

### General Description

The MIC4414 and MIC4415 are low-side MOSFET drivers designed to switch an N-channel enhancement type MOSFET in low-side switch applications. The MIC4414 is a non-inverting driver and the MIC4415 is an inverting driver. These drivers feature short delays and high peak current to produce precise edges and rapid rise and fall times.

The MIC4414/15 are powered from a 4.5V to 18V supply and can sink and source peak currents up to 1.5A, switching a 1000pF capacitor in 12ns. The on-state gate drive output voltage is approximately equal to the supply voltage (no internal regulators or clamps). High supply voltages, such as 10V, are appropriate for use with standard N-channel MOSFETs. Low supply voltages, such as 5V, are appropriate for use with many logic-level N-channel MOSFETs.

In a low-side configuration, the driver can control a MOSFET that switches any voltage up to the rating of the MOSFET.

The MIC4414 and MIC4415 are available in an ultra-small 4-pin 1.2mm x 1.2mm thin QFN package and is rated for -40°C to +125°C junction temperature range.

Data sheets and support documentation can be found on Micrel's web site at: [www.micrel.com](http://www.micrel.com).

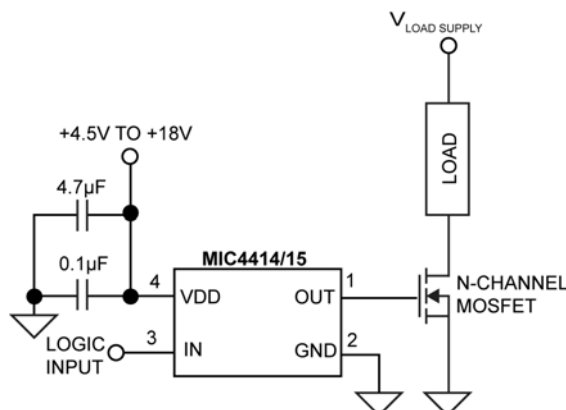
### Features

- Ultra-small 4-pin 1.2mm x 1.2mm thin QFN package
- +4.5V to +18V operating supply voltage range
- 1.5A peak current
  - 3.5Ω output resistance at 18V
  - 9Ω output resistance at 5V
- Low steady-state supply current
  - 77μA control input low
  - 445μA control input high
- 12ns rise and fall times into 1000pF load
- MIC4414 (non-inverting)
- MIC4415 (inverting)
- -40°C to +125°C junction temperature range

### Applications

- Switch mode power supplies
- Solenoid drivers
- Motor driver

### Typical Application



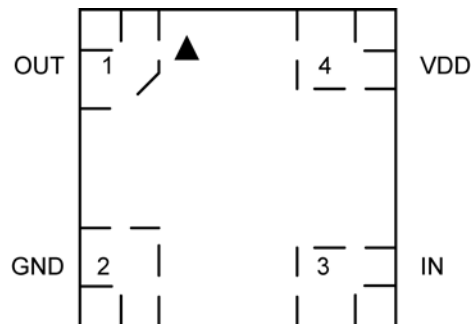
## Ordering Information

Part Number	Marking	Configuration	Package	Junction Temperature Range	Lead Finish
MIC4414YFT	D9	Non-Inverting	4-pin 1.2mm x 1.2mm Thin QFN	-40°C to +125°C	Pb-Free
MIC4415YFT	D8	Inverting	4-pin 1.2mm x 1.2mm Thin QFN	-40°C to +125°C	Pb-Free

### Note:

1. Thin QFN pin 1 identifier = "▲"

## Pin Configuration



1.2mm x 1.2mm Thin QFN  
(Top View)

## Pin Description

Pin Number	Pin Name	Pin Function
1	OUT	Gate Output: Connection to gate of external MOSFET.
2	GND	Ground.
3	IN	Control Input: MIC4414: Logic high drives the gate output above the supply voltage. Logic low forces the gate output near ground. Do not leave floating. MIC4415: Logic low drives the gate output above the supply voltage. Logic high forces the gate output near ground. Do not leave floating.
4	VDD	Supply Voltage: +4.5V to +18V supply.

**Absolute Maximum Ratings<sup>(1)</sup>**

VDD to GND.....	+20V
IN to GND.....	-20V to +20V
OUT to GND.....	+20V
Junction Temperature (T <sub>J</sub> ).....	-55°C to +150°C
Storage Temperature (T <sub>s</sub> ).....	-55°C to +165°C
ESD Rating <sup>(2)</sup> .....	ESD Sensitive

**Operating Ratings<sup>(3)</sup>**

VDD to GND.....	+4.5V to +18V
IN to GND.....	0V to VDD
Junction Temperature (T <sub>J</sub> ).....	-40°C to +125°C
Thermal Resistance	
1.2mm x 1.2mm Thin QFN (θ <sub>JC</sub> ).....	60°C/W
1.2mm x 1.2mm Thin QFN (θ <sub>JA</sub> ).....	140°C/W

**Electrical Characteristics<sup>(4)</sup>**

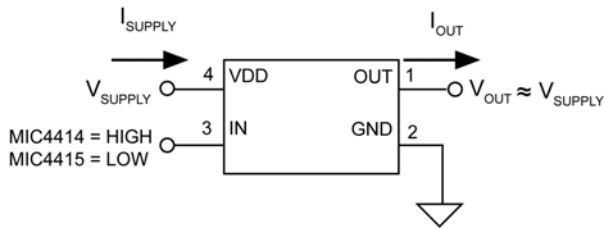
4.5V ≤ VDD ≤ 18V, C<sub>L</sub> = 1000pF; T<sub>A</sub> = 25°C, **Bold** values indicate -40°C ≤ T<sub>J</sub> ≤ +125°C.

