National Semiconductor

April 1995

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 a programmable delay time interval.

Designed for the automotive application environment the LM9061 has a wide operating temperature range of -40°C to $+125$°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 package, and an 8-pin dual in-line package.

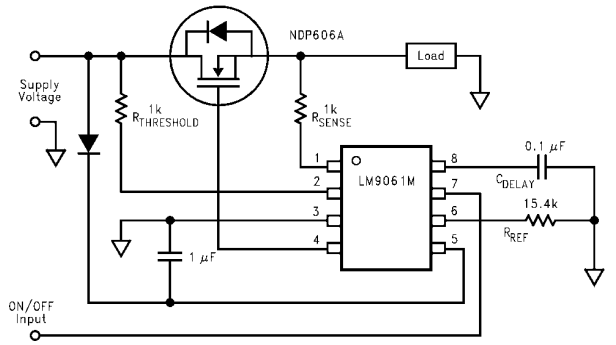
Features

- 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)
- Undervoltage shut OFF with $V_{CC} < 7V$
- Overvoltage shut OFF with $V_{CC} > 26V$
- Withstands 60V supply transients
- CMOS logic compatible ON/OFF control input
- Surface mount and dual in-line packages available

Applications

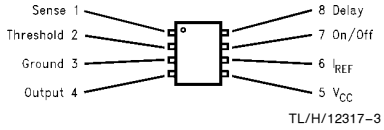
- Valve, relay and solenoid drivers
- Lamp drivers
- DC motor PWM drivers
- Logic controlled power supply distribution switch
- Electronic circuit breaker

Typical Application



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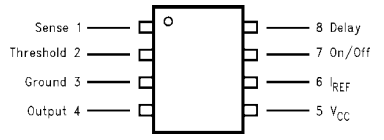
Connection Diagrams



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Top View

Order Number LM9061M
See NS Package Number M08A



TL/H/12317–2

Top View

Order Number LM9061N
See NS Package Number N08E

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RRD-B30M115/Printed in U. S. A.

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 kΩ)	−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 (Soldering, 10 seconds)	260°C

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
LM9061N	100°C/W

DC Electrical Characteristics

7V ≤ V_{CC} ≤20V, R_{REF} = 15.4 kΩ, −40°C ≤ T_J ≤ +125°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 μF, Includes Turn-ON Transient Output Current		40	mA
ON/OFF CONTROL INPUT					
$V_{IN}(0)$	ON/OFF Input Logic "0"	V_{OUT} = OFF		1.5	V
$V_{IN}(1)$	ON/OFF Input Logic "1"	V_{OUT} = 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	VON/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 μA		0.9	V
V_{CLAMP}	Sense to Output Clamp Voltage	ON/OFF = "1", V_{SENSE} = $V_{THRESHOLD}$	11	15	V
$I_{SINK(Normal-OFF)}$	Output Sink Current, Normal Operation	ON/OFF = "0", V_{DELAY} = 0V, V_{SENSE} = $V_{THRESHOLD}$	75	145	μA
$I_{SINK(Latch-OFF)}$	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
$I_{THR(LEAKAGE)}$	Threshold Pin Leakage Current	V_{CC} = Open, 7V ≤ $V_{THRESHOLD}$ ≤ 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 mA		0.4	V

AC Timing Characteristics

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

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

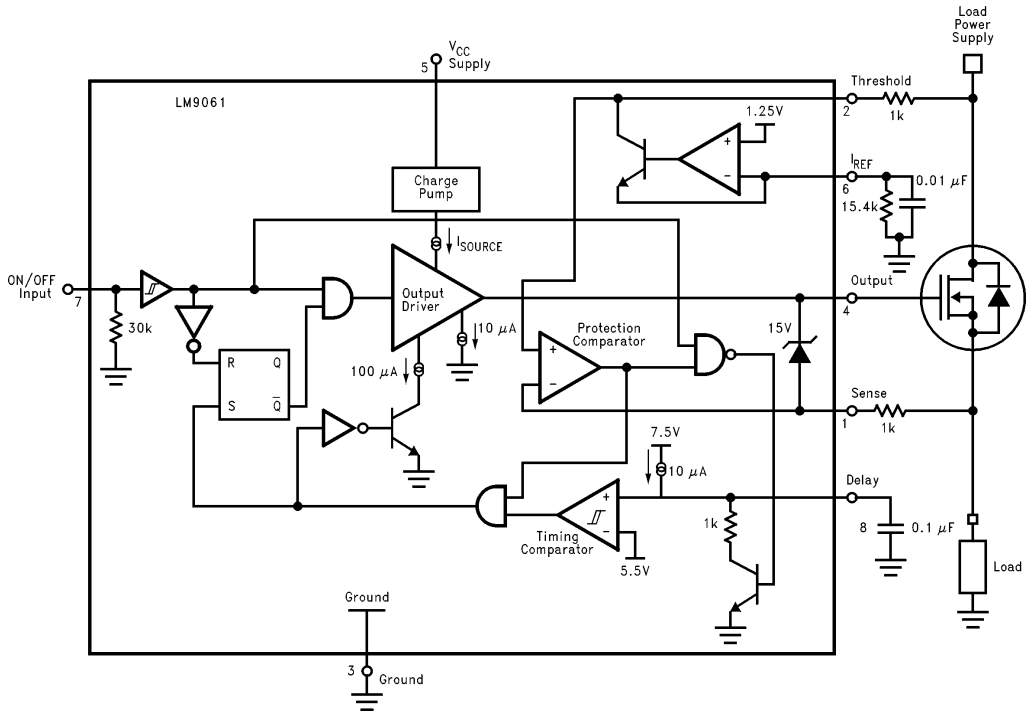
Note 1: Absolute Maximum Ratings indicate the limits beyond which damage to the device may occur.

