MIC5019

Ultra-Small High-Side N-Channel MOSFET Driver with Integrated Charge Pump

Features

- 4-lead 1.2 mm × 1.2 mm UDFN Package
- +2.7V to +9V Supply Voltage Range
- 16V Gate Drive at VDD = 9V
- 8V Gate Drive at VDD = 2.7V
- Operates in Low and High Side Configurations
- 150 µA (Typical) Supply Current at VDD = 5V
- <1 µA Shutdown Supply Current
- –40°C to +125°C Junction Temperature Range

Applications

- Load Switch
- Solenoid Drivers
- Motor Drivers

General Description

The MIC5019 is a high-side MOSFET driver with integrated charge pump designed to switch an N-Channel enhancement type MOSFET control signal in high-side or low–side applications.

The MIC5019 operates from a 2.7V to 9V supply, and generates gate voltages of 9.2V from a 3V supply, and 16V from a 9V supply. The device consumes a low 77 µA of supply current and less than 1 µA of supply current in shutdown mode.

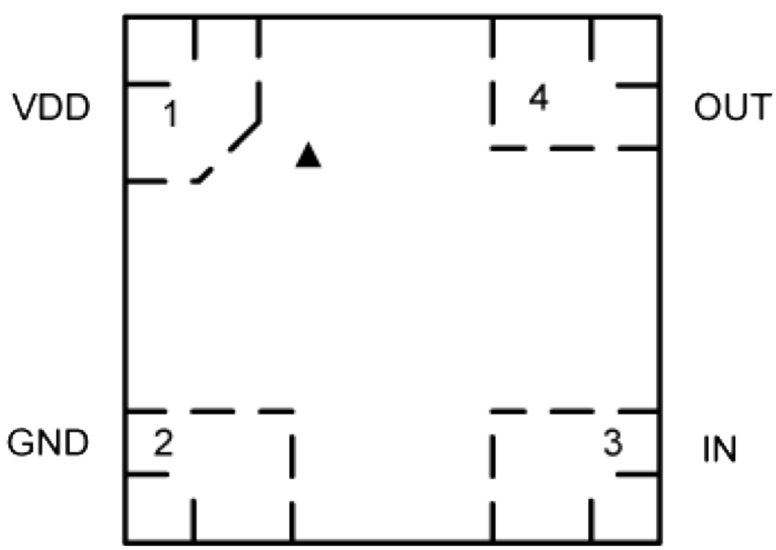
In high-side configurations, the source voltage of the MOSFET approaches the supply voltage when switched on. To keep the MOSFET turned on, the MIC5019's output drives the MOSFET gate voltage higher than the supply voltage.

The MIC5019 is available in an ultra-small 4-lead 1.2 mm × 1.2 mm UDFN Package and is rated for –40°C to +125°C junction temperature range.

Package Types

MIC5019

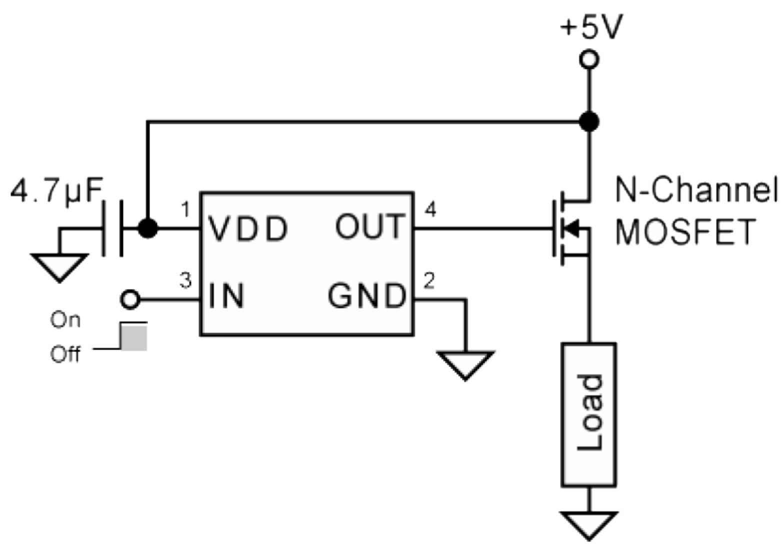
1.2 mm × 1.2 mm 4-Lead UDFN (FT)
(Top View)



