMOS logic compatible ON/OFF control input
- Available in 8-pin SOIC (SO-8) package

Applications

- Valve, relay and solenoid drivers
- Lamp drivers
- DC motor PWM drivers
- Logic controlled power supply distribution switch
- Electronic circuit breaker

Typical Application

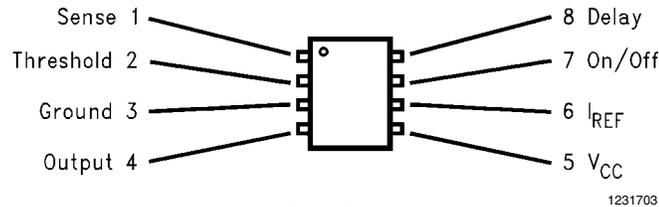


1231701

Ordering Information

Order Number	Package Type	Package Drawing	Supplied As
LM9061M	8 Lead SOIC	M08A	Rail of 95
LM9061MX	8 Lead SOIC	M08A	Tape and Reel of 2500

Connection Diagram



Top View
Order Number LM9061M
See NS Package Number M08A

Pin Descriptions

Pin #	Pin Symbol	Pin Description
1	Sense	The inverting input to the protection comparator, connected to the external MOSFET source pin and the load.
2	Threshold	The non-inverting input to the protection comparator, and a current sink for the threshold resistor to set the allowed voltage drop across the external MOSFET.
3	Ground	Ground
4	Output	The gate drive connection. Charges, and discharges, the MOSFET gate.
5	V_{CC}	The voltage supply pin. The V_{CC} operating range has a minimum value of 7V, and a maximum value of 26V.
6	I_{REF}	A resistor on this pin to ground sets the current through the threshold resistor, which sets the allowed voltage drop across the external MOSFET.
7	On/Off	The control pin. A low voltage, $V_{IN}(0)$, will disable device operation, while a high voltage, $V_{IN}(1)$, will enable device operation.
8	Delay	A capacitor on this pin to ground will provide a delay time between when the protection comparator detects excessive V_{GS} across the MOSFET and when the gate drive circuitry is latched-OFF.

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	60V
Reverse Supply Current	20 mA
Output Voltage	$V_{CC} + 15V$
Voltage at Sense and Threshold (through 1 k Ω)	-25V to +60V
ON/OFF Input Voltage	-0.3V to $V_{CC} + 0.3V$
Junction Temperature	150°C

Storage Temperature	-55°C to +150°C
Lead Temperature	260°C
Soldering, 10 seconds	

Operating Ratings (Note 2)

Supply Voltage	7V to 26V
ON/OFF Input Voltage	-0.3V to V_{CC}
Ambient Temperature Range	-40°C to +125°C
Thermal Resistance (θ_{J-A}) LM9061M	150°C/W

DC Electrical Characteristics $7V \leq V_{CC} \leq 20V$, $R_{REF} = 15.4 \text{ k}\Omega$, $-40^\circ\text{C} \leq T_J \leq +125^\circ\text{C}$, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Max	Units
POWER SUPPLY					
I_Q	Quiescent Supply Current	ON/OFF = "0"		5	mA
I_{CC}	Operating Supply Current	ON/OFF = "1", $C_{LOAD} = 0.025 \mu\text{F}$, Includes Turn-ON Transient Output Current		40	mA
ON/OFF CONTROL INPUT					
$V_{IN(0)}$	ON/OFF Input Logic "0"	$V_{OUT} = \text{OFF}$		1.5	V
$V_{IN(1)}$	ON/OFF Input Logic "1"	$V_{OUT} = \text{ON}$	3.5		V
V_{HYST}	ON/OFF Input Hysteresis	Peak to Peak	0.8	2	V
I_{IN}	ON/OFF Input Pull-Down Current	$V_{ON/OFF} = 5V$	50	250	μA
GATE DRIVE OUTPUT					
V_{OH}	Charge Pump Output Voltage	ON/OFF = "1"	$V_{CC} + 7$	$V_{CC} + 15$	V
V_{OL}	OFF Output Voltage	ON/OFF = "0", $I_{SINK} = 110 \mu\text{A}$		0.9	V
V_{CLAMP}	Sense to Output Clamp Voltage	ON/OFF = "1", $V_{SENSE} = V_{THRESHOLD}$	11	15	V
$I_{SINK(\text{Normal-OFF})}$	Output Sink Current Normal Operation	ON/OFF = "0", $V_{DELAY} = 0V$, $V_{SENSE} = V_{THRESHOLD}$	75	145	μA
$I_{SINK(\text{Latch-OFF})}$	Output Sink Current with Protection Comparator Tripped	$V_{DELAY} = 7V$, $V_{SENSE} < V_{THRESHOLD}$	5	15	μA
PROTECTION CIRCUITRY					
I_{REF}	Threshold Pin Reference Current	$V_{SENSE} = V_{THRESHOLD}$	75	88	μA
V_{REF}	Reference Voltage		1.15	1.35	V
$I_{THR(\text{LEAKAGE})}$	Threshold Pin Leakage Current	$V_{CC} = \text{Open}$, $7V \leq V_{THRESHOLD} \leq 20V$		10	μA
I_{SENSE}	Sense Pin Input Bias Current	$V_{SENSE} = V_{THRESHOLD}$		10	μA
DELAY TIMER					
I_{DELAY}	Delay Pin Source Current		6.74	15.44	μA
V_{TIMER}	Delay Timer Threshold Voltage		5	6.2	V
I_{DIS}	Delay Capacitor Discharge Current	$V_{DELAY} = 5V$	2	10	mA
V_{SAT}	Discharge Transistor Saturation Voltage	$I_{DIS} = 1 \text{ mA}$		0.4	V