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 1500Ω resistor.

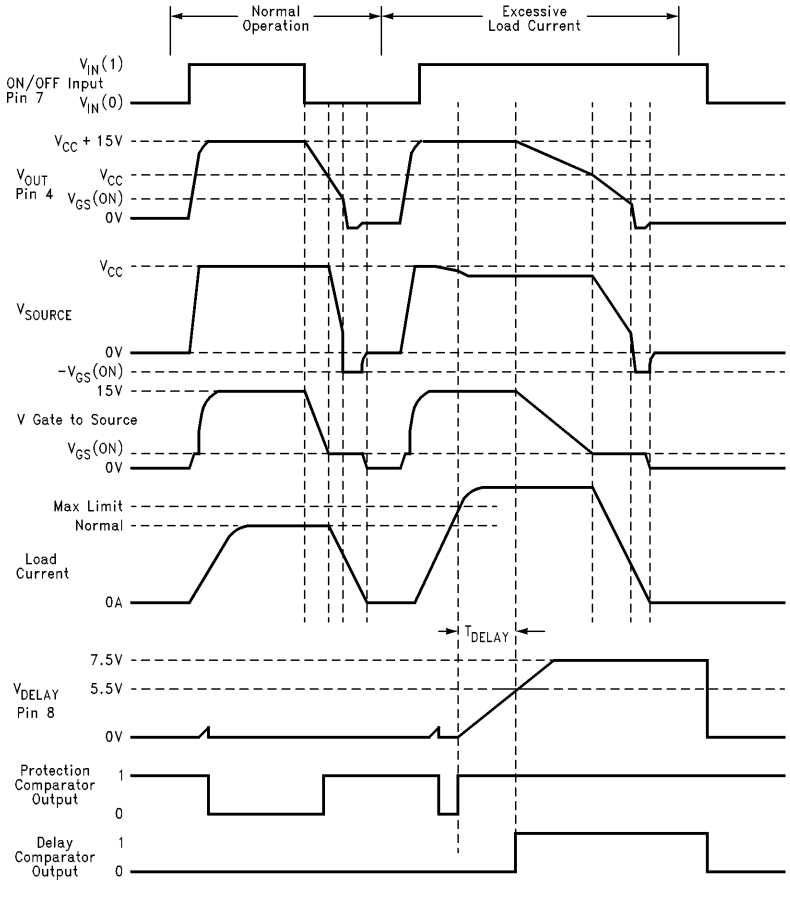
Note 4: The AC Timing specifications for T_{OFF} are not production tested, and therefore are not specifically guaranteed. Limits are provided for reference purposes only. Smaller load capacitances will have proportionally faster turn-ON and turn-OFF times.

Block Diagram



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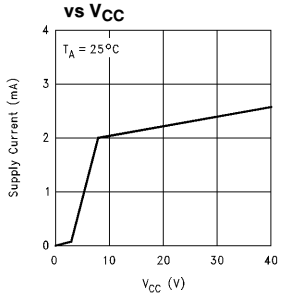
Typical Operating Waveforms



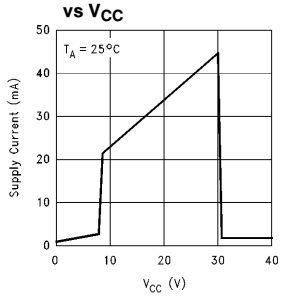
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Typical Electrical Characteristics