Typical Application Circuits

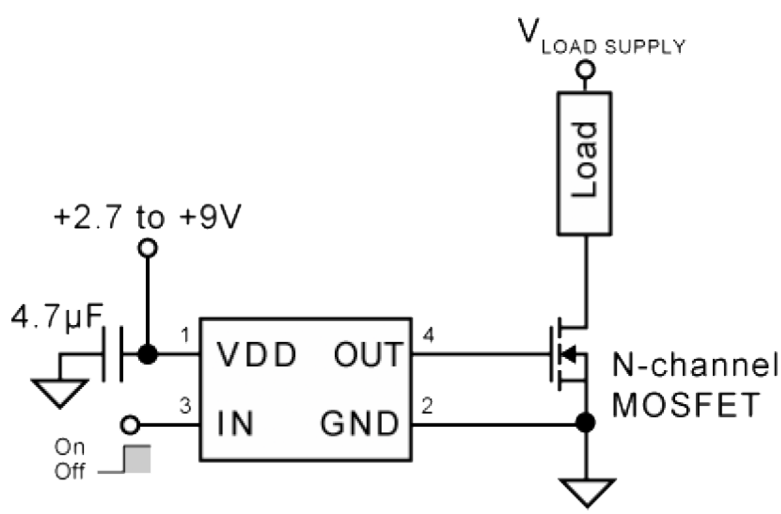
MIC5019

Low-Voltage High-Side Power Switch Configuration

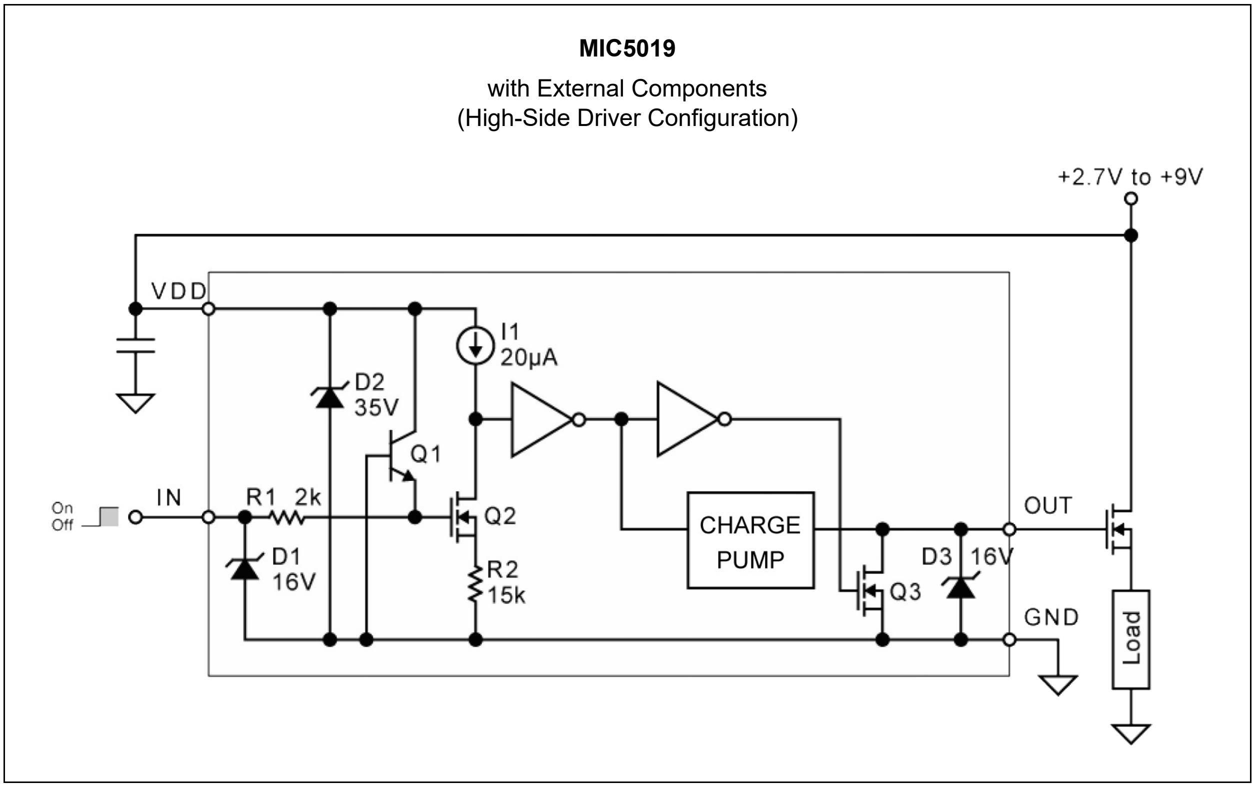


MIC5019

Low-Side Power Switch Configuration



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

VDD to GND .... +10V
IN to GND .... –0.6V to +10V
OUT to GND .... +19V
ESD Rating (Note 1) .... 1.5 kV HBM
ESD Rating .... 200V MM

Operating Ratings ‡

VDD to GND .... +2.7V to +9V
IN to GND .... 0V to VDD

† Notice: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

‡ Notice: The device is not guaranteed to function outside its operating ratings.

Note 1: Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5k in series with 100 pF.

ELECTRICAL CHARACTERISTICS (Note 1)

2.7V ≤ V_{DD} ≤ 9V; T_A = 25°C, unless noted. Bold values indicate −40°C ≤ T_J ≤ +125°C.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Supply Current	I_{VDD}	—	0.15	**1**	µA	VDD = 3.3V, IN = 0V
		—	77	**140**		VDD = 3.3V, IN = 3.3V
		—	—	**1**		VDD = 5V, IN = 0V
		—	150	**300**		VDD = 5V, IN = 3.3V
IN Voltage	V_{IN}	—	—	**0.8**	V	IN = Logic Low
		2.7	—	—		2.7V ≤ VDD ≤ 3.6V, IN = Logic High
		3.0	—	—		3.6V < VDD ≤ 9V, IN = Logic High
IN Current	I_{IN}	—	0.1	1	µA	2.7V ≤ VDD ≤ 9V
IN Capacitance	C_{IN}	—	5	—	pF	—
OUT Voltage	V_{OUT}	6.3	8.2	—	V	VDD = 2.7V
		7.1	9.3	—		VDD = 3.0V
		11.4	14.8	—		VDD = 4.5V
OUT Zener Diode Clamp Voltage	V_{OUT}	13	16.5	19	V	VDD = 9V
OUT Current (Note 2)	I_{OUT}		10.6		µA	VDD = 5V, V_{OUT} = 10V
OUT Turn-on Time (Note 3)	t_{ON}		0.440	1.5	ms	VDD = 4.5V, C_L = 1000 pF
			1.34	4.2		VDD = 4.5V, C_L = 3000 pF

Note 1: Specification for packaged product only.
2: Resistive load selected to achieve V_{OUT} = 10V.
3: Turn-On Time is the time required for the gate voltage to rise to 4V above the supply voltage.
4: Turn-Off Time is the time required for the gate voltage to fall to 4V above the supply voltage.