AC Timing Characteristics

$7V \leq V_{CC} \leq 20V$, $R_{REF} = 15.4 \text{ k}\Omega$, $-40^\circ\text{C} \leq T_J \leq +125^\circ\text{C}$, $C_{LOAD} = 0.025 \mu\text{F}$,
 $C_{DELAY} = 0.022 \mu\text{F}$, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Max	Units
T_{ON}	Output Turn-ON Time	$C_{LOAD} = 0.025 \mu\text{F}$ $7V \leq V_{CC} \leq 10V$, $V_{OUT} \geq V_{CC} + 7V$ $10V \leq V_{CC} \leq 20V$, $V_{OUT} \geq V_{CC} + 11V$		1.5 1.5	ms ms
$T_{OFF(NORMAL)}$	Output Turn-OFF Time, Normal Operation (Note 4)	$C_{LOAD} = 0.025 \mu\text{F}$ $V_{CC} = 14V$, $V_{OUT} \geq 25V$ $V_{SENSE} = V_{THRESHOLD}$	4	10	ms
$T_{OFF(Latch-OFF)}$	Output Turn-OFF Time, Protection Comparator Tripped (Note 4)	$C_{LOAD} = 0.025 \mu\text{F}$ $V_{CC} = 14V$, $V_{OUT} \geq 25V$ $V_{SENSE} = V_{THRESHOLD}$	45	140	ms
T_{DELAY}	Delay Timer Interval	$C_{DELAY} = 0.022 \mu\text{F}$	8	18	ms

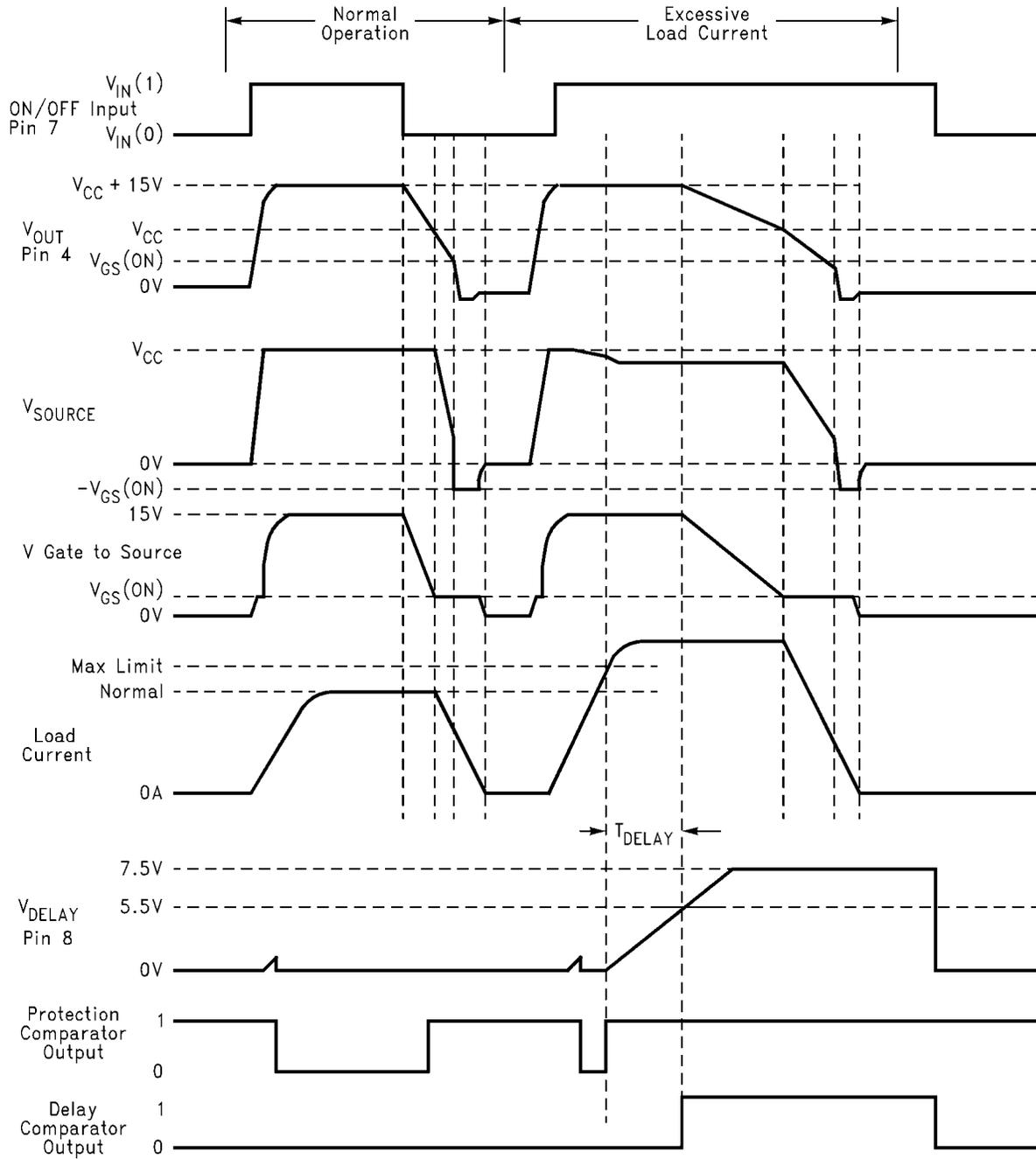
Note 1: Absolute Maximum Ratings indicate the limits beyond which damage to the device may occur.

Note 2: Operating Ratings indicate conditions for which the device is intended to be functional, but may not meet the guaranteed specific performance limits. For guaranteed specifications and test conditions see the Electrical Characteristics.

Note 3: ESD Human Body Model: 100 pF discharged through 1500 Ω resistor.