Parameter	Condition	Min	Typ	Max	Units	
Supply Current	MIC4414: IN = 0V, VDD = 18V		77	<b>200</b>	μA	
	MIC4415: IN = 5V, VDD = 18V					
	MIC4414: IN = 5V, VDD = 18V		445	<b>1500</b>		
	MIC4415: IN = 0V, VDD = 18V					
IN Voltage	IN = Logic Low			<b>0.8</b>	V	
	IN = Logic High	<b>3</b>			V	
IN Current	0V ≤ VIN ≤ VDD	<b>-10</b>		<b>+10</b>	μA	
Output Rise Time	VDD = 5V, C <sub>L</sub> = 1000pF		30		ns	
	VDD = 18V, C <sub>L</sub> = 1000pF		12			
Output Fall Time	VDD = 5V, C <sub>L</sub> = 1000pF		33		ns	
	VDD = 18V, C <sub>L</sub> = 1000pF		12			
Delay Time, IN Rising	VDD = 5V, C <sub>L</sub> = 1000pF		52		ns	
	VDD = 18V, C <sub>L</sub> = 1000pF		29			
Delay Time, IN Falling	VDD = 5V, C <sub>L</sub> = 1000pF		58		ns	
	VDD = 18V, C <sub>L</sub> = 1000pF		30			
Output Offset Voltage	OUT = High		-25		mV	
	OUT = Low		25			
Output Resistance	VDD = 5V, I <sub>OUT</sub> = 10mA	Source		9	Ω	
		Sink		9		
	VDD = 18V, I <sub>OUT</sub> = 10mA	Source		3.5		10
		Sink		3.5		10
Output Reverse Current		250			mA	

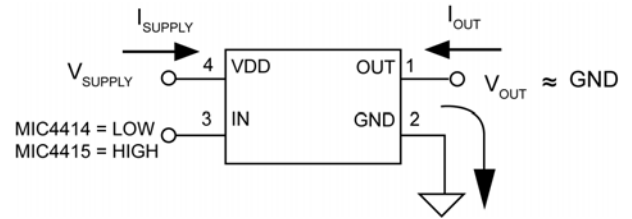
**Notes:**

- Exceeding the absolute maximum rating may damage the device.
- Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5kΩ in series with 100pF.
- The device is not guaranteed to function outside operating range.
- Specification for packaged product only.

# Timing Diagram

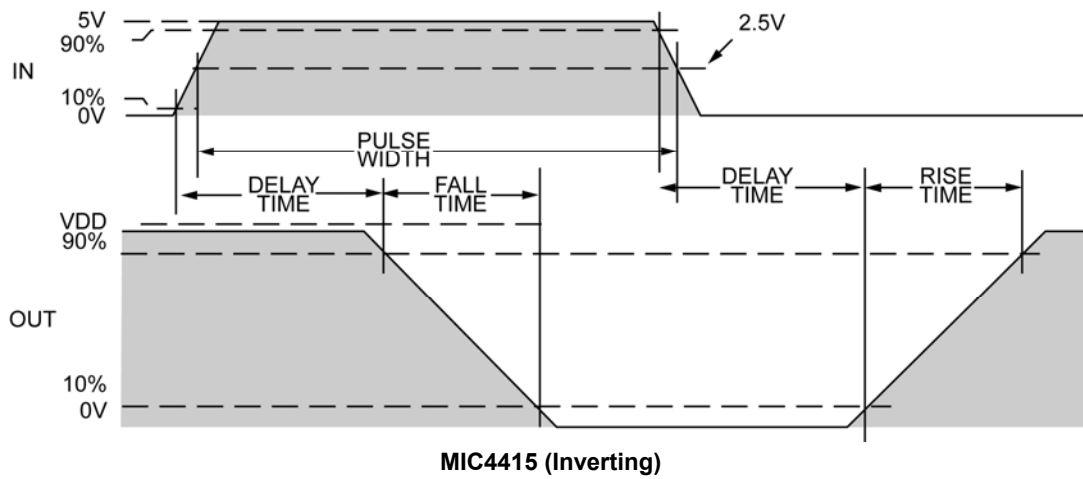
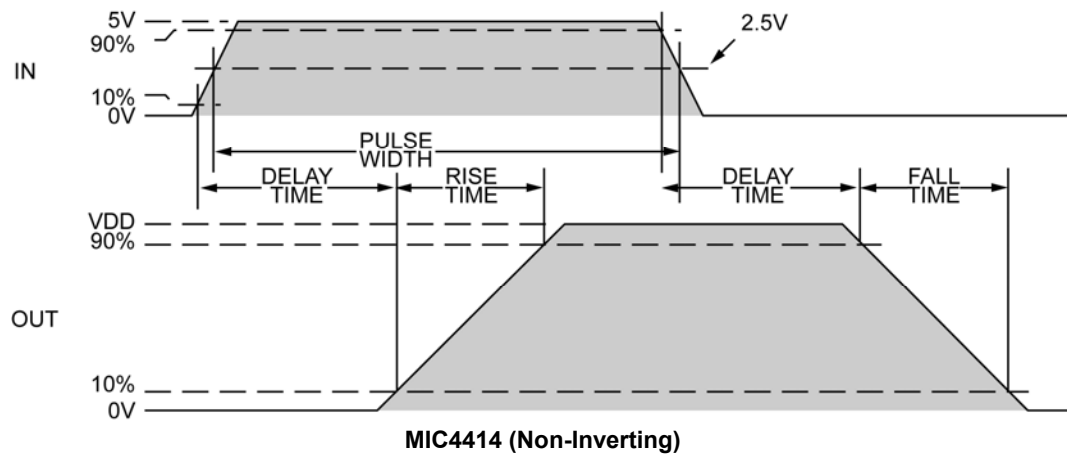


Source State  
(P-Channel On, N-Channel Off)



