International
IOR Rectifier

Application Note AN-940

How P-Channel MOSFETs Can Simplify Your Circuit

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P-Channel HEXFET® power MOSFETs offer the designer a new option that can simplify circuitry while optimizing performance and parts count. The main advantage of a P-Channel device is circuit simplification in medium and low power applications.

How P-Channel HEXFET Power MOSFETs Can Simplify Your Circuit

(HEXFET Power MOSFET is a trademark of International Rectifier's Power MOSFETs)

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P-Channel HEXFET Power MOSFETs offer the designer a new option that can simplify circuitry while optimizing performance and parts count. In principle, nothing can be done with a P-Channel MOSFET that cannot be done with an N-Channel *plus some extra gate drive circuitry*. The main advantage of a P-Channel device is circuit simplification in medium and low power applications. As explained in the next section, the P-Channel MOSFET has significant higher power losses that discourage its application in higher power circuits.

1. Basic Characteristics of P-Channel HEXFET Power MOSFETs

Like their N-Channel counterparts, P-Channel HEXFET Power MOSFETs are enhancement mode devices. A voltage between the gate and the source terminals enhances the conductivity and allows current to flow, while no drain current flows when the gate is shorted to the source. For drain current to flow, the gate voltage has to be increased (in absolute value) towards the drain voltage. In a P-Channel device the conventional flow of drain current is in the "Negative" direction—that is, current flows out of the drain, with a negative gate-to-source voltage applied (Figure 1).
P-Channel MOSFETs are built on P-type epitaxial material, where the majority carriers are holes. Since holes have lower mobility than electrons (the carriers in the N-Channel MOSFETs), the on-resistance of P-Channel devices is two or three times higher than that of an N-Channel of the same area. Transconductance is lower, capacitances are slightly higher and so is threshold. The reverse recovery of the internal diode is snappier.

A close analysis of the data sheet would also show that the temperature variations of the threshold voltage, on-resistance and transconductance for a P- and an N-Channel are slightly different. This difference can, however, be considered a second order effect in most practical applications.

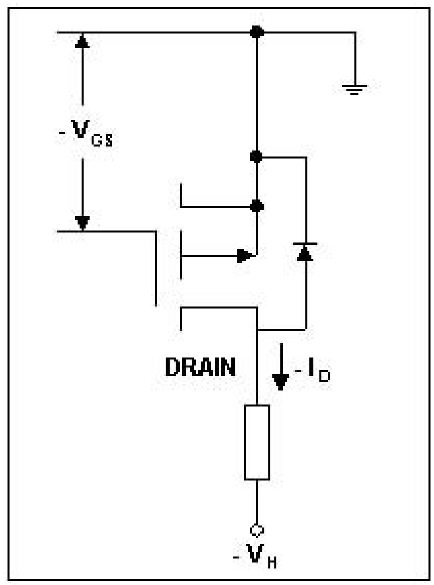


Figure 1. P-Channel HEXFET

As shown in Figure 1, the P-Channel HEXFET Power MOSFET, like its N-Channel counterpart, has an integral reverse rectifier, whose anode is connected to the drain. This diode has the same current handling capability as the transistor itself. However, in the high-density HEXFET Power MOSFETs in surface-mountable packages, the current rating of the diode may be less than that of the HEXFET Power MOSFET. This is due to the fact that the power dissipation of the diode at rated current is higher than that of the HEXFET Power MOSFET on account of the very low on-resistance of the new technology and the high thermal resistance of the package.
In the following sections, we present a brief overview of the areas where a P-Channel can be used to particular advantage.

2. Grounded Loads

One area where P-Channel HEXFET Power MOSFETs yield circuit simplification and cost savings is where the load is connected to ground. In these applications the use of a P-Channel device allows the load to be tied to the drain so that the gate drive can be referenced to one side of the supply. If an N-Channel were used, a separate supply would be required, referenced to the source, as explained in AN-937.