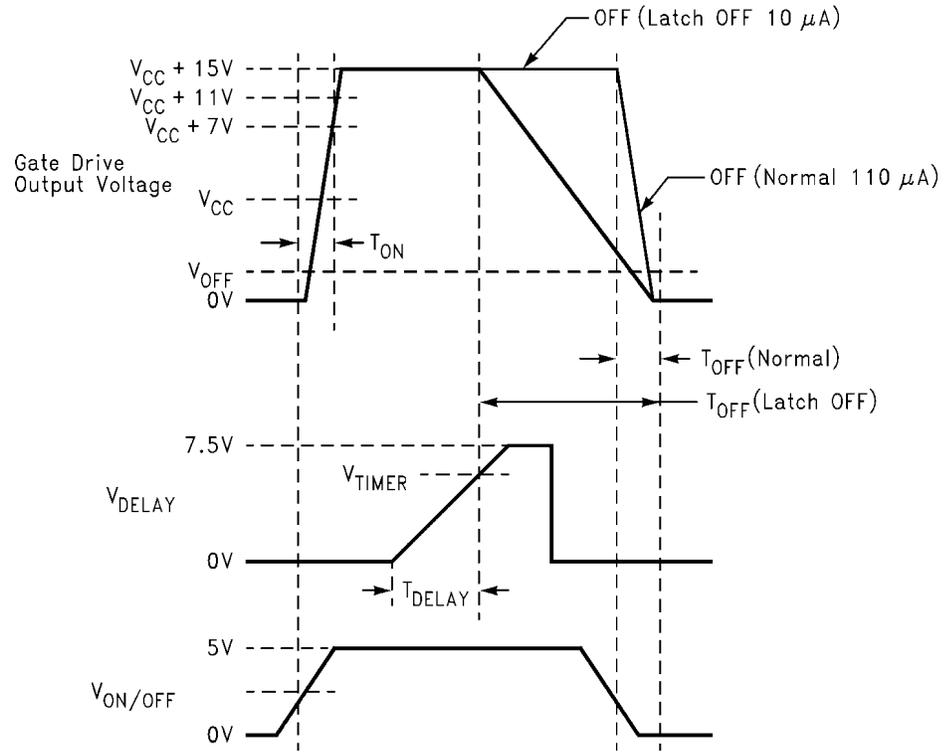
Note 4: The AC Timing specifications for T_{OFF} are not production tested, and therefore are not specifically guaranteed. Limits are provided for reference purposes only. Smaller load capacitances will have proportionally faster turn-ON and turn-OFF times.