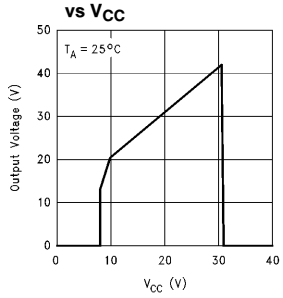
Standby Supply Current vs V_{CC}



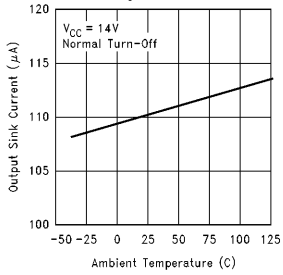
Operating Supply Current vs V_{CC}



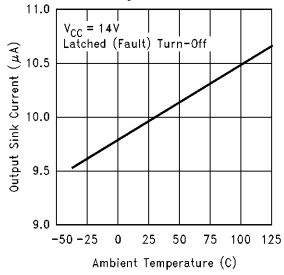
Output Voltage vs V_{CC}



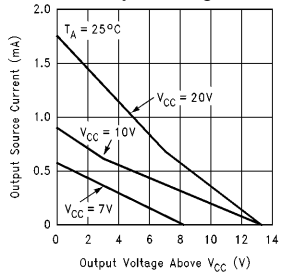
Output Sink Current vs Temperature



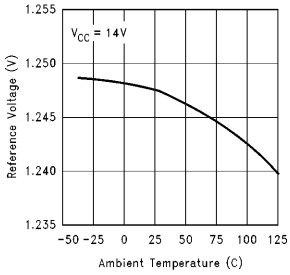
Output Sink Current vs Temperature



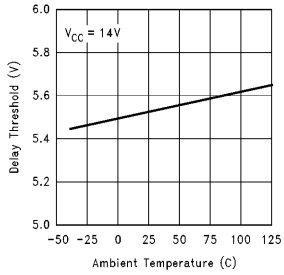
Output Source Current vs Output Voltage



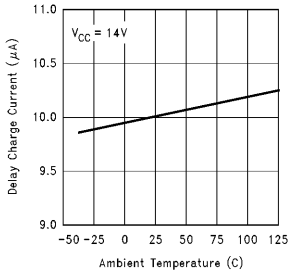
Reference Voltage vs Temperature



Delay Threshold vs Temperature



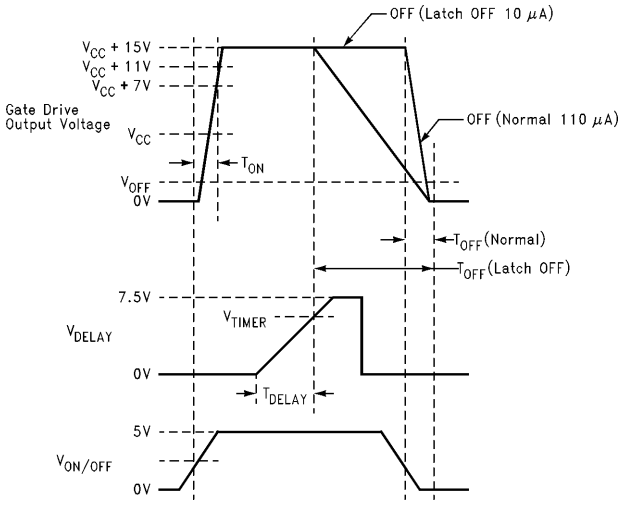
Delay Charge Current vs Temperature



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Typical Electrical Characteristics (Continued)

Timing Definitions

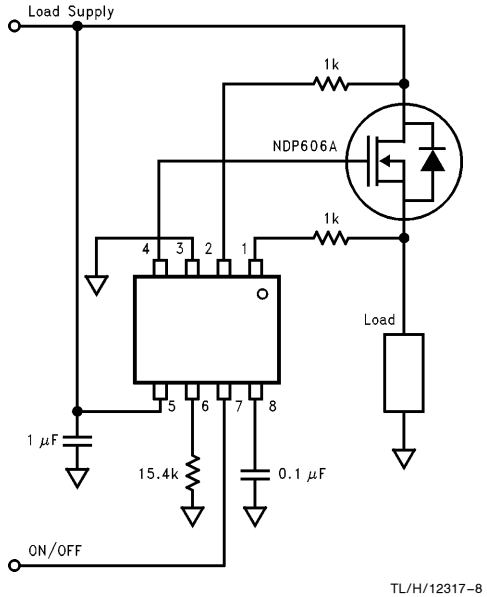


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Application Hints

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.



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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).

Application Hints (Continued)

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 t1, 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 reaches V_{CC}. While V_{GS} is constant only C_{GD} is charging. When the source voltage reaches V_{CC}, at time t2, 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 t3, the charge pump reaches its maximum potential and the switch remains ON.

At time t4, 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 μA/($C_{GD} + C_{GS}$).