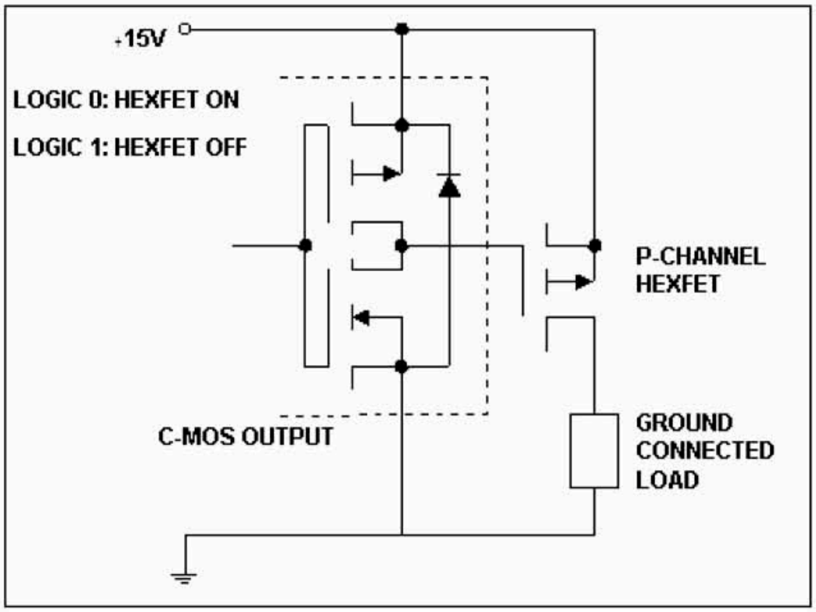


Figure 2. Switching Ground-Connected Loads Operating from Low Voltages

Figure 2 shows how such a circuit would operate when driven from a C-MOS gate. However, if the load is operated at voltages above 15V, a direct connection between the C-MOS and the gate of the MOSFET is not possible because the supply of the logic cannot be tied to the source of the P-Channel. Level shifting becomes necessary, as it will be seen later, and the P-Channel loses much of its appeal. To perform the same function an N-Channel HEXFET Power MOSFET would require a separate supply referenced to the source, or a charge pump or a bootstrap MGD. However, the N-Channel would also have a much smaller die size and cost and, as shown elsewhere, these gate drive solution can be implemented with simple techniques.

A P-Channel device can also be operated in linear mode as shown in Figure 3. The device can be used to do voltage or current regulation by means of suitable feedback. In the applications shown in Figures 3(b) the device regulates the voltage to a grounded load operated from a source higher than 18 V. For parallel connection of devices, or where fast slew rate is important, a current boosting stage at the output of the operational amplifier may be required.