Typical Operating Waveforms



1231705

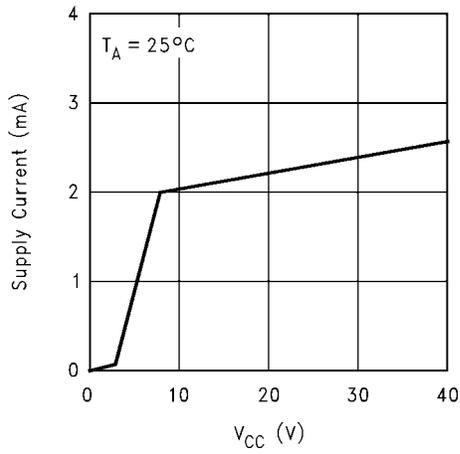
Timing Definitions



1231707

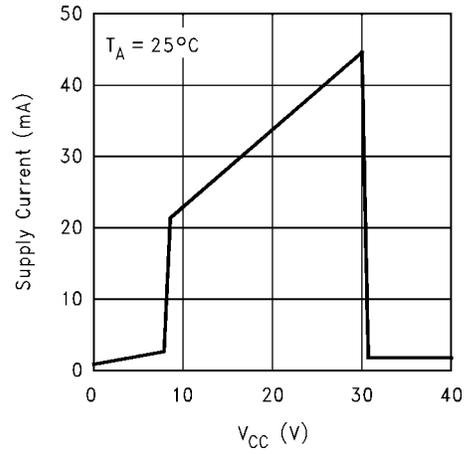
Typical Electrical Characteristics

Standby Supply Current vs V_{CC}



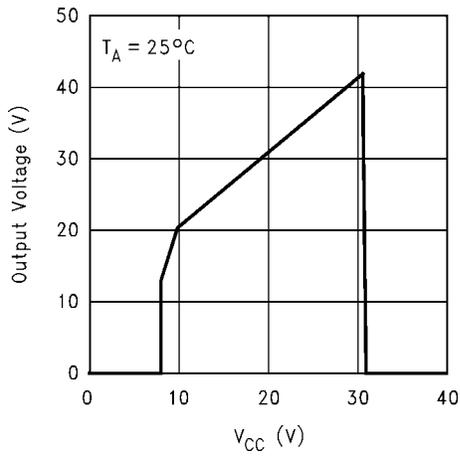
1231717

Operating Supply Current vs V_{CC}



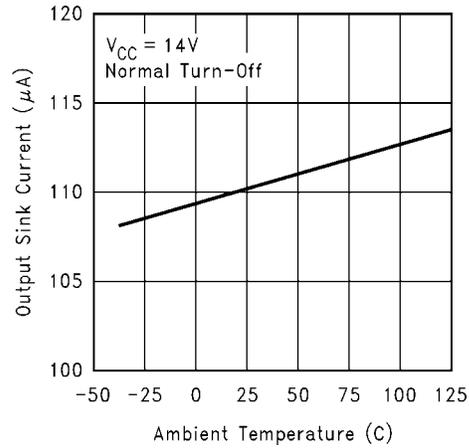
1231718

Output Voltage vs V_{CC}



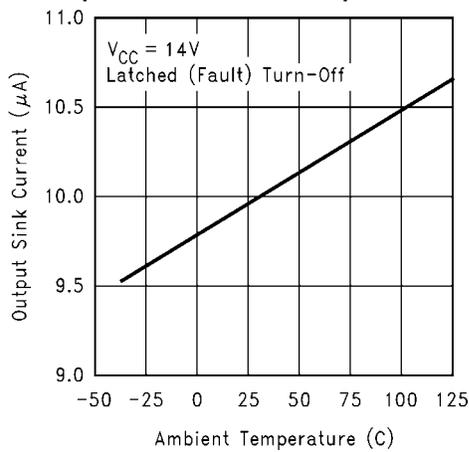
1231719

Output Sink Current vs Temperature



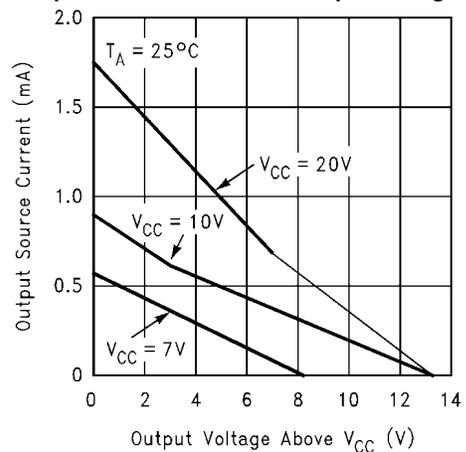
1231720

Output Sink Current vs Temperature



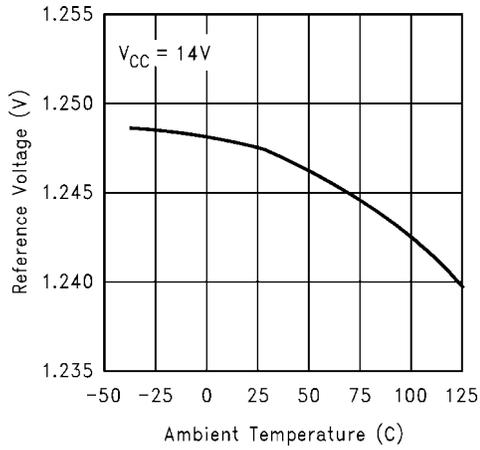
1231721

Output Source Current vs Output Voltage



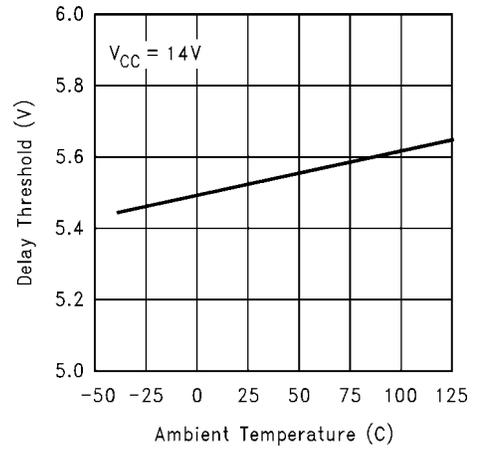
1231722

Reference Voltage vs Temperature



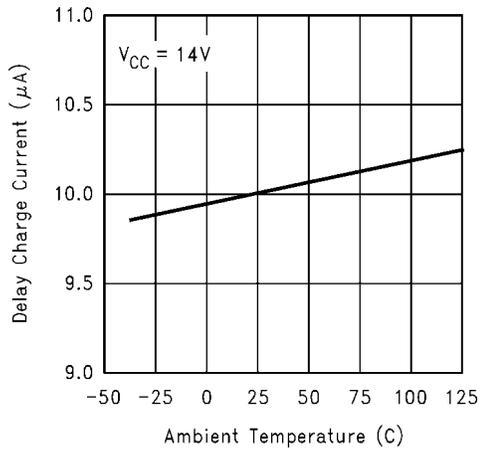
1231723

Delay Threshold vs Temperature



1231724

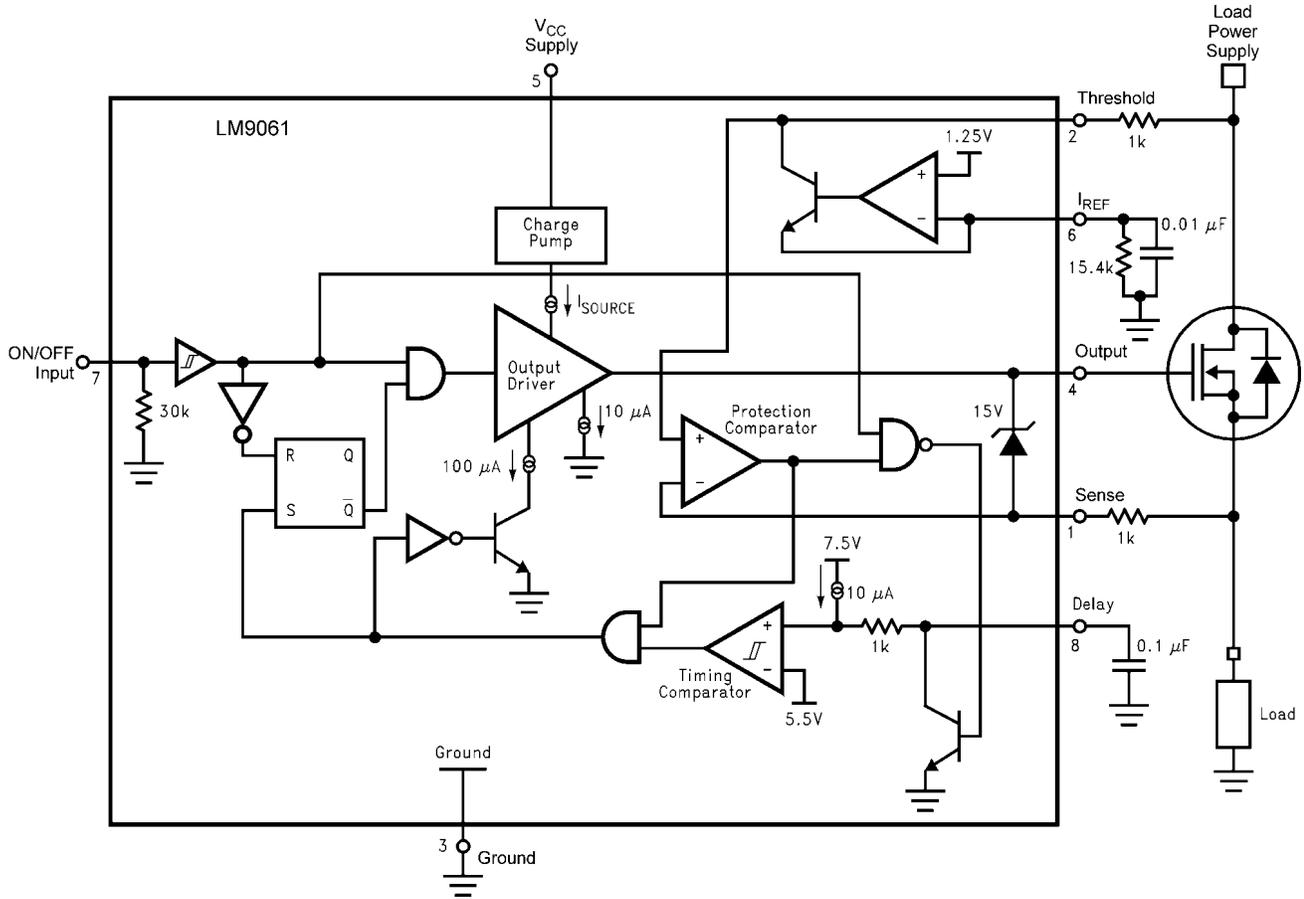
Delay Charge Current vs Temperature



1231725

Block Diagram

LM9061



1231704

Application Information

BASIC OPERATION

The LM9061 contains a charge pump circuit that generates a voltage in excess of the applied supply voltage to provide gate drive voltage to power MOSFET transistors. Any size of N-channel power MOSFET, including multiple parallel connected MOSFETs for very high current applications, can be used to apply power to a ground referenced load circuit in what is referred to as "high side drive" applications. Figure 1 shows the basic application of the LM9061.