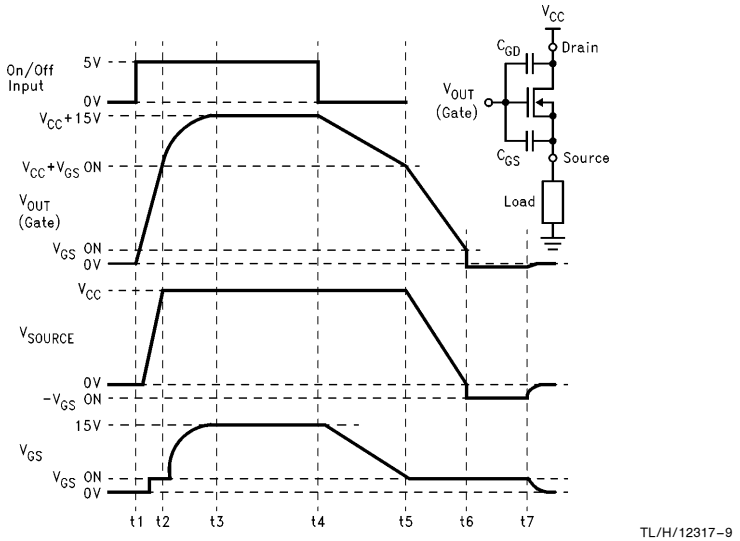
The load is still fully energized until time t5 when the gate voltage has reached a potential of the source voltage (V_{CC}) plus the $V_{GS(ON)}$ threshold voltage of the MOSFET. Between time t5 and t6, the V_{GS} voltage remains constant and the source voltage follows the gate voltage. With the voltage on C_{GD} held constant the discharge rate now becomes 110 μA/C_{GD}.

At time t6 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 t6, 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 t7).

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 ¼W 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.



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FIGURE 2. Turn ON and Turn OFF Waveforms

Application Hints (Continued)

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.

Figure 3 illustrates how the threshold voltage for the internal protection comparator is established.

Two resistors connect the drain and source of the MOSFET to the LM9061. The Sense input, pin 1, monitors the source voltage while the Threshold input, pin 2, is connected to the drain, which is also connected to the constant load power supply. Both of these inputs are the two inputs to the protection comparator. Should the voltage at the sense input ever drop below the voltage at the threshold input, the protection comparator output goes high and initiates an automatic latch-OFF function to protect the power device. Therefore the switching threshold voltage of the comparator directly controls the maximum V_{DS} allowed across the MOSFET while conducting load current.

The threshold voltage is set by the voltage drop across resistor $R_{THRESHOLD}$. A reference current is fixed by a resistor to ground at I_{REF}, pin 6. To precisely regulate the reference current over temperature, a stable band gap reference voltage is provided to bias a constant current sink. The reference current is set by:

$$I_{REF} = \frac{V_{REF}}{R_{REF}}$$

The reference current sink output is internally connected to the threshold pin. I_{REF} then flows from the load supply through $R_{THRESHOLD}$. The fixed voltage drop across $R_{THRESHOLD}$ is approximately equal to the maximum value of V_{DS} across the MOSFET before the protection comparator trips.

It is important to note that the programmed reference current serves a multiple purpose as it is used internally for biasing and also has a direct effect on the internal charge pump switching frequency. The design of the LM9061 is optimized for a reference current of approximately 80 μA, set with a 15.4 kΩ $\pm$1% resistor for R_{REF}. To obtain the guaranteed performance characteristics it is recommended that a 15.4 kΩ resistor be used for R_{REF}.

The protection comparator is configured such that during normal operation, when the output of the comparator is low, the differential input stage of the comparator is switched in

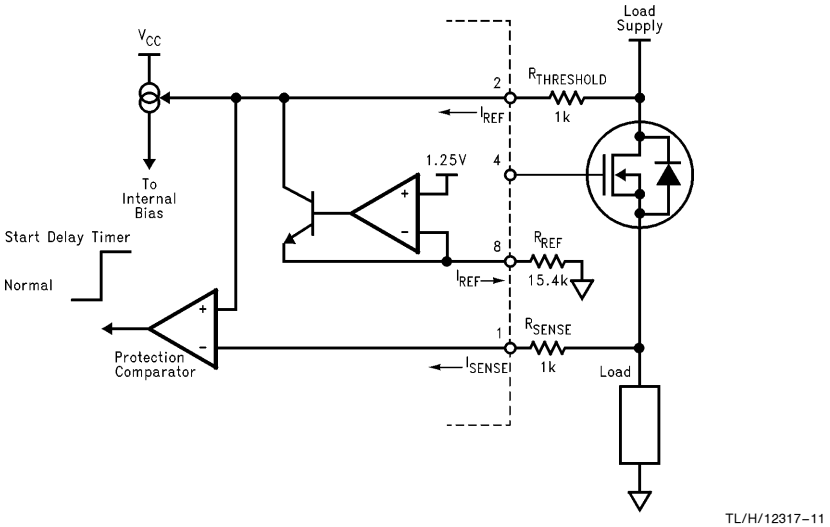


FIGURE 3. Protection Comparator Biasing

Application Hints (Continued)