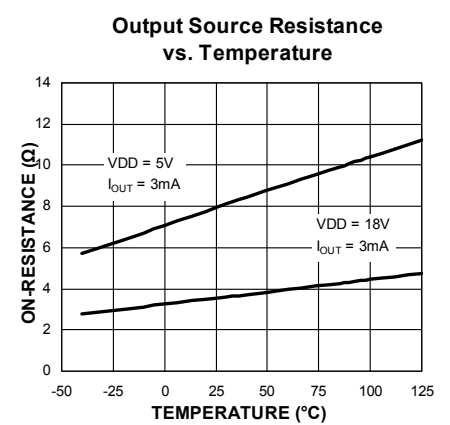
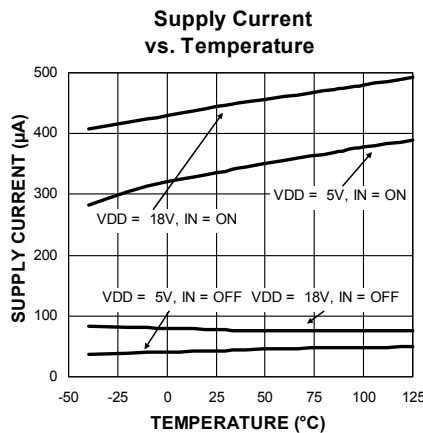
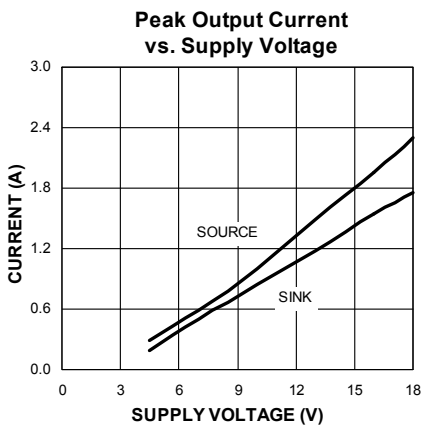
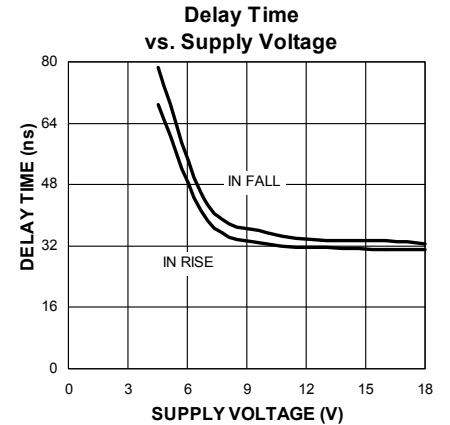
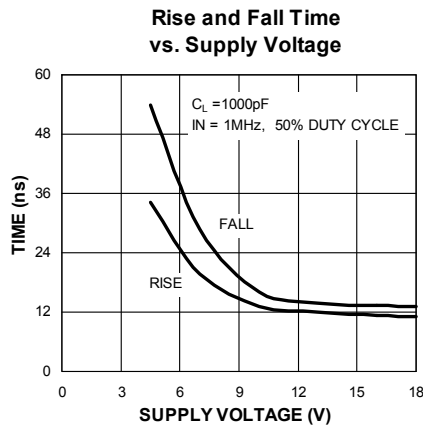
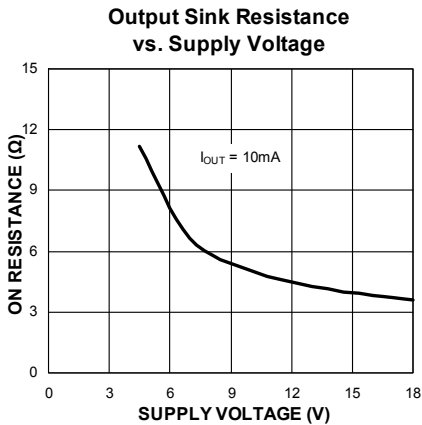
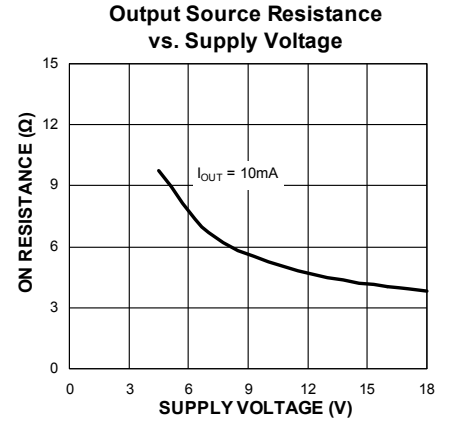
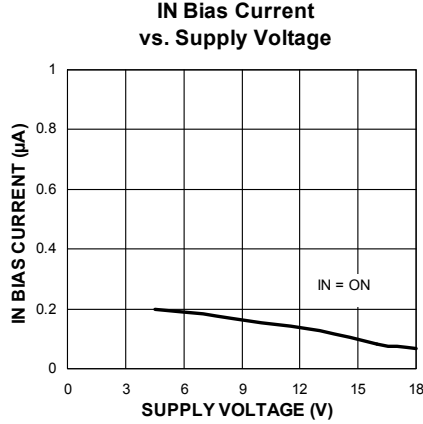
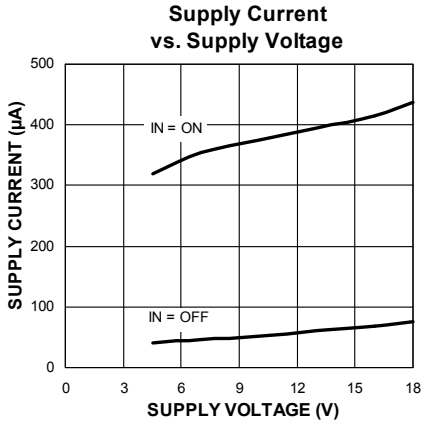
Sink State  
(P-Channel Off, N-Channel On)