ELECTRICAL CHARACTERISTICS (CONTINUED)(Note 1)

2.7V ≤ V_{DD} ≤ 9V; T_A = 25°C, unless noted. Bold values indicate −40°C ≤ T_J ≤ +125°C.						
Parameters	**Sym.**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions**
OUT Turn-off Time (Note 4)	t_{OFF}		5.56	20	µs	VDD = 4.5V, C_L = 1000 pF
			17.6	60		VDD = 4.5V, C_L = 3000 pF

Note 1: Specification for packaged product only.
2: Resistive load selected to achieve V_{OUT} = 10V.
3: Turn-On Time is the time required for the gate voltage to rise to 4V above the supply voltage.
4: Turn-Off Time is the time required for the gate voltage to fall to 4V above the supply voltage.

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Operating Junction Temperature Range	T_J	–40	—	+125	°C	—
Maximum Junction Temperature Range	$T_{J(MAX)}$	–55	—	+150	°C	—
Storage Temperature Range	T_S	–55	—	+165	°C	—
Thermal Resistance						
Junction-to-case Thermal Resistance	θ_{JC}	—	+60	—	°C/W	—
Junction-to-ambient Thermal Resistance	θ_{JA}	—	+140	—		—

2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

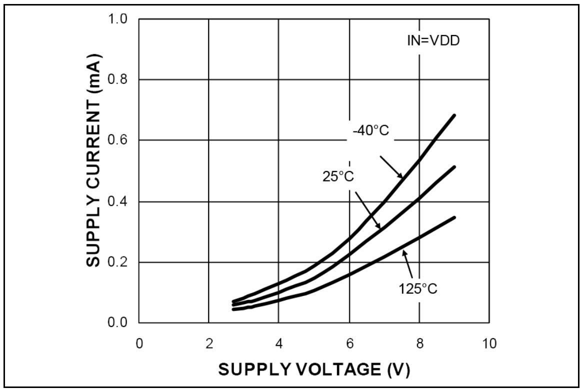


FIGURE 2-1: *V_{DD} Supply Current vs. Supply Voltage.*

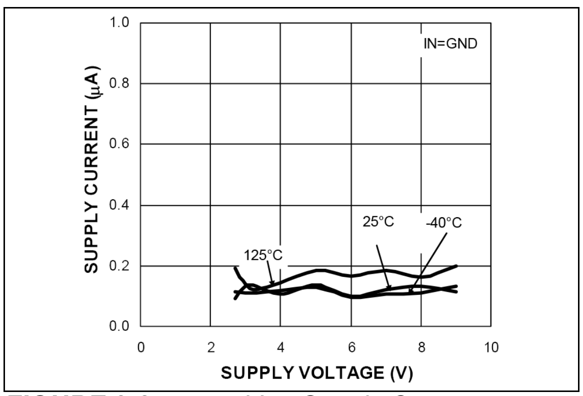


FIGURE 2-2: *V_{DD} Supply Current vs. Supply Voltage.*

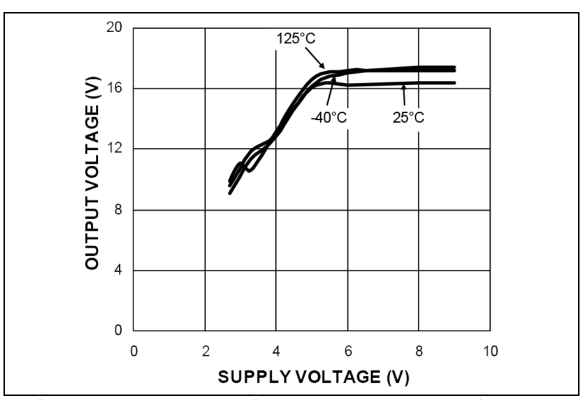


FIGURE 2-3: *Output Voltage vs. Supply Voltage.*

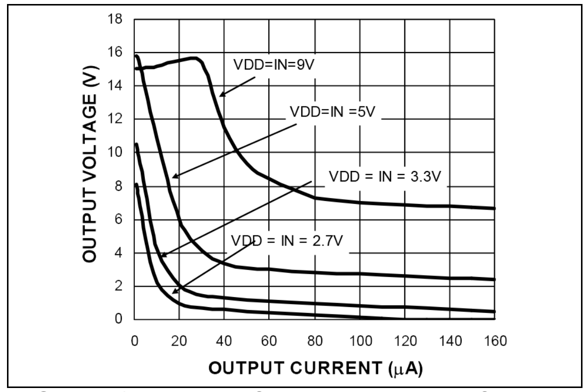