a manner that there is virtually no current flowing into the non-inverting input of the comparator. Therefore, only I_{REF} flows through resistor $R_{THRESHOLD}$. All of the input bias current, 20 μA maximum, for the comparator input stage (twice the I_{SENSE} specification of 10 μA maximum, defined for equal potentials on each of the comparator inputs) however flows into the inverting input through resistor R_{SENSE}. At the comparator threshold, the current through R_{SENSE} will be no more than the I_{SENSE} specification of 10 μA.

To tailor the $V_{DS\ (MAX)}$ threshold for any particular application, the resistor $R_{THRESHOLD}$ can be selected per the following formula:

$$V_{DS\ (MAX)} = \frac{V_{REF} \times R_{THR}}{R_{REF}} - (I_{SENSE} \times R_{SENSE}) + V_{OS}$$

where $R_{REF} = 15.4\ k\Omega$, I_{SENSE} is the input bias current to the protection comparator, R_{SENSE} is the resistor connected to pin 1 and V_{OS} is the offset voltage of the protection comparator (typically in the range of ± 10 mV).

The resistor R_{SENSE} is optional, but is strongly recommended to provide transient protection for the Sense pin, especially when driving inductive type loads. A minimum value of 1 kΩ will protect the pin from transients ranging from -25V to $+60$V. This resistor should be equal to, or less than, the resistor used for $R_{THRESHOLD}$. Never set R_{SENSE} to a value larger than $R_{THRESHOLD}$. When the protection comparator output goes high, the total bias current for the input stage transfers from the Sense pin to the Threshold pin, thereby changing the voltages present at the inputs to the comparator. For consistent switching of the comparator right at the desired threshold point, the voltage drop that occurs at the non-inverting input (Threshold) should equal, or exceed, the rise in voltage at the inverting input (Sense).

In automotive applications the load supply may be the battery of the vehicle whereas the V_{CC} supply for the LM9061 is a switched ignition supply. When the V_{CC} supply is switched OFF there is always a concern for the amount of current drained from the battery. The only current drain under this condition is a leakage current into the Threshold pin which is less than 10 μA.

A bypass capacitor across R_{REF} is optional and is used to help keep the reference voltage constant in applications where the V_{CC} supply is subject to high levels of transient noise. This bypass capacitor should be no larger than 0.1 μF, and is not needed for most applications.

DELAY TIMER

To allow the MOSFET to conduct currents beyond the protection threshold for a brief period of time, a delay timer function is provided. This timer delays the actual latching OFF of the MOSFET for a programmable interval. This feature is important to drive loads which require a surge of current in excess of the normal ON current upon start up, or at any point in time, such as lamps and motors. *Figure 4* details the delay timer circuitry. A capacitor connected from the Delay pin 8, to ground sets the delay time interval. With the MOSFET turned ON and all conditions normal, the output of the protection comparator is low and this keeps the discharge transistor ON. This transistor keeps the delay capacitor discharged. Should a surge of load current trip the protection comparator high, the discharge transistor turns OFF and an internal 10 μA current source begins linearly charging the delay capacitor.

If the surge current, with excessive V_{DS} voltage, lasts long enough for the capacitor to charge to the timing comparator threshold of typically 5.5V, the output of the comparator will go high to set a flip-flop and immediately latch the MOSFET OFF. It will not re-start until the ON/OFF Input is toggled low then high.

The delay time interval is set by the selection of C_{DELAY} and can be found from:

$$T_{DELAY} = \frac{(V_{TIMER} \times C_{DELAY})}{I_{DELAY}}$$

where typically $V_{TIMER} = 5.5$V and $I_{DELAY} = 10\mu$A.

Charging of the delay capacitor is clamped at approximately 7.5V which is the internal bias voltage for the 10 μA current source.

MINIMUM DELAY TIME

A minimum delay time interval is required in all applications due to the nature of the protection circuitry. At the instant the MOSFET is commanded ON, the voltage across the MOSFET, V_{DS}, is equal to the full load supply voltage because the source is held at ground by the load. This condition will immediately trip the protection comparator. Without a minimum delay time set, the timing comparator will trip and force the MOSFET to latch OFF thereby never allowing the load to be energized.