## MIC4414/MIC4415 Operating States



# Typical Characteristics

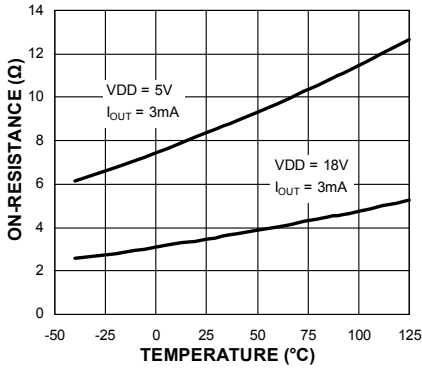
MIC4414 ON IN=5V, OFF IN=0V. MIC4415 ON IN=0V, OFF IN=5V.



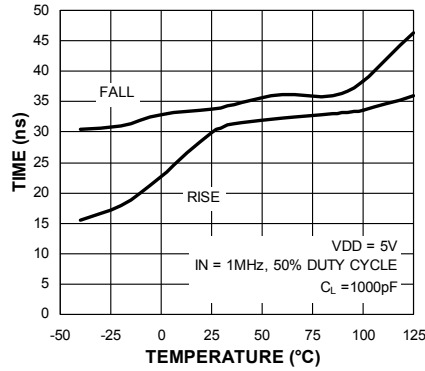
# Typical Characteristics (Continued)

MIC4414 ON IN=5V, OFF IN=0V. MIC4415 ON IN=0V, OFF IN=5V.

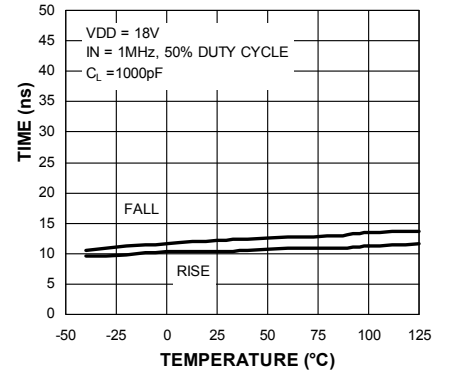
**Output Sink Resistance vs. Temperature**



