# Application Note 1

**MIC5011 Design Techniques**

**by Mitchell Lee**

## Introduction

Power MOSFETs are often preferred over bipolar transistors as high current switches. In static switching applications the MOSFET takes no drive power, where a bipolar transistor requires a large base current. Bipolar transistors also exhibit inferior SOA when compared to power MOSFETs. In high side switching circuits N-channel MOSFETs are preferred over P-channel devices owing to the lower cost of an N-channel device for a given "on" resistance. Unfortunately, N-channel MOSFETs are not well-suited in high-side switch applications because in order to fully enhance the MOSFET, the gate must be driven to a potential higher than the drain supply. While a separate supply could be used for the gate drive circuitry, this is unnecessary if a charge pump is used to drive the MOSFET's gate.

A simple charge pump voltage doubler is shown in Figure 1. The object is to charge C1 from the supply, and then transfer its charge to C2. Since C2 is referred to $V_{DD}$, $V_{OUT}$ will be greater than $V_{DD}$.

The switch is first connected to ground, charging C1 (through D1) to the supply voltage. Next, the switch is toggled to supply. C1 dumps its charge through D2 into C2. If the process is repeated, C2 will eventually charge to a potential equal to $V_{DD}$, lifting $V_{OUT}$ to 2 x $V_{DD}$ (neglecting switch and diode losses). If $V_{OUT}$ is used to drive the gate of an N-channel MOSFET, the device will be enhanced by an amount equal to $V_{DD}$. A similar technique is employed by the MIC5011 high side MOSFET pre-driver to enhance an N-channel MOSFET without the need for a second supply.

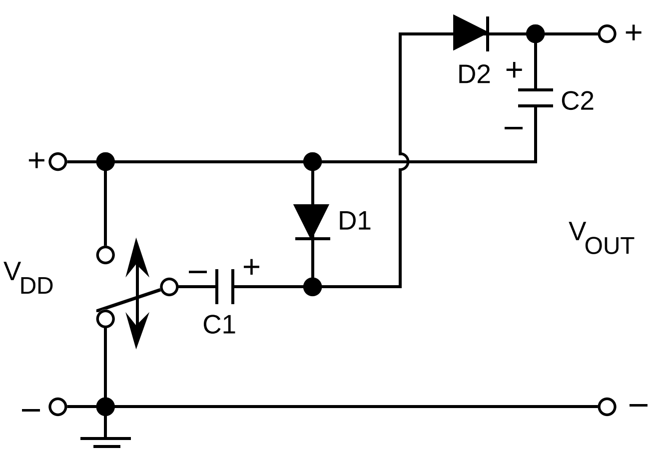



**Figure 1. Charge Pump Voltage Doubler**

## The MIC5011

A simplified block diagram of the MIC5011 is shown in Figure 2. The charge pump is configured as a tripler, and operates at a 100 kHz rate. The oscillator is enabled by the control logic to turn the MOSFET on. For supplies greater than 13V the charge pump can develop in excess of 20V gate drive–more than the average power MOSFET can safely handle. A clamp is included on-chip to limit the gate drive to approximately 12.5V. Figure 3 shows gate drive as a function of supply voltage.

Turning the MOSFET off involves more than just stopping the charge pump oscillator: charge stored on the gate of the MOSFET must be dumped by an active pull-down. The pull-down is turned off when the MIC5011 is commanded to turn the power MOSFET back on.

Small charge pump capacitors (≈100pF) are included on-chip, and provision is made for adding external pump capacitors (pins 6, 7, and 8) where faster switching is desired. A useful increase in turn-on switching speed will be observed for values of 100pF to 1nF. Full enhancement gate rise times range from several hundred microseconds for low supply voltage, a large MOSFET, and no external charge pump capacitors, to less than 50µs for supplies of 12 to 15V and 1nF external charge pump capacitors. The output rise time is very fast when operating on high (15V) supply voltages, as the charge pump drives the MOSFET gate up to $V_{DD}$ within 2µs of the input going high.

The control input turns the MOSFET on for any input greater than approximately 3.5V, so the MIC5011 interfaces directly with CMOS logic, open collector gates, opto-isolators, switches, etc. Interfacing techniques are discussed in greater detail in a later section.