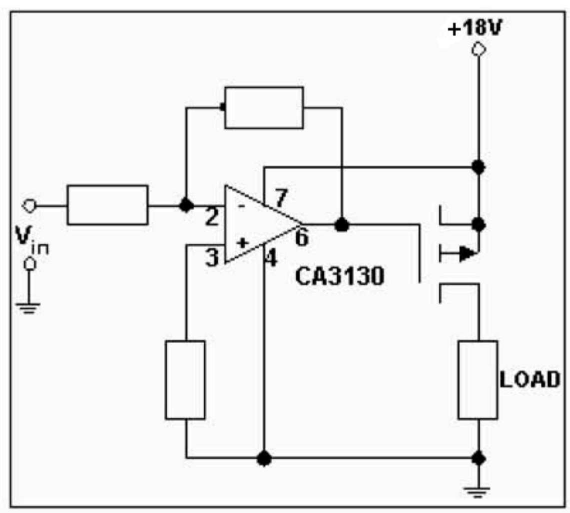
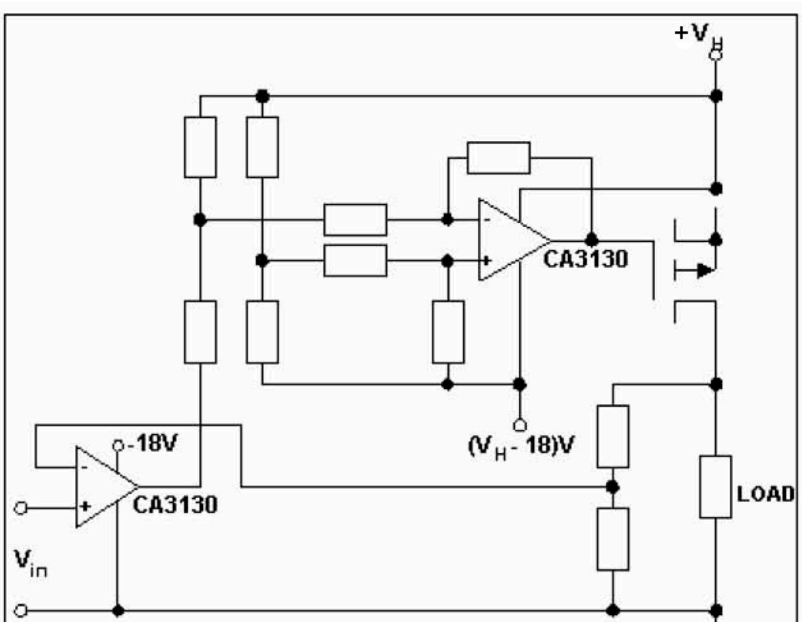
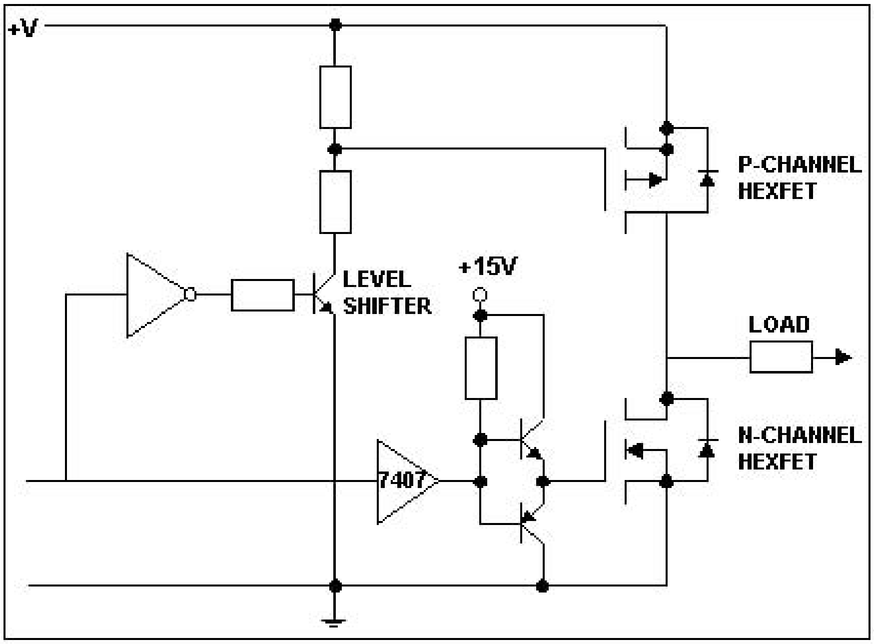


Figure 3(a). Driving Grounded Load in



3. Totem Pole Switching Circuits

One of the most common building blocks for switching applications is the "totem pole." It is used in a variety of applications, such as switching power supplies, DC-to-AC converters, AC motor speed controllers AM transmitters and Class D switching audio amplifiers. When implemented with a complementary pair, the totem pole can be common source or source follower, depending on the connection.



A common source totem pole suitable for high voltage operation is shown in Figure 4. Both gate drive signals are referenced to fixed potentials, the two separate ends of the DC supply. The drive signal for the high-side P-Channel is level-shifted from the low side with a resistive divider. Since the drains of the HEXFET Power MOSFETs are normally connected to the header of the package, the two devices can be mounted on the same conducting substrate or heatsink. Radiated EMI may be a concern if the heatsink swings with significant dv/dt.