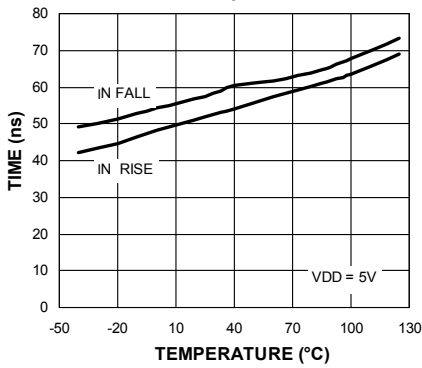
**Rise and Fall Time vs. Temperature**



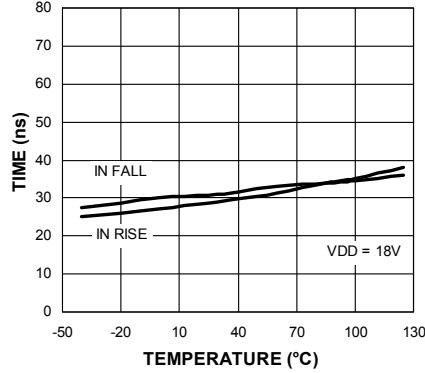
**Rise and Fall Time vs. Temperature**



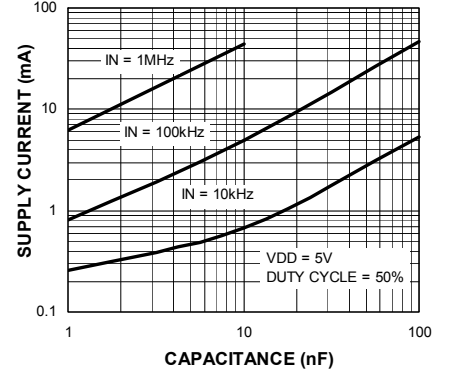
**Delay Time vs. Temperature**



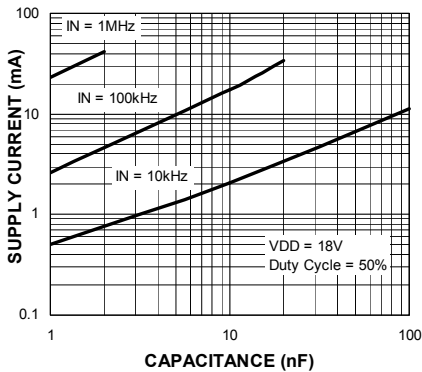
**Delay Time vs. Temperature**



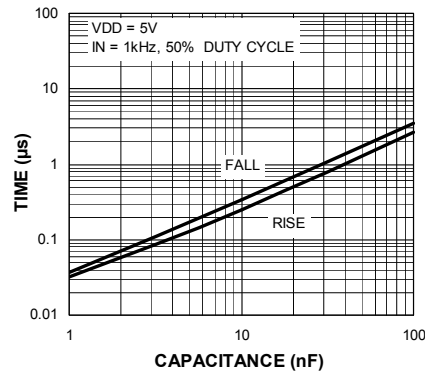
**Supply Current vs. Load Capacitance**



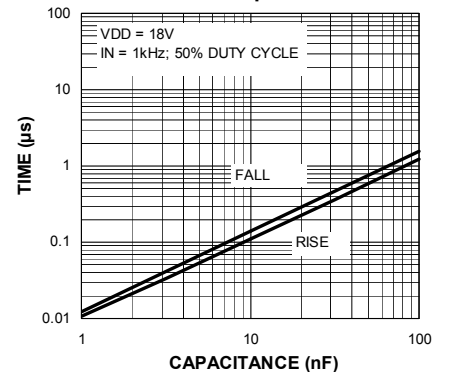
**Supply Current vs. Load Capacitance**



**Output Rise and Fall Time vs. Load Capacitance**

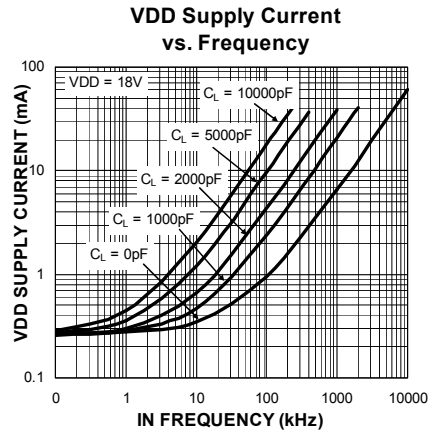
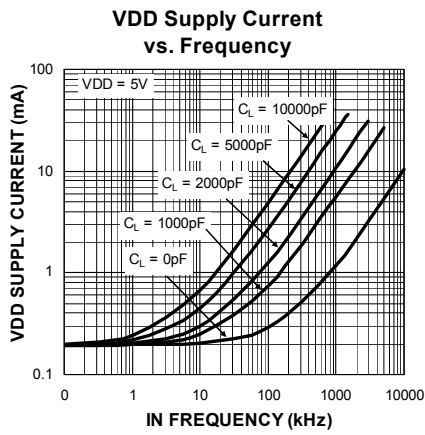


**Output Rise and Fall Time vs. Load Capacitance**

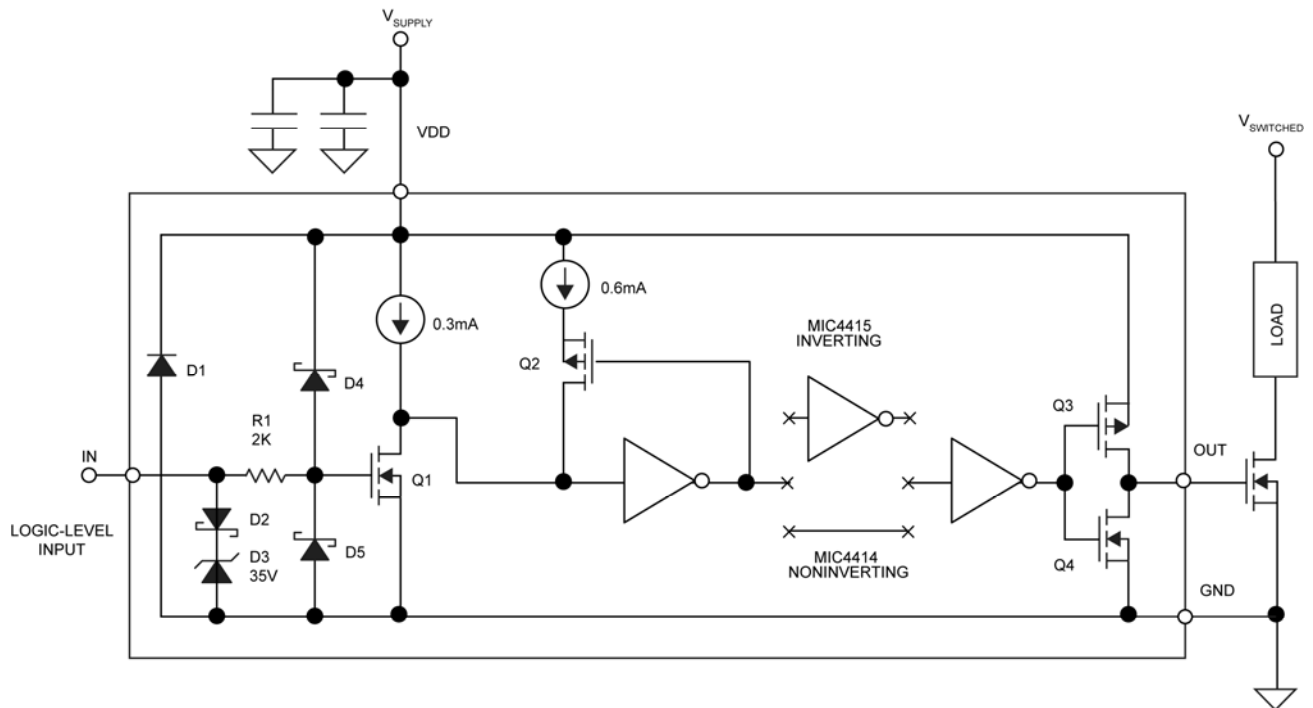


## Typical Characteristics (Continued)

MIC4414 ON IN=5V, OFF IN=0V. MIC4415 ON IN=0V, OFF IN=5V.



## Functional Diagram



## Functional Description

The MIC4414 is a non-inverting driver. A logic high on the IN (control) pin produces gate drive output. The MIC4415 is an inverting driver. A logic low on the IN (control) pin produces gate drive output. The OUT is used to turn on an external N-channel MOSFET. The OUT pin will be driven to 0V or VDD depending on the status of IN pin.

### VDD

VDD (supply) is rated for +4.5V to +18V. External capacitors are recommended to decouple noise.

### IN

IN must be forced high or low by an external signal. A floating input will cause unpredictable operation.

A high input turns on Q1, which sinks the output of the 0.3mA and the 0.6mA current source, forcing the input of the first inverter low.

### Hysteresis

The control threshold voltage, when IN is rising, is slightly higher than the control threshold voltage when IN is falling. When IN is low, Q2 is on, which applies the additional 0.6mA current source to Q1. Forcing IN high turns on Q1 which must sink 0.9mA from the two current sources. The higher current through Q1 causes a larger drain-to-source voltage drop across Q1. A slightly higher control voltage is required to pull the input of the first inverter down to its

threshold.