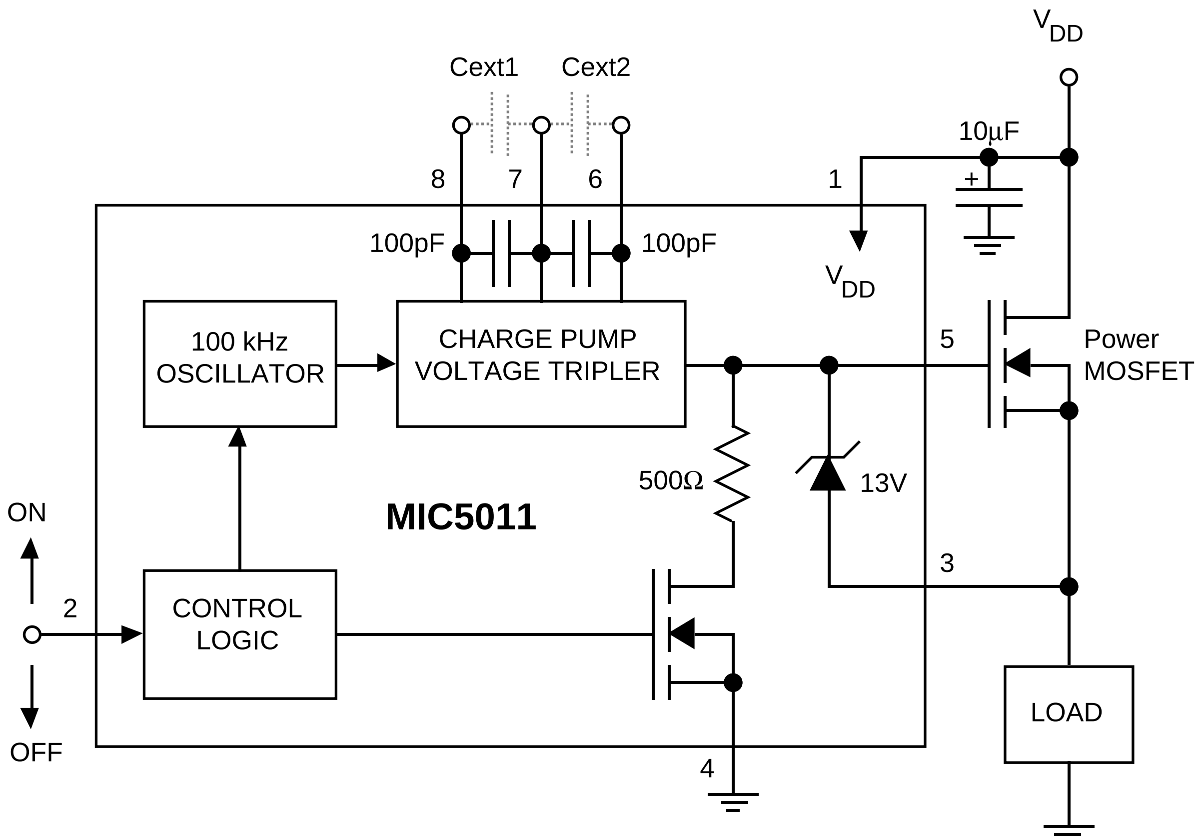



**Figure 2. MIC5011 Block Diagram**

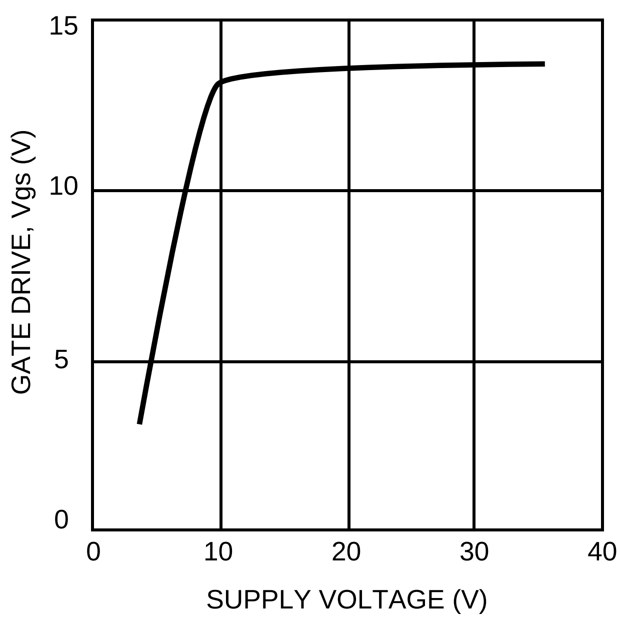



**Figure 3. Gate Drive vs. Supply Voltage**

## Inductive Loads

Many loads such as solenoids, motors, and relays, exhibit inductive characteristics. When an inductive load is commutated a negative voltage spike results (see Figure 4). The spike is clamped by the power MOSFET's source as the MIC5011 holds the gate at ground potential. The load inductance drives the source as far negative as necessary to threshold the MOSFET and force it to carry the load current (typically 5 to 8V below ground). In Figure 4 the spike develops 29V across the MOSFET while it carries the full load current. No clamp diode is necessary since the MOSFET performs this task, but safe operating area (SOA) and the additional dissipation should not be forgotten. SOA is often not an issue, such as in this example where the IRF530 can handle 25A at 29V $V_{DS}$ (the load is only 0.5A).