FIGURE 2-4: *Output Voltage vs. Output Current.*

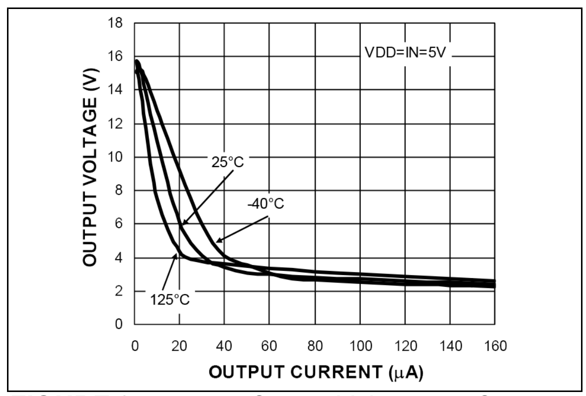


FIGURE 2-5: *Output Voltage vs. Output Current.*

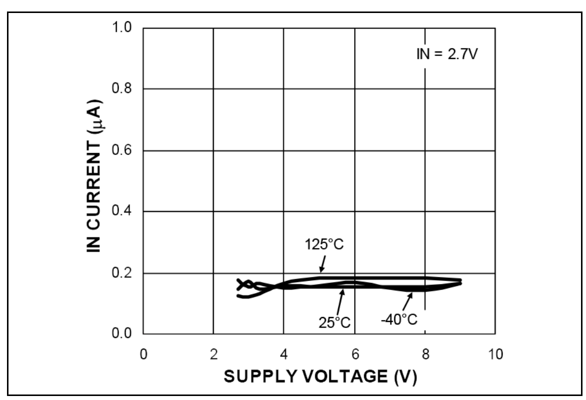


FIGURE 2-6: *IN Current vs. Supply Voltage.*

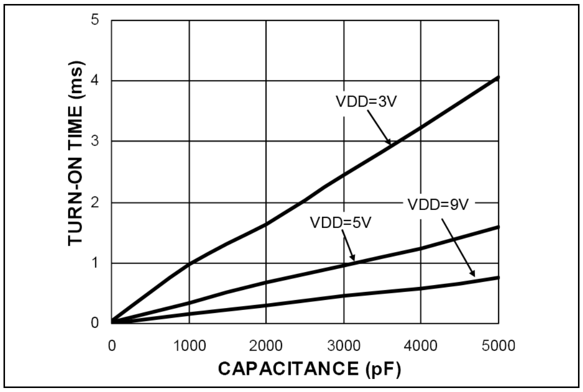


FIGURE 2-7: *OUT Turn-on Time vs. Load Capacitance.*

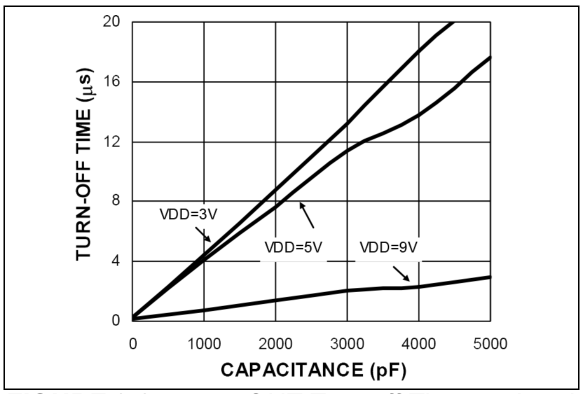


FIGURE 2-8: *OUT Turn-off Time vs. Load Capacitance.*

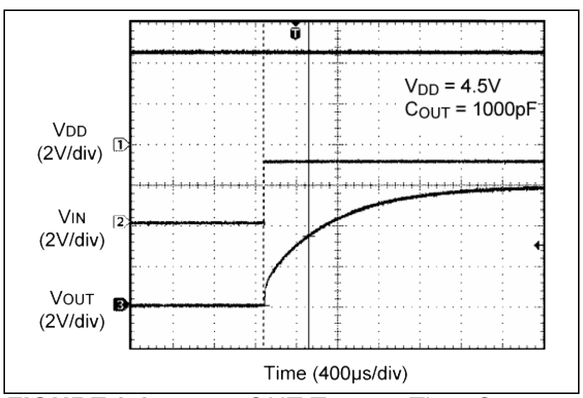


FIGURE 2-9: *OUT Turn-on Time C_{OUT} = 1 nF.*

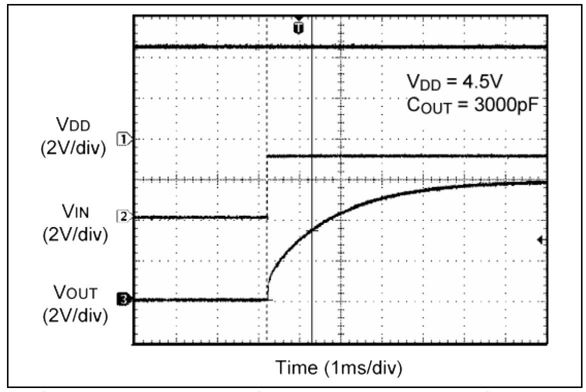


FIGURE 2-10: *OUT Turn-on Time C_{OUT} = 3 nF.*

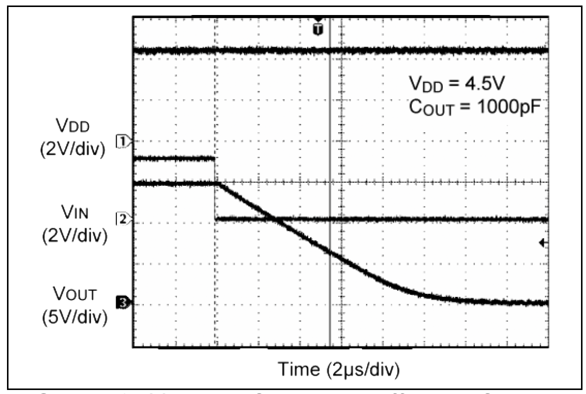


FIGURE 2-11: *OUT Turn-off Time C_{OUT} = 1 nF.*

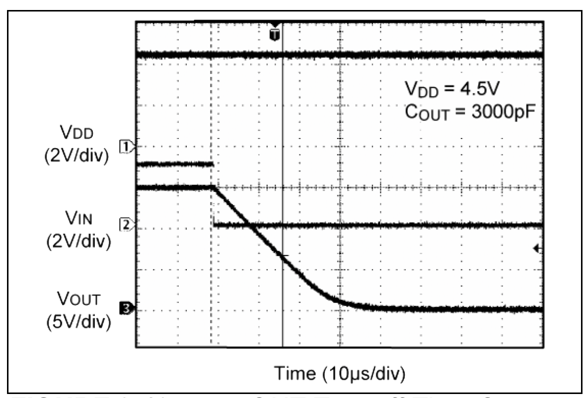


FIGURE 2-12: *OUT Turn-off Time C_{OUT} = 3 nF.*

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin Number	Pin Name	Description
1	VDD	Supply Voltage: +2.7V to +9V supply.
2	GND	Ground.
3	IN	Control Input: Logic high drives the gate output above the supply voltage. Logic low forces the gate output near ground. Do not leave this pin floating.
4	OUT	Gate Output: Connection to gate of external MOSFET.

4.0 FUNCTIONAL DESCRIPTION

The MIC5019 is a non-inverting device. Applying a logic high signal to IN (control input) produces gate drive output. The OUT (gate output) is used to turn on an external N-channel MOSFET.