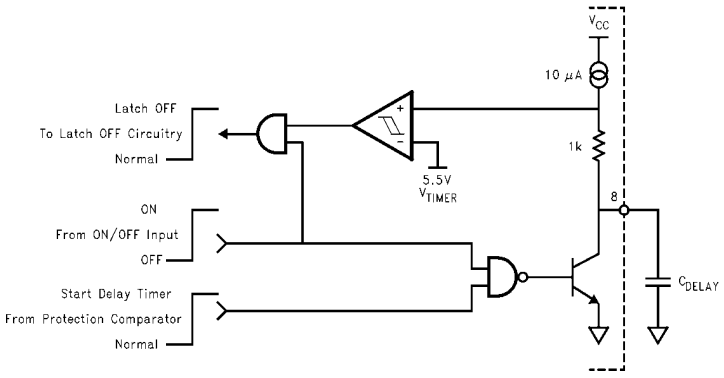


FIGURE 4. Delay Timer

Application Hints (Continued)

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 ($T_{START-UP}$). Some experimentation is required if a specific minimum delay time characteristic is desired. Therefore:

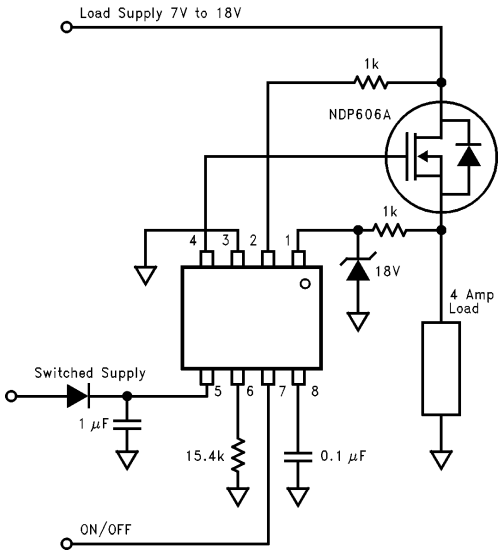
$$C_{DELAY} = \frac{(I_{DELAY} \times T_{START-UP})}{V_{TIMER}}$$

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_{ZENER} + $V_{THRESHOLD}$), 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.



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FIGURE 5. Adding Over-Voltage Protection

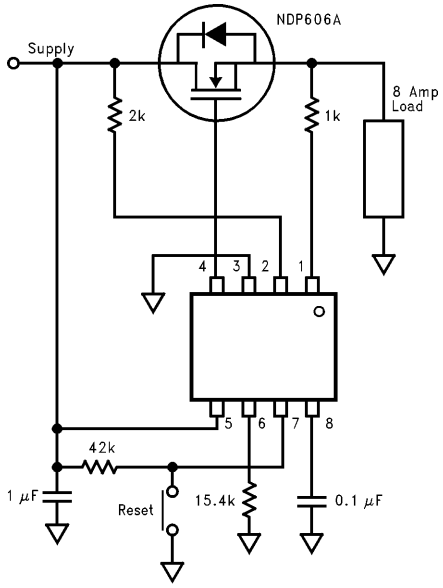
REVERSE BATTERY

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

As an additional protection feature the LM9061 incorporates an Undervoltage Shut-OFF function. If the V_{CC} supply to the package drops below 7V, where it may not be assured that the MOSFET is actually ON when it should be, circuitry will automatically turn OFF the power MOSFET.

Figure 6 shows the LM9061 used as an electronic circuit breaker. This circuit provides low voltage shutdown, overvoltage latch OFF, and overcurrent latch 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 reset switch on the ON/OFF pin will allow a ''push-button reset'' of the circuit after latching OFF.



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FIGURE 6. Electronic Circuit Breaker

Scaling of the external resistor value, from V_{CC} to the ON/OFF input pin, with the internal 30k resistor can be used to increase the startup voltage. The circuit operation then becomes dependent on the resistor ratio and V_{CC} providing an ON/OFF pin voltage being above the ON threshold rather than the LM9061 low V_{CC} shutdown feature.