Motors, which are often considered "inductive" loads present a different problem. A spinning motor continues to generate a voltage after the MIC5011 shuts off. In applications where feedback is employed to control the MIC5011, the motor voltage may interfere with the operation of the circuit. The circuits of Figure 5 and "Push Button Control" of Figure 7 will not work with motor loads.

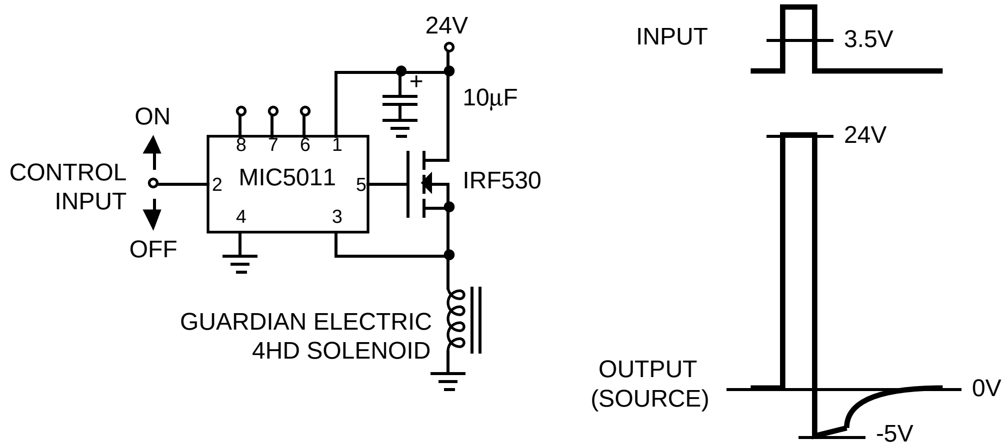



**Figure 4. Clamping Inductive Transients**

## Noise Immunity

In combination with an appropriate power MOSFET, the MIC5011 can control virtually any load that operates on a 4.75 to 32V supply. Aside from the negative spike produced by inductive loads, other pitfalls await the unwary high-side switch designer. For example, ground noise generated when switching a high-power load, especially one with a high inrush current such as an incandescent lamp, can cause oscillations at turn-on or turn-off with slow-moving inputs. Good bypassing is essential; a 10µF aluminum electrolytic capacitor is recommended from supply to ground. Don't confuse charge pump action with spurious oscillations. A slight "ripple" (synchronous with the charge pump clock at pin 8) is normally present on the rising edge of the output; rail-to-rail oscillations at the output are indicative of spurious feedback.

Attention should be paid to layout. For example, the MIC5011 ground pin should be returned to the input signal ground, not the load ground. The MIC5011 is non-inverting, and hysteresis is easily added for any load other than a motor (see Figure 5). Any arbitrary noise margin is added by selecting the appropriate resistor ratio.

## 5V Operation

The MIC5011 is suitable for use in high-side driver circuits down to about 7V. A low-side driver topology works down to 4.75V, and is suitable for operation on a 5V logic supply. Figure 6 shows a complete low-side driver for use on 4.75 to 15V supplies. Pin 3 is grounded to clamp the gate potential at 12.5V.

Only the power MOSFET breakdown ratings limit the load voltage. In fact, half- or full-wave rectified ac could be applied to the load where economy is important. Don't forget to add a clamp diode to inductive loads.