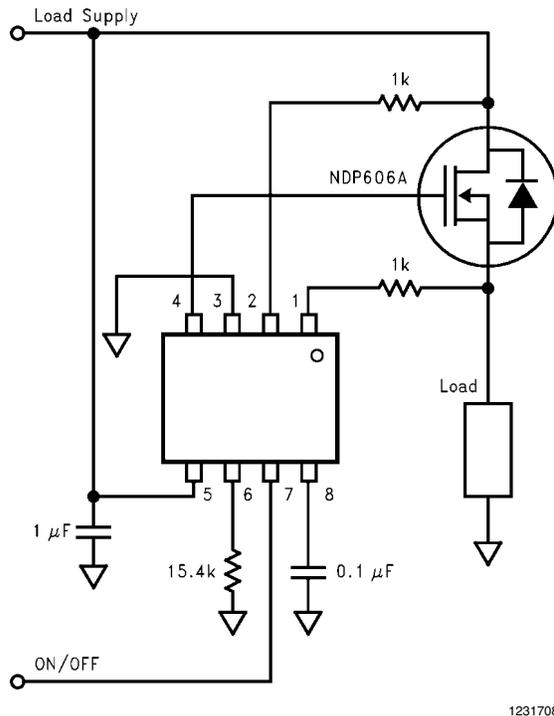


FIGURE 1. Basic Application Circuit

When commanded ON by a logic "1" input to pin 7 the gate drive output, pin 4, rises quickly to the V_{CC} supply potential at pin 5. Once the gate voltage exceeds the gate-source threshold voltage of the MOSFET, $V_{GS(ON)}$, (the source is connected to ground through the load) the MOSFET turns ON and connects the supply voltage to the load. With the source at near the supply potential, the charge pump continues to provide a gate voltage greater than the supply to keep the MOSFET turned ON. To protect the gate of the MOSFET, the output voltage of the LM9061 is clamped to limit the maximum V_{GS} to 15V.

It is important to remember that during the Turn-ON of the MOSFET the output current to the Gate is drawn from the V_{CC} supply pin. The V_{CC} pin should be bypassed with a capacitor with a value of at least ten times the Gate capacitance, and no less than 0.1 μF . The output current into the Gate will typically be 30 mA with V_{CC} at 14V and the Gate at 0V. As the Gate voltage rises to V_{CC} , the output current will decrease. When the Gate voltage reaches V_{CC} , the output current will typically be 1 mA with V_{CC} at 14V.

A logic "0" on pin 7 turns the MOSFET OFF. When commanded OFF a 110 μA current sink is connected to the output pin. This current discharges the gate capacitances of the MOSFET linearly. When the gate voltage equals the source

voltage (which is near the supply voltage) plus the $V_{GS(ON)}$ threshold of the MOSFET, the source voltage starts following the gate voltage and ramps toward ground. Eventually the source voltage equals 0V and the gate continues to ramp to zero thus turning OFF the power device. This gradual Turn-OFF characteristic, instead of an abrupt removal of the gate drive, can, in some applications, minimize the power dissipation in the MOSFET or reduce the duration of negative transients, as is the case when driving inductive loads. In the event of an overstress condition on the power device, the turn OFF characteristic is even more gradual as the output sinking current is only 10 μA (see Protection Circuitry Section).

TURN ON AND TURN OFF CHARACTERISTICS

The actual rate of change of the voltage applied to the gate of the power device is directly dependent on the input capacitances of the MOSFET used. These times are important to know if the power to the load is to be applied repetitively as is the case with pulse width modulation drive. Of concern are the capacitances from gate to drain, C_{GD} , and from gate to source, C_{GS} . Figure 2 details the turn ON and turn OFF intervals in a typical application. An inductive load is assumed to illustrate the output transient voltage to be expected. At time t_1 , the ON/OFF input goes high. The output, which drives the gate of the MOSFET, immediately pulls the gate voltage towards the V_{CC} supply of the LM9061. The source current from pin 4 is typically 30 mA which quickly charges C_{GD} and C_{GS} . As soon as the gate reaches the $V_{GS(ON)}$ threshold of the MOSFET, the switch turns ON and the source voltage starts rising towards V_{CC} . V_{GS} remains equal to the threshold voltage until the source voltage reaches V_{CC} . While V_{GS} is constant only C_{GD} is charging. When the source voltage reaches V_{CC} , at time t_2 , the charge pump takes over the drive of the gate to ensure that the MOSFET remains ON.

The charge pump is basically a small internal capacitor that acquires and transfers charge to the output pin. The clock rate is set internally at typically 300 kHz. In effect the charge pump acts as a switched capacitor resistor (approximately 67k) connected to a voltage that is clamped at 13V above the Sense input pin of the LM9061 which is equal to the V_{CC} supply in typical applications. The gate voltage rises above V_{CC} in an exponential fashion with a time constant dependent upon the sum of C_{GD} and C_{GS} . At this time however the load is fully energized. At time t_3 , the charge pump reaches its maximum potential and the switch remains ON.

At time t_4 , the ON/OFF input goes low to turn OFF the MOSFET and remove power from the load. At this time the charge pump is disconnected and an internal 110 μA current sink begins to discharge the gate input capacitances to ground. The discharge rate ($\Delta V/\Delta T$) is equal to $110 \mu\text{A}/(C_{GD} + C_{GS})$. The load is still fully energized until time t_5 when the gate voltage has reached a potential of the source voltage (V_{CC}) plus the $V_{GS(ON)}$ threshold voltage of the MOSFET. Between time t_5 and t_6 , the V_{GS} voltage remains constant and the source voltage follows the gate voltage. With the voltage on C_{GD} held constant the discharge rate now becomes $110 \mu\text{A}/C_{GD}$.

At time t_6 the source voltage reaches 0V. As the gate moves below the $V_{GS(ON)}$ threshold the MOSFET tries to turn OFF. With an inductive load, if the current in the load has not collapsed to zero by time t_6 , the action of the MOSFET turning OFF will create a negative voltage transient (flyback) across the load. The negative transient will be clamped to $-V_{GS(ON)}$ because the MOSFET must turn itself back ON to continue conducting the load current until the energy in the inductance has been dissipated (at time t_7).