DRIVING MOSFET ARRAYS

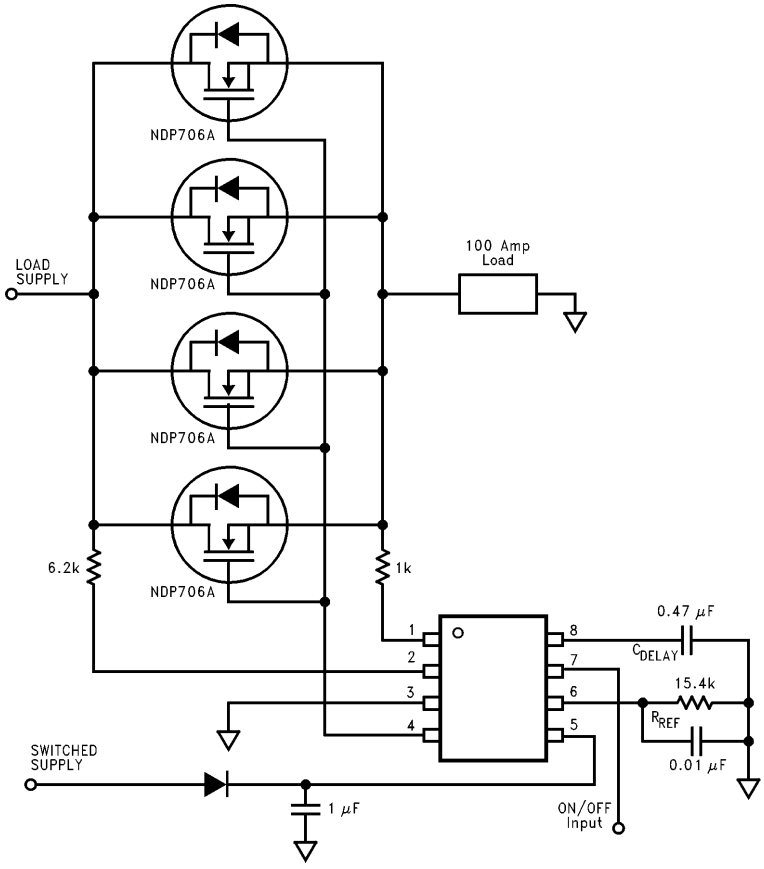
The LM9061 is an ideal driver for any application that requires multiple parallel MOSFETs to provide the necessary load current. Only a few ''common sense'' precautions need to be observed. All MOSFETs in the array must have identical electrical and thermal characteristics. This can be solved by using the same part number from the same

Application Hints (Continued)

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.

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

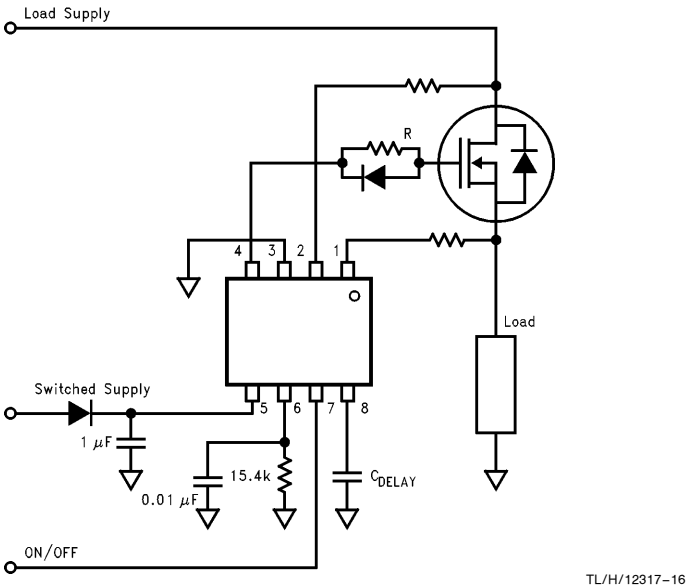
With the V_{DS} threshold voltage being set to 500 mV, this circuit will provide a typical maximum load current of 150A at 25°C, and a typical maximum load current of 100A at 125°C. The maximum dissipation, per MOSFET, will be nearly 20W at 25°C, and 12.5W at 125°C. With up to 20W being dissipated by 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.



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FIGURE 7. Driving Multiple MOSFETs

Application Hints (Continued)



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FIGURE 8. Increasing MOSFET Turn On Time

INCREASING MOSFET TURN ON TIME

The ability of the LM9061 to quickly turn on the MOSFET is an important factor in the management of the MOSFET power dissipation. Caution should be exercised when attempting to increase the MOSFET Turn On time by limiting the Gate drive current. The MOSFET average dissipation, and the LM9061 Delay time, must be recalculated with the extended switching transition time.

Figure 8 shows a method of increasing the MOSFET Turn On time, without affecting the Turn Off time. In this method the Gate is charged at an exponential rate set by the added external Gate resistor and the MOSFET Gate capacitances.