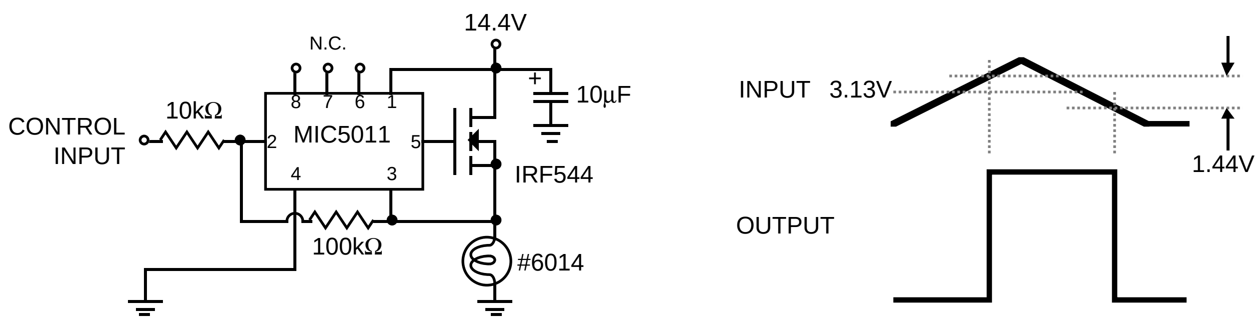



**Figure 5. Adding Hysteresis to Suppress Oscillations with Slow-Moving Inputs**

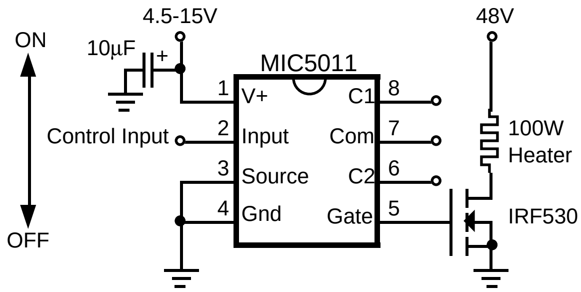
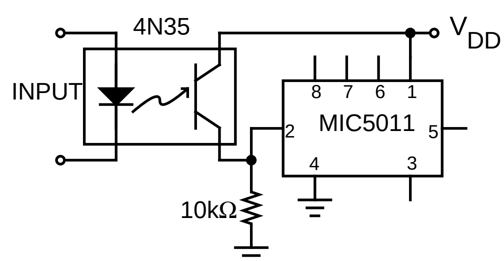



**Figure 6. Low-Side Driver**

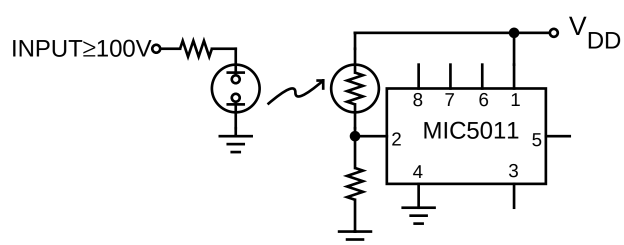
## Control Inputs

The MIC5011 is easily interfaced to any control signal. The input threshold is approximately 3.5V, and the input current is less than 1µA. Some examples of typical control inputs are shown in Figure 7. For industrial applications, electrical isolation may be desirable for either safety or noise reasons. Opto-isolators are a good choice for this use and with the hysteresis circuit shown, they provide clean switching. High voltages can be sensed and acted upon with a neon light and a light-dependent resistor.

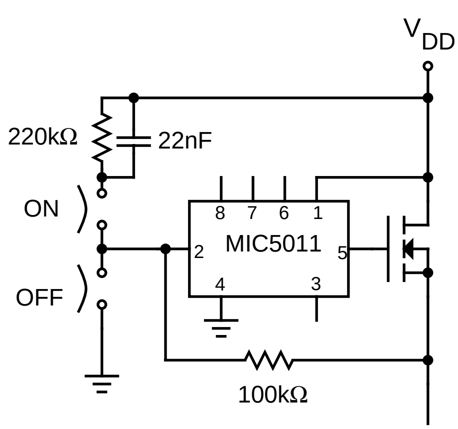
Familiar momentary “ON/OFF” push buttons are easily accommodated as shown. The “ON” button is AC coupled so that any contention between the “ON” and “OFF” buttons is resolved in favor of the “OFF” button. Hysteresis is used to latch the output into the appropriate state. 5V logic commands are interfaced by a CMOS gate. Since the MIC5011 input includes electrostatic discharge protection to the supply, the logic gate should not be powered from a supply higher than $V_{DD}$.



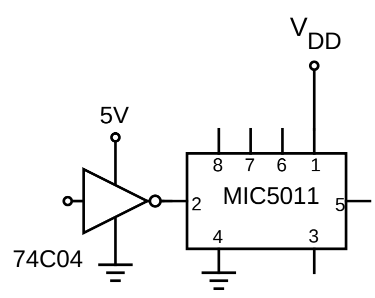

**OPTICALLY ISOLATED INPUT**




**HIGH VOLTAGE INPUT (POSITIVE OR NEGATIVE POLARITY)**




**PUSH BUTTON CONTROL**




**5V LOGIC INTERFACE**

**Figure 7. Various Interface Circuits**