Q2 turns off after the first inverter output goes high. This reduces the current through Q1 to 0.3mA. The lower current reduces the drain-to-source voltage drop across Q1. A slightly lower control voltage will pull the input of the first inverter up to its threshold.

### Drivers

The second (optional) inverter permits the driver to be manufactured in inverting and non-inverting versions.

The last inverter functions as a driver for the output MOSFETs Q3 and Q4.

### OUT

OUT is designed to drive a capacitive load. The OUT voltage is either approximately the supply voltage or approximately ground, depending on the logic state applied to IN. If IN is high, and VDD (supply) drops to zero, the gate output will be floating (unpredictable).

### ESD Protection

D1 protects VDD from negative ESD voltages. D2 and D3 clamp positive and negative ESD voltages applied to IN. R1 isolates the gate of Q1 from sudden changes on the IN pin. D4 and D5 prevent Q1's gate voltage from exceeding the supply voltage or going below ground.



## Application Information

The MIC4414 and MIC4415 are designed to provide high peak current for charging and discharging capacitive loads. The 1.5A peak value is a nominal value determined under specific conditions. This nominal value is used to compare its relative size to other low-side MOSFET drivers. The MIC4414 and MIC4415 are not designed to directly switch 1.5A continuous loads.

### 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.

4.7 $\mu$ F or 10 $\mu$ F ceramic or tantalum capacitor is suitable for many applications. Low-ESR (equivalent series resistance) metalized film capacitors may also be suitable. An additional 0.1 $\mu$ F ceramic capacitor is suggested in parallel with the larger capacitor to control high-frequency transients. 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 instantaneously applying voltage, capable of very high peak current, directly to or near low ESR capacitors without additional current limiting. Normal power supply turn-on (slow rise time) or printed circuit trace resistance is usually adequate.

### Circuit Layout

Avoid long power supply and ground traces. They exhibit inductance that can cause voltage transients (inductive kick). Even with resistive loads, inductive transients can sometimes exceed the ratings of the MOSFET and the driver. When a load is switched off, supply lead inductance forces current to continue flowing and results in a positive voltage spike. Inductance in the ground (return) lead to the supply has similar effects, except the voltage spike is negative. Switching transitions momentarily draw current from VDD to GND. This combines with supply lead inductance to create voltage transients at turn on and turnoff. Transients can also result in slower apparent rise or fall times when driver's ground shifts with respect to the control input.

Minimize the length of supply and ground traces or use ground and power planes when possible. Bypass capacitors should be placed as close as practical to the driver.

## MOSFET Selection

### Standard MOSFET

A standard N-channel power MOSFET is fully enhanced with a gate-to-source voltage of approximately 10V and has an absolute maximum gate-to-source voltage of  $\pm 20$ V. The MIC4414/15's on-state output is approximately equal to the supply voltage. The lowest usable voltage depends upon the behavior of the MOSFET.

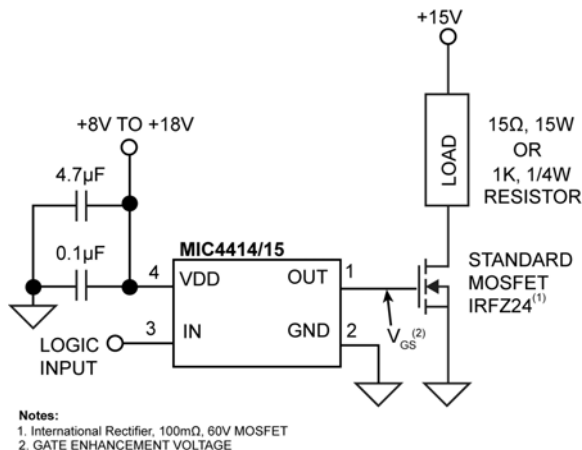


Figure 1. Using a Standard MOSFET

### Logic-Level MOSFET

Logic-level N-channel power MOSFETs are fully enhanced with a gate-to-source voltage of approximately 5V and some of them have an absolute maximum gate-to-source voltage of  $\pm 10$ V. They are less common and generally more expensive. The MIC4414/15 can drive a logic-level MOSFET if the supply voltage, including transients, does not exceed the maximum MOSFET gate-to-source rating (10V).

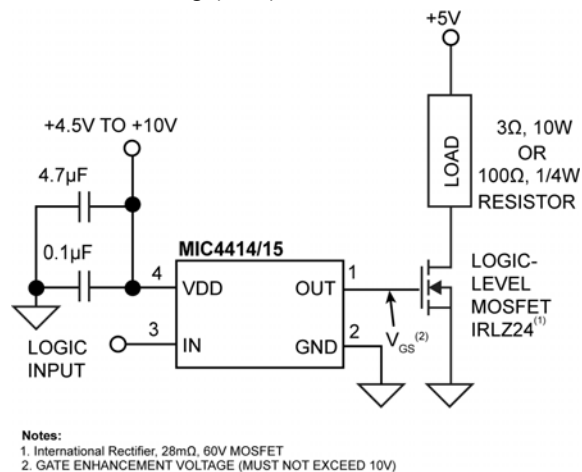


Figure 2. Using a Logic-Level MOSFET

At low voltages, the MIC4414/15's internal P- and N-channel MOSFET's on-resistance will increase and slow the output rise time. Refer to "Typical Characteristics" graphs.

**Inductive Loads**

Switching off an inductive load in a low-side application forces the MOSFET drain higher than the supply voltage (as the inductor resists changes to current). To prevent exceeding the MOSFET's drain-to-gate and drain-to-source ratings, a Schottky diode should be connected across the inductive load.