4.1 Supply

VDD (supply) is rated for +2.7V to +9V. An external capacitor is recommended to decouple noise.

4.2 Control

IN is the control input. IN must be forced high or low by an external signal. Do not leave IN floating as a floating input may cause unpredictable operation.

A high input turns on Q2, which sinks the output of current source I1, making the input of the first inverter low. The inverter output becomes high enabling the charge pump.

4.3 Charge Pump

The charge pump is enabled when IN is logic high. The charge pump consists of an oscillator and voltage quadrupler (4×). The output voltage is limited to 16V typically by a Zener diode. The charge pump output voltage will be approximately:

EQUATION 4-1:

$$V_{OUT} = 4 \times V_{DD} - 2.8V$$

But not exceeding 19 V(MAX).

The oscillator operates from approximately 70 kHz to approximately 100 kHz depending upon the supply voltage and temperature.

4.4 OUT

The charge pump output is connected directly to the OUT pin. The charge pump is active only when IN is high. When IN is low, Q3 is turned on by the second inverter and discharges the gate of the external MOSFET to force it off.

If IN is high, and the voltage applied to VDD drops to zero, the gate output will be floating (unpredictable).

4.5 ESD Protection

D1 and D2 clamp positive and negative ESD voltages. R1 isolates the gate of Q2 from sudden changes on the IN input. Q1 turns on if the emitter (IN input) is forced below ground to provide additional input protection. Zener D3 also clamps ESD voltages for the OUT (gate output).

5.0 APPLICATION INFORMATION

5.1 Supply Bypass

A capacitor from VDD to GND is recommended to control switching and supply transients. Load current and supply lead length are some of the factors that affect capacitor size requirements.

A 4.7 µF or 10 µF ceramic capacitor, aluminum electrolytic or tantalum capacitor is suitable for many applications.

The low ESR (equivalent series resistance) of ceramic and tantalum capacitors makes them especially effective, but also makes them susceptible to uncontrolled inrush current from low impedance voltage sources (such as NiCd batteries or automatic test equipment). Avoid applying voltage instantaneously, capable of high peak current, directly to or near tantalum capacitors without additional current limiting. Normal power supply turn-on (slow rise time) or printed circuit trace resistance is usually adequate for normal product usage.

5.2 MOSFET Selection

The MIC5019 is designed to drive N-channel enhancement type MOSFETs. The gate output (OUT) of the MIC5019 provides a voltage, referenced to ground, that is greater than the supply voltage. Refer to the Figure 2-3 graph.

The supply voltage and the MOSFET drain-to-source voltage drop determine the gate-to-source voltage.

EQUATION 5-1:

$$V_{GS} = V_{OUT} - (V_{DD} - V_{DS})$$

Where:

V_{GS}	Gate-to-source voltage (enhancement)
V_{OUT}	OUT voltage (from Figure 2-3 graph)
V_{DD}	Supply voltage
V_{DS}	Drain-to-source voltage (approx. 0V at low current, or when fully enhanced

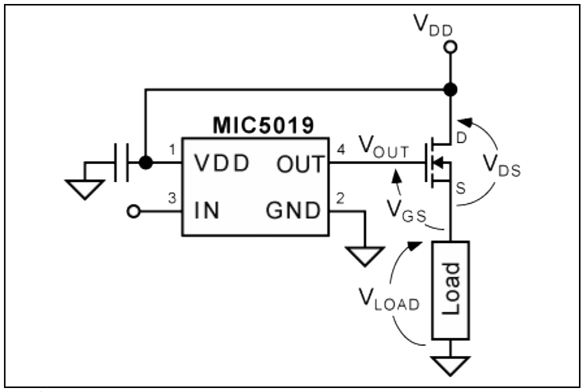


FIGURE 5-1: Node Voltages.

The performance of the MOSFET is determined by the gate-to-source voltage. Choose the type of MOSFET according to the calculated gate-to-source voltage.

5.3 Standard MOSFET

Standard MOSFETs are fully enhanced with a gate-to-source voltage of about 10V. Their absolute maximum gate-to-source voltage is ±20V.With a 4.5V supply, the MIC5019 produces a gate output of approximately 15V. Figure 5-2 shows how the remaining voltages conform.

The actual drain-to-source voltage drop across an IRFZ24 is less than 0.1V with a 1A load and 10V enhancement. Higher current increases the drain-to-source voltage drop, increasing the gate-to-source voltage.

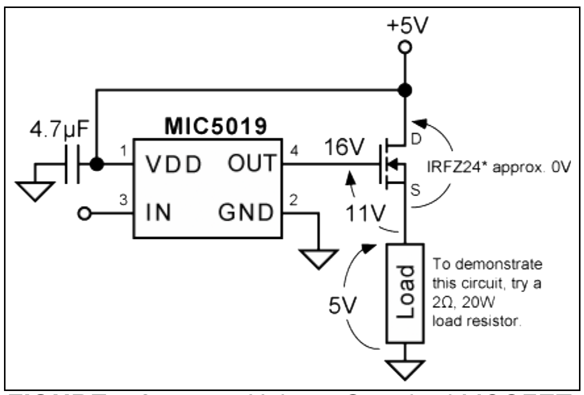


FIGURE 5-2: Using a Standard MOSFET.

The MIC5019 has an internal Zener diode that limits the gate-to-ground voltage to approximately 16V.

Lower supply voltages, such as 3.3V, produce lower gate output voltages which will not fully enhance standard MOSFETs. This significantly reduces the maximum current that can be switched. Always refer to the MOSFET data sheet to predict the MOSFET's performance in specific applications.

5.4 Logic-Level MOSFET

Logic-level N-channel MOSFETs are fully enhanced with a gate-to-source voltage of approximately 5V. Some of the MOSFET's may have an absolute maximum gate-to-source voltage of ±10V (Refer to MOSFET data sheet).