MOSFET PROTECTION CIRCUITRY

A unique feature of the LM9061 is the ability to sense excessive power dissipation in the MOSFET and latch it OFF to prevent permanent failure. Instead of sensing the actual current flowing through the MOSFET to the load, which typically requires a small valued power resistor in series with the load, the LM9061 monitors the voltage drop from drain to source, V_{DS} , across the MOSFET. This "lossless" technique allows all of the energy available from the supply to be conducted to the load as required. The only power loss is that of the MOSFET

itself and proper selection of a particular power device for an application will minimize this concern. Another benefit of this technique is that all applications use only standard inexpensive $\frac{1}{4}W$ or less resistors.

To utilize this lossless protection technique requires knowledge of key characteristics of the power MOSFET used. In any application the emphasis for protection can be placed on either the power MOSFET or on the amount of current delivered to the load, with the assumption that the selected MOSFET can safely handle the maximum load current.

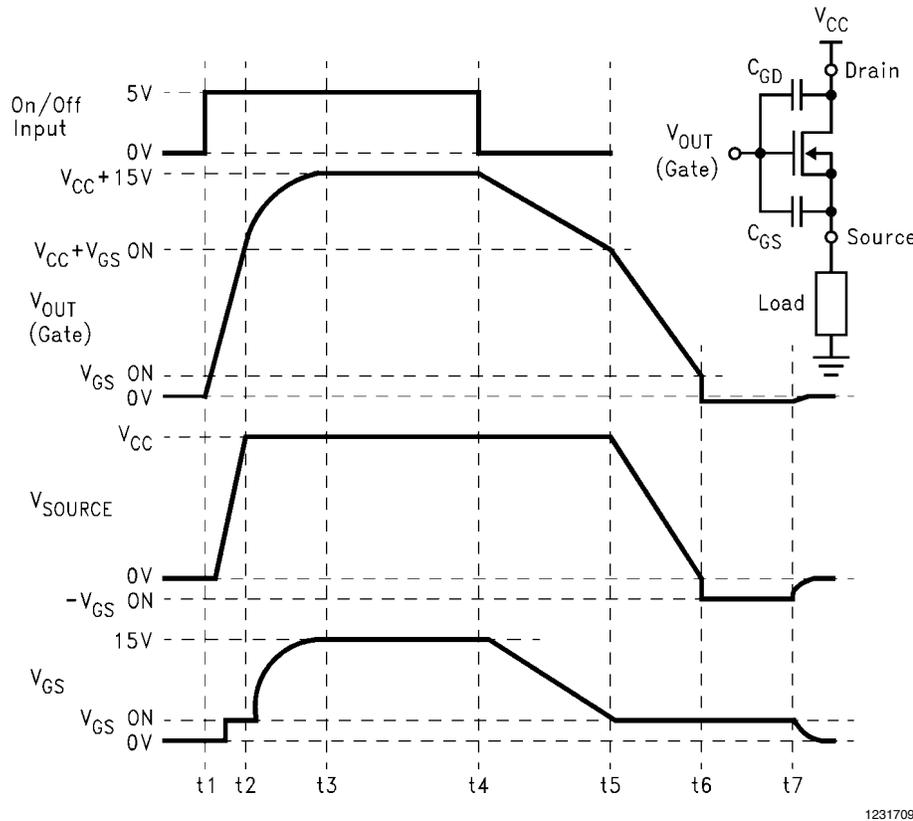


FIGURE 2. Turn ON and Turn OFF Waveforms

To protect the MOSFET from exceeding its maximum junction temperature rating, the power dissipation needs to be limited. The maximum power dissipation allowed (derated for temperature) and the maximum drain to source ON resistance, $R_{DS(ON)}$, with both at the maximum operating ambient temperature, needs to be determined. When switched ON the power dissipation in the MOSFET will be:

$$P_{DISS} = \frac{V_{DS}^2}{R_{DS(ON)}}$$

The V_{DS} voltage to limit the maximum power dissipation is therefore:

$$V_{DS(MAX)} = \sqrt{P_{D(MAX)} \times R_{DS(ON)(MAX)}}$$

With this restriction the actual load current and power dissipation obtained will be a direct function of the actual $R_{DS(ON)}$ of the MOSFET at any particular ambient temperature but the

junction temperature of the power device will never exceed its rated maximum.

To limit the maximum load current requires an estimate of the minimum $R_{DS(ON)}$ of the MOSFET (the minimum $R_{DS(ON)}$ of discrete MOSFETs is rarely specified) over the required operating temperature range.

The maximum current to the load will be:

$$I_{LOAD(MAX)} = \frac{V_{DS}}{R_{DS(ON)(MIN)}}$$

The maximum junction temperature of the MOSFET and/or the maximum current to the load can be limited by monitoring and setting a maximum operational value for the drain to source voltage drop, V_{DS} . In addition, in the event that the load is inadvertently shorted to ground, the power device will automatically be turned-OFF.

In all cases, should the MOSFET be switched OFF by the built in protection comparator, the output sink current is switched to only 10 μA to gradually turn OFF the power device.

To prevent this situation a delay capacitor is required at pin 8. The selection of a minimum capacitor value to ensure proper start-up depends primarily on the load characteristics and how much time is required for the MOSFET to raise the load voltage to the point where the Sense input is more positive than the Threshold input ($T_{\text{START-UP}}$). Some experimentation is required if a specific minimum delay time characteristic is desired. Therefore:

$$C_{\text{DELAY}} = \frac{(I_{\text{DELAY}} \times T_{\text{START-UP}})}{V_{\text{TIMER}}}$$

In the absence of a specific delay time requirement, a value for C_{DELAY} of 0.1 μF is recommended.

OVER VOLTAGE PROTECTION

The LM9061 will remain operational with up to +26V on V_{CC} . If V_{CC} increases to more than typically +30V the LM9061 will turn off the MOSFET to protect the load from excessive voltage. When V_{CC} has returned to the normal operating range the device will return to normal operation without requiring toggling the ON/OFF input. This feature will allow MOSFET operation to continue in applications that are subject to periodic voltage transients, such as automotive applications.