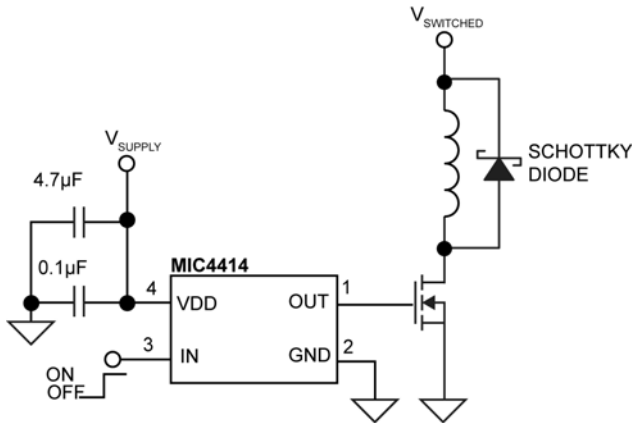


Figure 3. Switching an Inductive Load

**Power Dissipation**

The maximum power dissipation must not be exceeded to prevent die meltdown or deterioration. Power dissipation in on/off switch applications is negligible.

Fast repetitive switching applications, such as SMPS (switch mode power supplies), cause a significant increase in power dissipation with frequency. Power is dissipated each time current passes through the internal output MOSFETs when charging or discharging the external MOSFET. Power is also dissipated during each transition when some current momentarily passes from VDD to GND through both internal MOSFETs. Power dissipation is the product of supply voltage and supply current:

$$P_D = V_{DD} \times I_{DD} \tag{Equation 1}$$

where:

$P_D$  = Power dissipation (W)

$V_{DD}$  = Supply voltage (V)

$I_{DD}$  = Supply current (A)

Supply current is a function of supply voltage, switching

frequency, and load capacitance. Determine this value from the "Typical Characteristics: Supply Current vs. Frequency" graph or measure it in the actual application.

Do not allow  $P_D$  to exceed  $P_D (MAX)$ , as shown in the Eq 2.

$T_J$  (junction temperature) is the sum of  $T_A$  (ambient temperature) and the temperature rise across the thermal resistance of the package. In another form:

$$P_D (MAX) \leq \frac{125 - T_A}{140} \tag{Equation 2}$$

where:

$P_D (MAX)$  = maximum power dissipation (W)

125 = Operating maximum junction temperature (°C)

$T_A$  = ambient temperature (°C)

140 = package thermal resistance (°C/W)

**High-Frequency Operation**

Although the MIC4414/15 driver will operate at frequencies greater than 1MHz, the MOSFET's capacitance and the load will affect the output waveform (at the MOSFET's drain). For example, an MIC4414/IRL3103 test circuit using a 47Ω, 5W load resistor will produce an output waveform that closely matches the input signal shape up to about 500kHz. The same test circuit with a 1kΩ load resistor operates only up to about 25kHz before the MOSFET source waveform shows significant change.

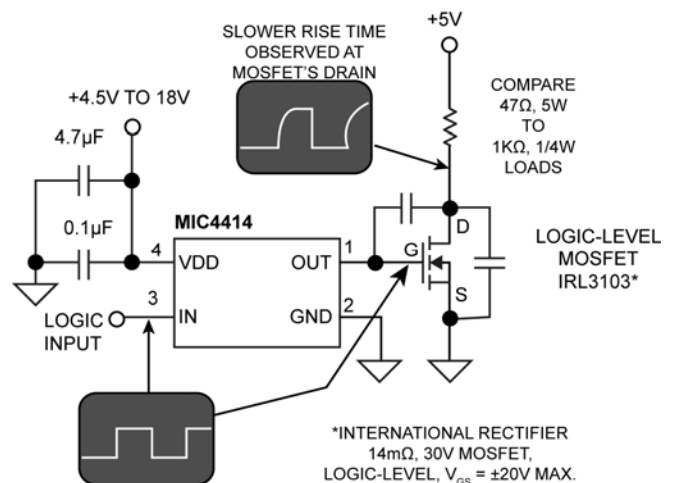
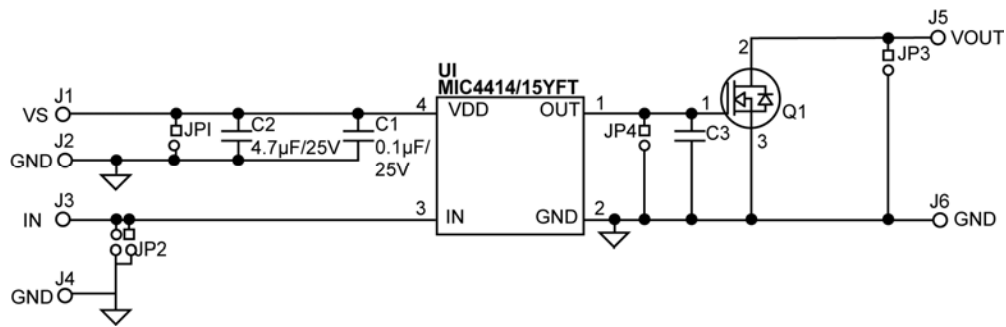


Figure 4. MOSFET Capacitance Effects at High Switching Frequency

When the MOSFET is driven off, the slower rise occurs because the MOSFET's output capacitance recharges through the load resistance (RC circuit). A lower load resistance allows the output to rise faster. For the fastest driver operation, choose the smallest power MOSFET that will safely handle the desired voltage, current, and safety margin. The smallest MOSFETs generally have the lowest capacitance.