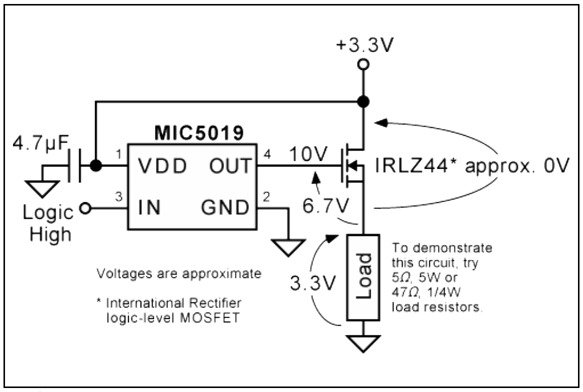


FIGURE 5-3: Using a Logic-Level MOSFET.

Refer to Figure 5-3 for an example showing nominal voltages. The maximum gate-to-source voltage rating of some of the logic-level MOSFET can be ±10V; this can be exceeded if a higher supply voltage is used. An external Zener diode can clamp the gate-to-source voltage as shown in Figure 5-4. The Zener voltage, plus its tolerance, must not exceed the absolute maximum gate voltage of the MOSFET.

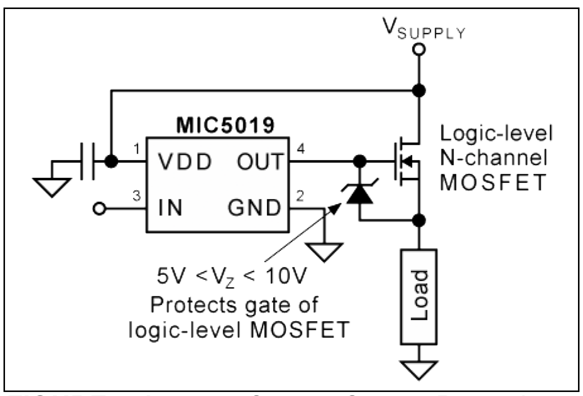


FIGURE 5-4: Gate-to-Source Protection.

A gate-to-source Zener may also be required when the maximum gate-to-source voltage could be exceeded due to normal part-to-part variation in gate output voltage. Other conditions can momentarily increase the gate-to-source voltage, such as turning on a capacitive load or shorting a load.

5.5 Inductive Loads

Inductive loads include relays, and solenoids. Long leads may also have enough inductance to cause adverse effects in some circuits.

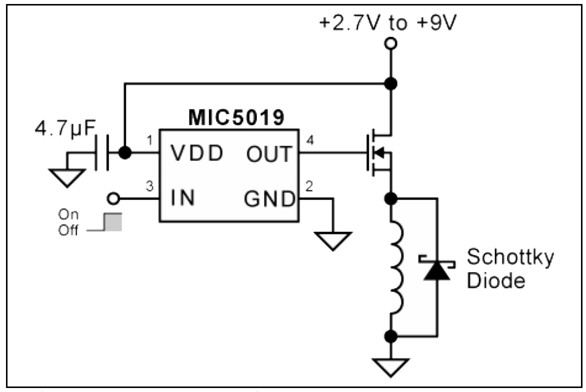


FIGURE 5-5: Switching an Inductive Load.

Switching off an inductive load in a high-side application momentarily forces the MOSFET source negative (as the inductor opposes changes to current). This voltage spike can be very large and can exceed a MOSFET's gate-to-source and drain-to-source ratings. A Schottky diode across the inductive load provides a discharge current path to minimize the voltage spike. The peak current rating of the diode should be greater than the load current.

In a low-side application, switching off an inductive load will momentarily force the MOSFET drain higher than the supply voltage. The same precaution applies.

5.6 Split Power Supply

Refer to Figure 5-6. The MIC5019 can be used to control a 12V load by separating the driver supply from the load supply.

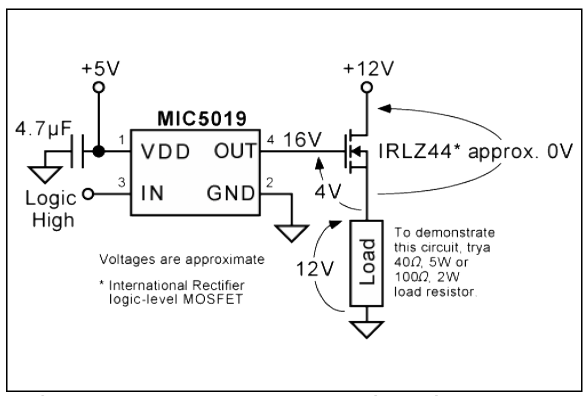


FIGURE 5-6: 12V High-Side Switch.

A logic-level MOSFET is required. The MOSFET's maximum current is limited slightly because the gate is not fully enhanced. To predict the MOSFETs performance for any pair of supply voltages, calculate the gate-to-source voltage and refer to the MOSFET data sheet.

EQUATION 5-2:

$$V_{GS} = V_{OUT} - (V_{LOADSUPPLY} - V_{DS})$$

V_{OUT} is determined from the driver supply voltage using the Figure 2-3 graph.

5.7 Low-Side Switch Configuration

The low-side configuration makes it possible to switch a voltage much higher than the MIC5019's maximum supply voltage.