For circuits where the load is sensitive to high voltages, the circuit shown in *Figure 5* can be used. The addition of a zener on the Sense input (pin 1) will provide a maximum voltage reference for the Protection Comparator. The Sense resistor is required in this application to limit the zener current. When the device is ON, and the load supply attempts to rise higher than $(V_{\text{ZENER}} + V_{\text{THRESHOLD}})$, the Protection comparator will trip, and the Delay Timer will start. If the high supply voltage condition lasts long enough for the Delay Timer to time out, the MOSFET will be latched off. The ON/OFF input will need to be toggled to restart the MOSFET.

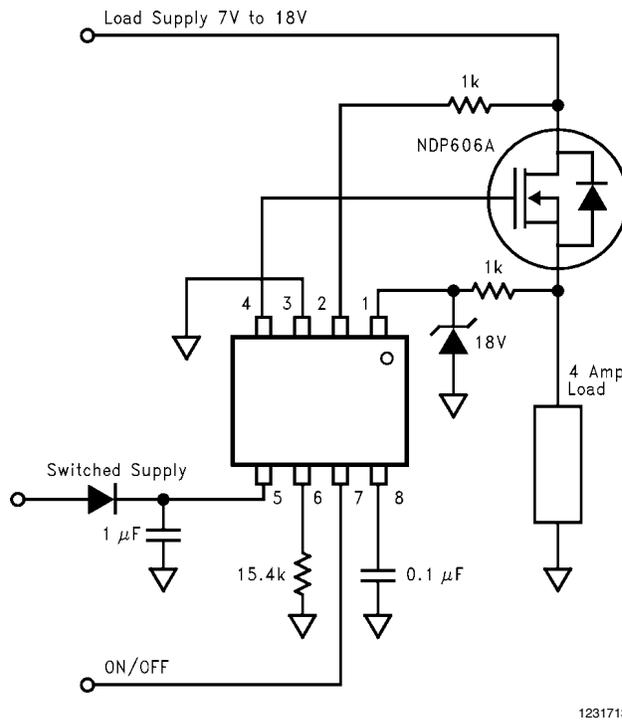


FIGURE 5. Adding Over-Voltage Protection

REVERSE BATTERY

The LM9061 is not protected against reverse polarity supply connections. If the V_{CC} supply should be taken negative with respect to ground, the current from the V_{CC} pin should be limited to 20 mA. The addition of a diode in series with the V_{CC} input is recommended. This diode drop does not subtract significantly from the charge pump gate overdrive output voltage.

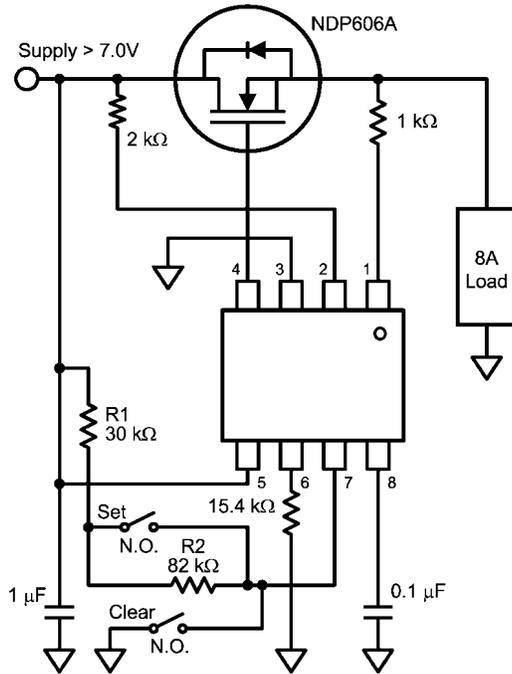
LOW BATTERY

An additional feature the LM9061 is an Under-Voltage Shut-OFF function (UVSO). The typical UVSO threshold is 6.2V, and does not have hysteresis. When V_{CC} is between the guaranteed minimum operating voltage of 7.0V, and the UVSO threshold, the operation of the MOSFET gate drive, the delay timer, and the protection circuitry is not guaranteed. Operation in this region should be avoided. When V_{CC} falls below the UVSO threshold the charge pump will be disabled and the gate will be discharged at the Normal-OFF current sink rate, typically 110 μA .

Figure 6 shows the LM9061 used as an electronic circuit breaker. This circuit provides low voltage shutdown, over-voltage latch-OFF, and over-current latch-OFF.

The low voltage shutdown uses the 'On' and 'Off' voltage thresholds, and the typical 1.2V of hysteresis, to disable the LM9061 if V_{CC} falls near, or below, the 7.0V minimum operating voltage. The low voltage shutdown is accomplished with a voltage divider biased off V_{CC} . The voltage divider is formed by R1 (30 k Ω), R2 (82 k Ω), and the internal pull-down resistor of the ON/OFF pin (30 k Ω typical). In normal operation, V_{CC} will be above the minimum operating voltage of 7.0V, and the On/Off pin will be biased above the 'Off' threshold of 1.5V maximum (1.8V typical). When V_{CC} falls to 7.0V the On/Off pin voltage will fall below the 'Off' threshold voltage and the LM9061 will be turned off.

In the event of a latch-OFF shutdown, the circuit can be reset by shutting the main supply off, then back on. An optional, normally open, switch (Clear) from the ON/OFF pin to ground, will allow a "push button clear" of the circuit after latching OFF.



1231714

FIGURE 6. Electronic Circuit Breaker

This voltage divider arrangement requires a mechanism to raise the ON/OFF pin above the 'On' threshold of 3.5V minimum (3.1V typical) when V_{CC} is less than typically 16V. This can be accomplished with a second, normally open, switch from the ON/OFF pin across R2 (Set), so that closing the switch will short R2 and the voltage at the ON/OFF pin will be typically one-half of V_{CC} . When V_{CC} is at the minimum operating voltage of 7.0V this will bias the ON/OFF pin to about 3.5V causing the LM9061 to turn on. When V_{CC} is above typically 16.5V the resistor divider will have the ON/OFF pin biased above 3.5V and shorting of the resistor R2 will not be needed.

While the scaling of the external resistor values between V_{CC} and the ON/OFF input pin, against the internal 30 kΩ resistor, can be used to increase the startup voltage, it is im-

portant that the resistor ratio always has the ON/OFF pin biased below the 'Off' threshold (1.5V) when V_{CC} falls below the minimum operating voltage of 7.0V.