## Evaluation Board Schematic



## Bill of Materials

Item	Part Number	Manufacturer	Description	Qty.
C1	GRM188R71E104KA01D	Murata <sup>(1)</sup>	0.1µF/25V Ceramic Capacitor, X7R, Size 0603	1
C2	C2012X5R1E475K	TDK <sup>(2)</sup>	4.7µF/25V Ceramic Capacitor, X5R, Size 0805	1
	GRM21BR61E475KA12L	Murata		
	08053D475KAT2A	AVX <sup>(3)</sup>		
C3 (OPEN)			Used as gate Capacitor, different values	
Q1 (OPEN)				
U1	MIC4414YFT	Micrel, Inc. <sup>(4)</sup>	1.5A/4.5V to 18V Low Side MOSFET Driver	1
	MIC4415YFT			

**Notes:**

1. Murata: [www.murata.com](http://www.murata.com).
2. TDK: [www.tdk.com](http://www.tdk.com).
3. AVX: [www.avx.com](http://www.avx.com).
4. Micrel, Inc.: [www.micrel.com](http://www.micrel.com).

# PCB Layout

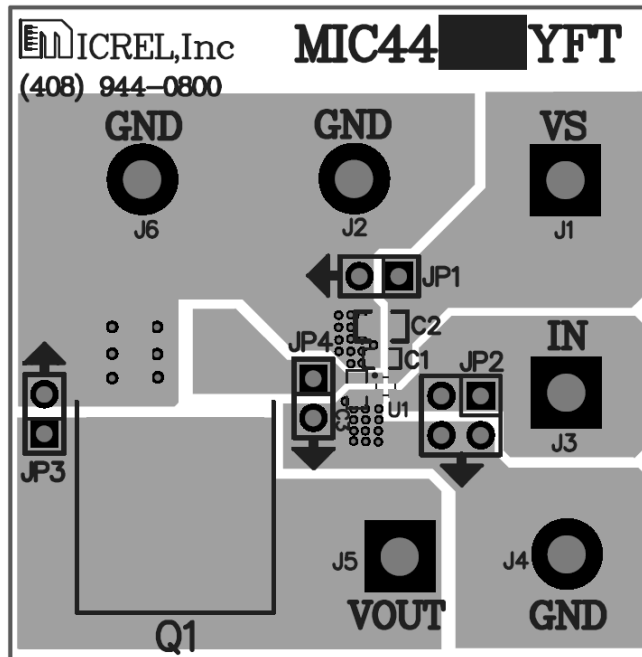


Figure 5. MIC4414/15 Evaluation Board Top Layer

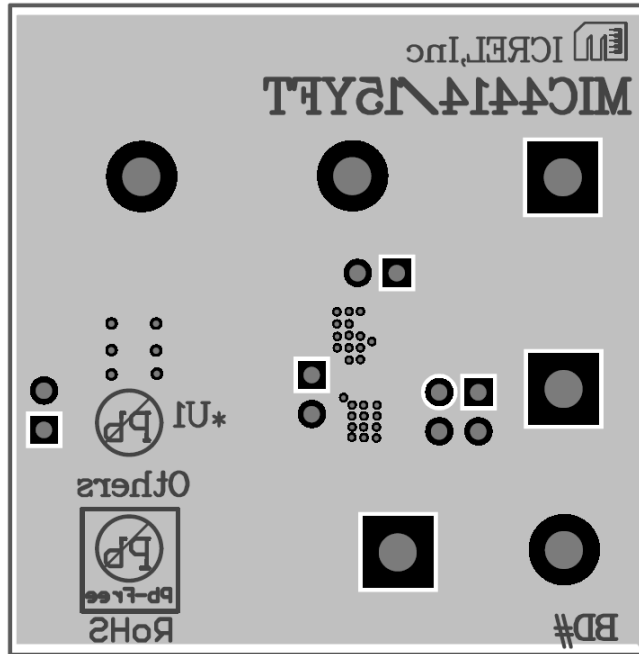
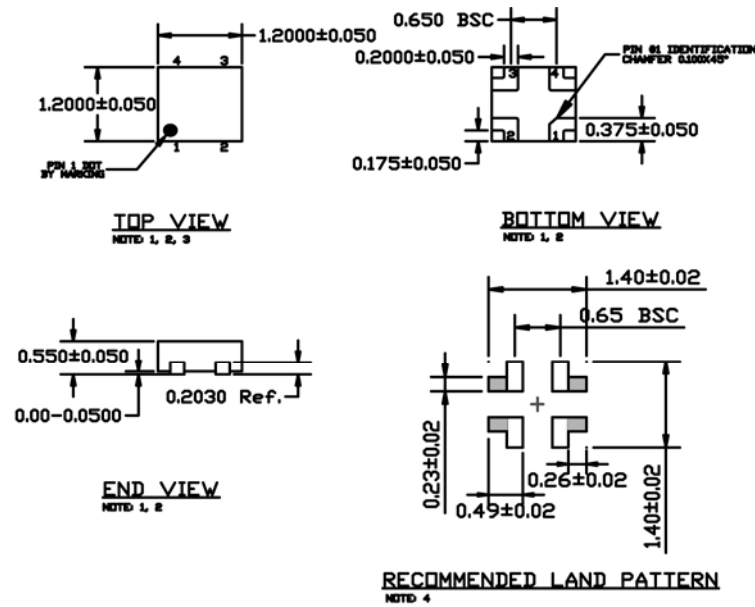


Figure 6. MIC4414/15 Evaluation Board Bottom Layer

## Package Information



- NOTE:**
1. MAX PACKAGE WARPAGE IS 0.05 MM
  2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
  3. PIN #1 IS ON TOP WILL BE LASER MARKED
  4. GREEN SHADED AREAS REPRESENT OPTIONAL SOLDER STENCIL OPENING FOR IMPROVED THERMAL PERFORMANCE

### 4-Pin 1.2mm x 1.2mm Thin QFN (FT)

**MICREL, INC. 2180 FORTUNE DRIVE SAN JOSE, CA 95131 USA**

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