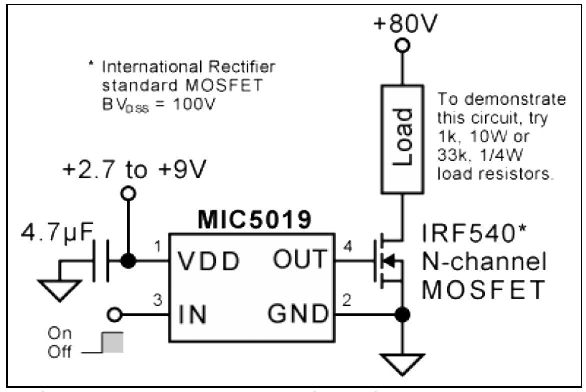
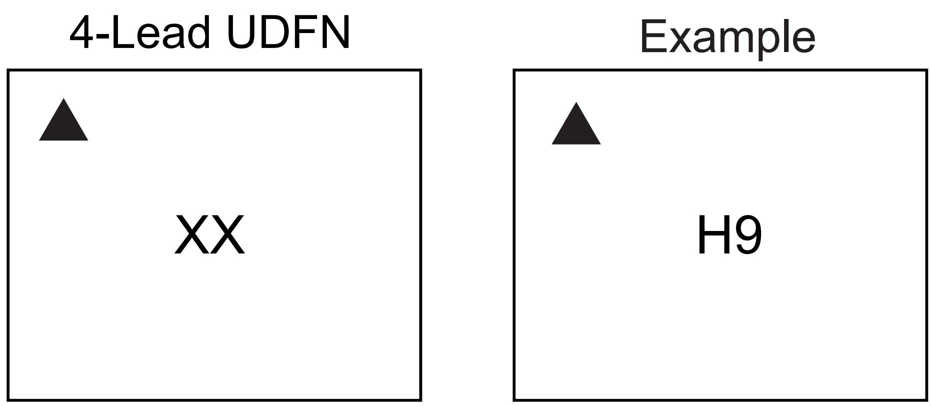


FIGURE 5-7: *Low-Side Switch Configuration.*

The maximum switched voltage is limited only by the MOSFET's maximum drain-to-source ratings.

6.0 PACKAGING INFORMATION

6.1 Package Marking Information

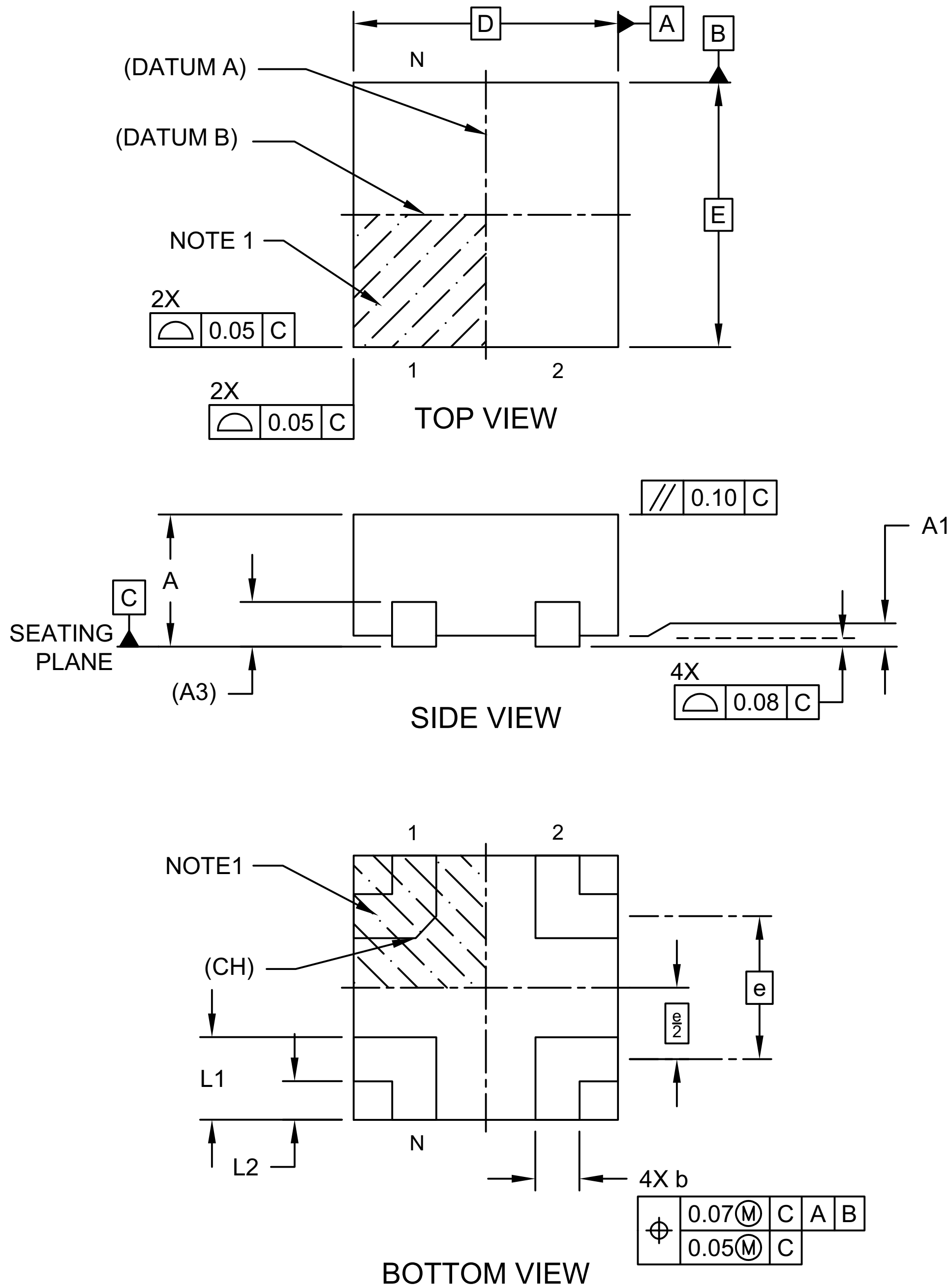


Legend:	XX...X	Product code or customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.
	●, ▲, ▼	Pin one index is identified by a dot, delta up, or delta down (triangle mark).
Note:		In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo. Underbar (_) and/or Overbar (‾) symbol may not be to scale.