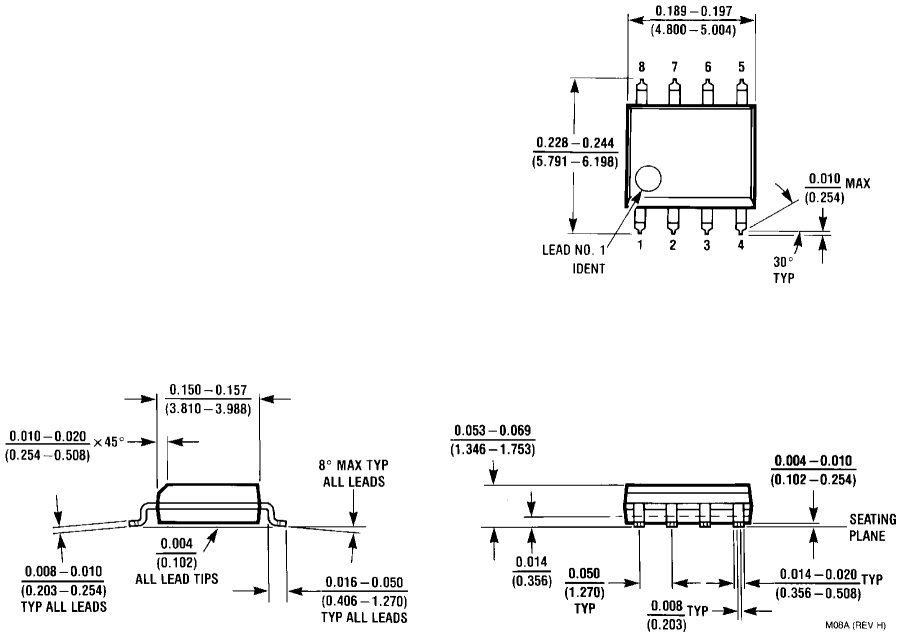
Although the LM9061 will drive MOSFETs from any manufacturer, National Semiconductor offers a wide range of power MOSFETs. *Figure 9* shows a small sample of the devices available.

Part	I_D	V_{DSS}	$R_{DS(ON)}$	Package
NDP706A	75A	60V	0.015Ω	TO-220
NDP706B	70A	60V	0.018Ω	TO-220
NDP708A	60A	80V	0.022Ω	TO-220
NDB708A	60A	80V	0.022Ω	TO-263
NDP606A	48A	60V	0.025Ω	TO-220
NDP606B	42A	60V	0.028Ω	TO-220
NDP608A	36A	80V	0.042Ω	TO-220
NDB608A	36A	80V	0.042Ω	TO-263
NDP508A	19A	80V	0.080Ω	TO-220
NDB508A	19A	80V	0.080Ω	TO-263
NDP408A	11A	80V	0.160Ω	TO-220
NDS9410	7A	30V	0.03Ω	SO-8
NDS9936*	5A	30V	0.05Ω	SO-8
NDS9945*	3.5A	60V	0.10Ω	SO-8

* Dual

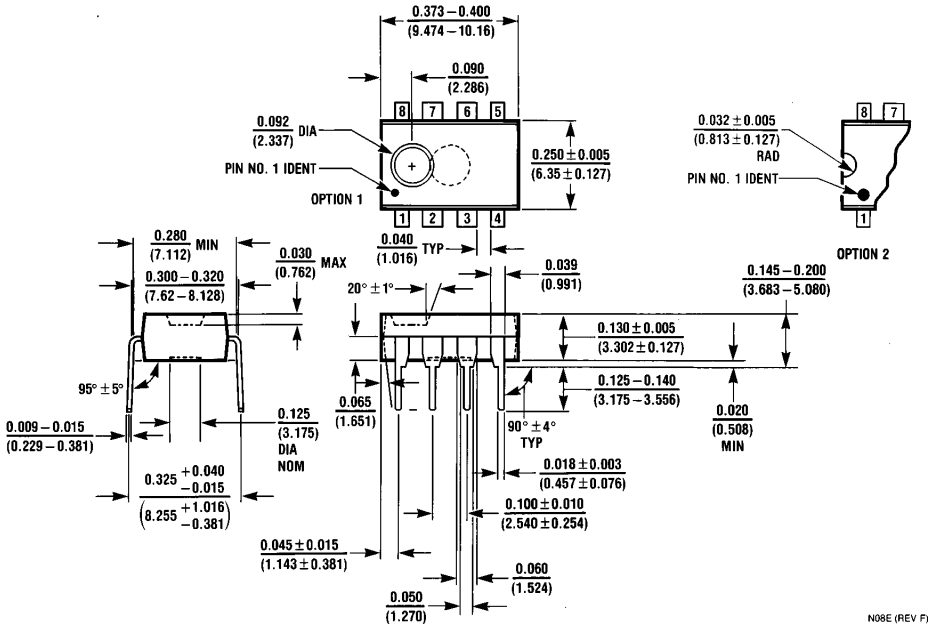
FIGURE 9. Recommended DMOS Power MOSFETs

Physical Dimensions inches (millimeters)



Order Number LM9061M
NS Package Number M08A

Physical Dimensions inches (millimeters) (Continued)



Order Number LM9061N
NS Package Number N08E

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