The accuracy of this voltage divider arrangement is affected by normal manufacturing variations of the 'On' and 'Off' voltage thresholds and the value of internal resistor at the ON/OFF pin. If any application needs to detect with greater precision when V_{CC} is near to 7.0V, an external voltage monitor should be used to drive the ON/OFF pin. The external voltage monitor would also eliminate both the need for the switch to short R2 to start the LM9061, as well as R2.

DRIVING MOSFET ARRAYS

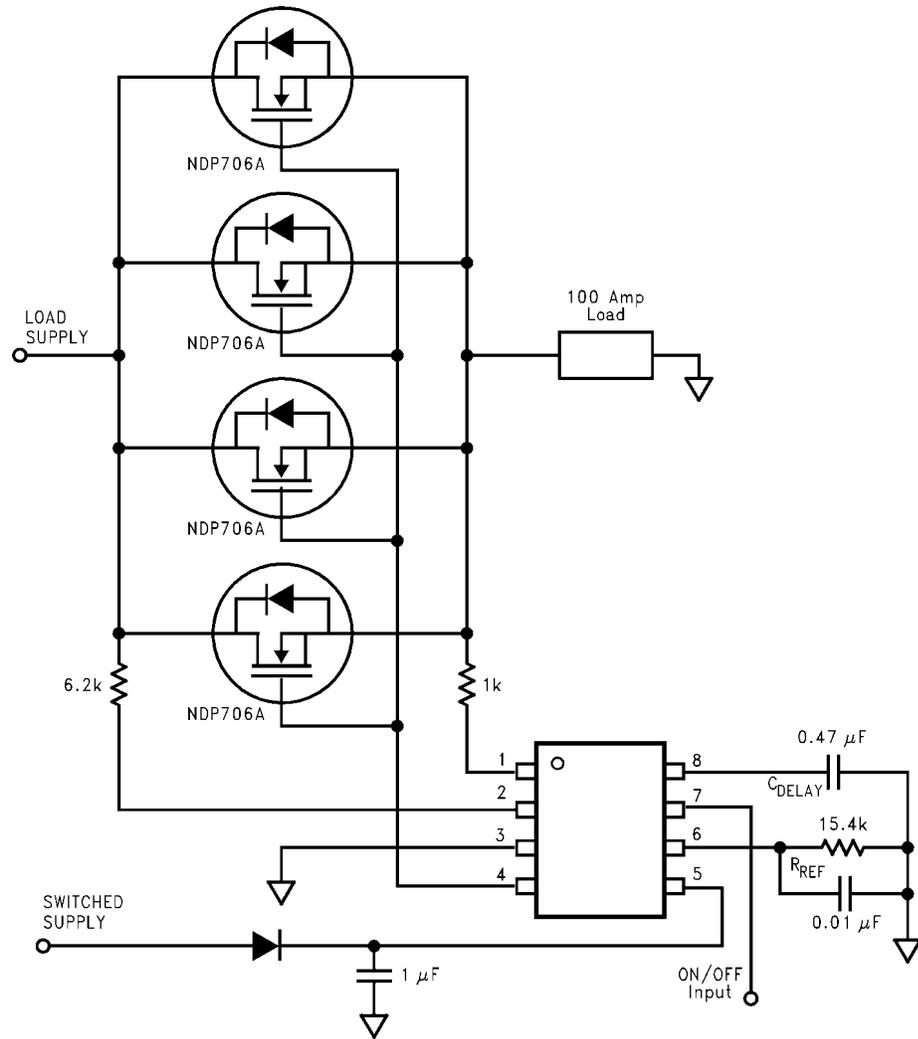
The LM9061 is an ideal driver for any application that requires multiple parallel MOSFETs to provide the necessary load current. Only a few "common sense" precautions need to be observed. All MOSFETs in the array must have identical electrical and thermal characteristics. This can be solved by using the same part number from the same manufacturer for all of the MOSFETs in the array. Also, all MOSFETs should have the same style heat sink or, ideally, all mounted on the same heat sink. The electrical connection of the MOSFETs should get special attention. With typical $R_{DS(ON)}$ values in the range of tens of milli-Ohms, a poor electrical connection for one of the MOSFETs can render it useless in the circuit.

Also, the MOSFET dissipation during the Normal-OFF discharge of the gate capacitance, 70 μ A minimum and 110 μ A typical, needs consideration.

One particular caution is that, in the event of a fault condition, the Latch-OFF current sink, 10 μ A typical, may not be able to discharge the total gate capacitance in a timely manner to prevent damage to the MOSFETs.

Figure 7 shows a circuit with four parallel NDP706A MOSFETs. This particular MOSFET has a typical $R_{DS(ON)}$ of 0.013 Ω with a T_J of 25°C, and 0.020 Ω with a T_J of +125°C.

With the V_{DS} threshold voltage being set to 500 mV, this circuit will provide a typical maximum load current of 150A at 25°C, and a typical maximum load current of 100A at 125°C. The maximum dissipation, per MOSFET, will be nearly 20W at 25°C, and 12.5W at 125°C. With up to 20W being dissipated by each of the four devices, an effective heat sink will be required to keep the T_J as low as possible when operating near the maximum load currents.



1231715

FIGURE 7. Driving Multiple MOSFETs

Notes

LM9061

Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at:

Products		Design Support	
Amplifiers	www.national.com/amplifiers	WEBENCH® Tools	www.national.com/webench
Audio	www.national.com/audio	App Notes	www.national.com/appnotes
Clock and Timing	www.national.com/timing	Reference Designs	www.national.com/refdesigns
Data Converters	www.national.com/adc	Samples	www.national.com/samples
Interface	www.national.com/interface	Eval Boards	www.national.com/evalboards
LVDS	www.national.com/lvds	Packaging	www.national.com/packaging
Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage Reference	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Solutions	www.national.com/solutions
Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero
Temperature Sensors	www.national.com/tempensors	SolarMagic™	www.national.com/solarmagic
Wireless (PLL/VCO)	www.national.com/wireless	PowerWise® Design University	www.national.com/training

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2009 National Semiconductor Corporation

For the most current product information visit us at www.national.com



**National Semiconductor
Americas Technical
Support Center**
Email: support@nsc.com
Tel: 1-800-272-9959

**National Semiconductor Europe
Technical Support Center**
Email: europe.support@nsc.com

**National Semiconductor Asia
Pacific Technical Support Center**
Email: ap.support@nsc.com

**National Semiconductor Japan
Technical Support Center**
Email: jpn.feedback@nsc.com