Note: If the full seven-character YYWWNNN code cannot fit on the package, the following truncated codes are used based on the available marking space: 6 Characters = YWWNNN; 5 Characters = WWNNN; 4 Characters = WNNN; 3 Characters = NNN; 2 Characters = NN; 1 Character = N.

4-Lead 1.2 mm × 1.2 mm UDFN [HEA] Package Outline and Recommended Land Pattern

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



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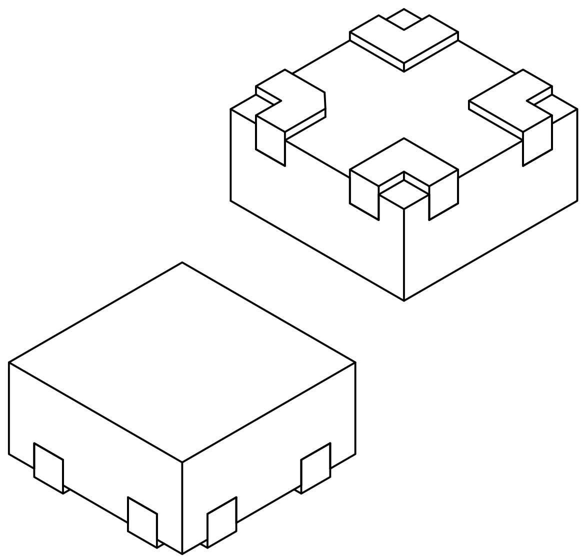
4-Lead 1.2 mm × 1.2 mm UDFN [HEA] Package Outline and Recommended Land Pattern

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



		Units	MILLIMETERS		
	Dimension Limits		MIN	NOM	MAX
Number of Terminals	N			4	
Pitch	e			0.65 BSC	
Overall Height	A		0.50	0.55	0.60
Standoff	A1		0.00	0.02	0.05
Terminal Thickness	A3			0.203 REF	
Overall Length	D			1.20 BSC	
Overall Width	E			1.20 BSC	
Terminal Width	b		0.15	0.20	0.25
Terminal Length	L1		0.325	0.375	0.425
Edge to Terminal	L2		0.125	0.175	2.25

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

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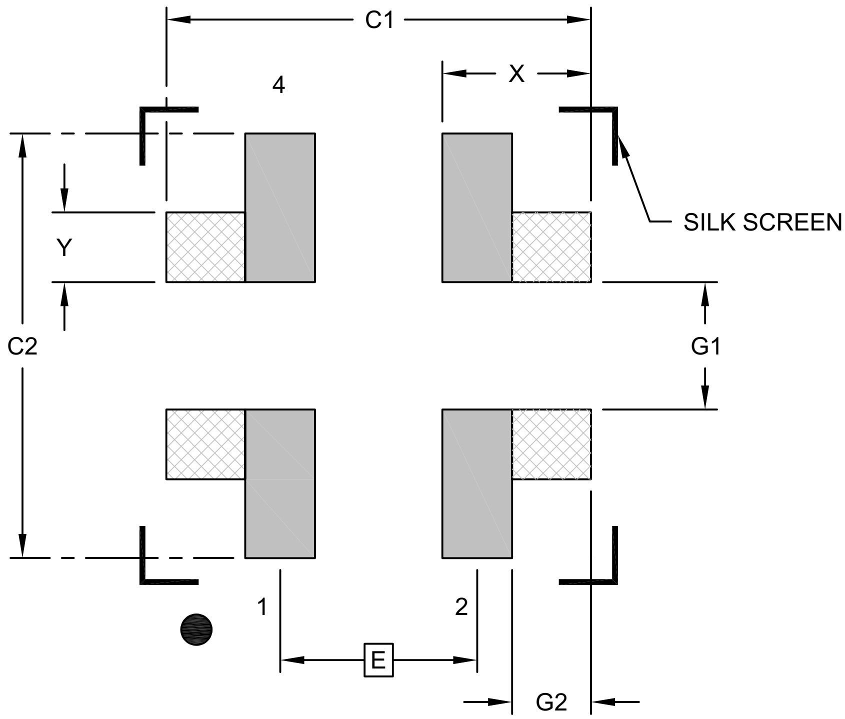
4-Lead 1.2 mm × 1.2 mm UDFN [HEA] Package Outline and Recommended Land Pattern

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

	Units	MILLIMETERS		
Dimension	Limits	MIN	NOM	MAX
Contact Pitch	E		0.65 BSC	
Contact Pad Spacing	C1		1.40	
Contact Pad Spacing	C2		1.40	
Contact Pad Width (X4)	X			0.51
Contact Pad Length (X4)	Y			0.25
Contact Pad to Contact Pad (X4)	G1	0.42		
Edge to Contact Pad (X4)	G2	0.24		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-3044 Rev A

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (March 2024)

- Converted Micrel document MIC5019 to Microchip data sheet DS20006883A.
- Content related to the Schematic Diagram, Bill of Materials, and PCB Layout removed as that can be found in the MIC5019 User's Guide.
- Minor text changes throughout.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

PART No.	X	XX	-XX
Device	Junction Temp. Range	Package	Media Type

Device:	MIC5019:	Ultra-Small High-Side N-Channel MOSFET Driver with Integrated Charge Pump
Junction Temperature Range:	Y =	–40°C to +125°C
Package:	FT =	4-Lead UDFN
Media Type:	-TR = -T5 =	5000/Reel 500/Reel

Examples:

a) MIC5019YFT-TR: MIC5019, –40°C to +125°C Temp. Range, 4-Lead UDFN, 5000/Reel

b) MIC5019YFT-T5: MIC5019, –40°C to +125°C Temp. Range, 4-Lead UDFN, 500/Reel

Note1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

NOTES:

Note the following details of the code protection feature on Microchip products:

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner, within operating specifications, and under normal conditions.
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