Figure 4. Common source totem pole with its drive circuitry

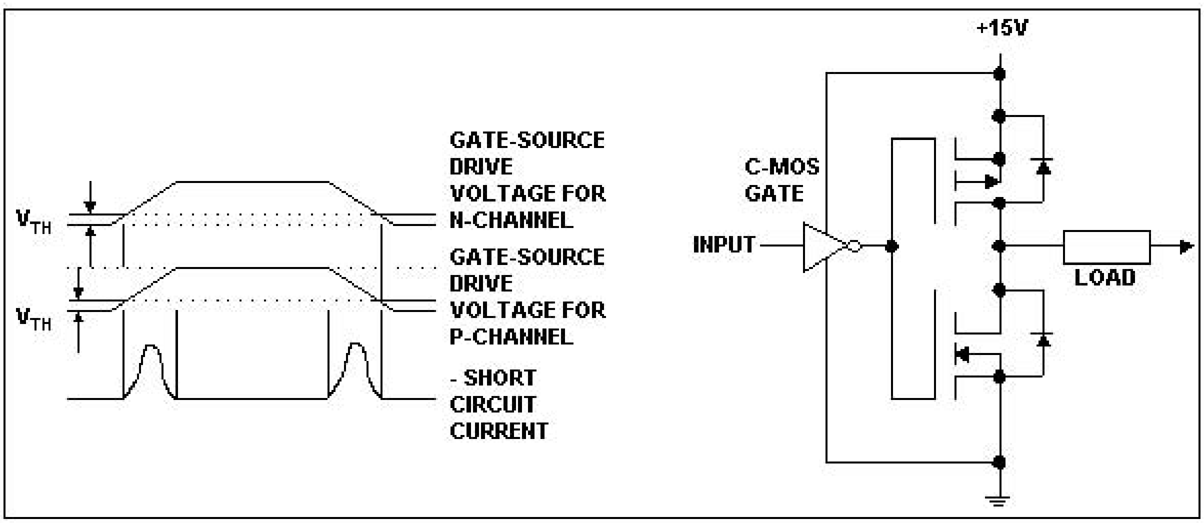


Figure 5. P/N-Channel HEXFET Power MOSFET Totem Pole with Drive Circuit for Operation at Low Voltages

If the supply voltage is less than 20V, the two gates can be connected together and driven with respect to either end of the supply (Figure 5). When using this gate connection, care should be exercised to have a gate drive signal with fast rise time to minimize cross-conduction, i.e. the time during which both MOSFETs are on in linear mode. As shown in Figure 5, if the two gates have the same drive signal, there is a period of time when the gate drive transitions between the lower threshold, say 3 V, and the

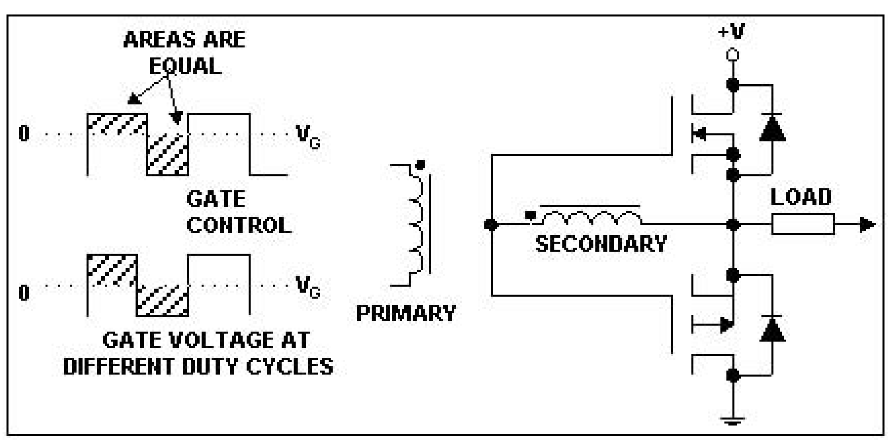


Figure 6. Complementary source-follower totem pole

upper threshold , say 15-3 V=12 V, in which both devices are on.

This is equivalent to a “make before break” set of contacts and there is a finite amount of charge that is lost at each switching operation. The inverter building block of the C-MOS logic family is easily recognizable in this circuit configuration.

A source follower totem pole is shown in Figure 6. The relative positions of the P- and N-Channel HEXFET Power MOSFET devices have been interchanged so that both have the load connected to the source. The gate drive signals are now referenced to the same point that, unfortunately, is neither of the two supply leads.

This circuit has an inherent dead-time, as the gate voltage of either device has to decrease below its own threshold before it can exceed the threshold of the other device. This is equivalent to a “break before make” set a contacts, because it is inherently impossible to drive both devices ON simultaneously. The duty-cycle limitations of the transformer drive can be eliminated as indicated in AN-950 or in AN-937.

This configuration has an additional feature that is of particular interest to power designers: it has an excellent performance in terms of radiated EMI. Since both drains are at fixed potential the heatsink can be grounded with no signal capacitively coupled into it. The top device needs to be isolated from the sink. Being an N-Channel, has lower losses and may be able to afford the additional thermal resistance.

The gate drive of the source follower totem pole is much simpler at low voltage.

4. Applications of the Complementary Totem Pole

The two most common applications of the complementary totem pole are the following:

- Complementary source followers as buffer drivers . Typical applications are shown in AN-937.
- Complementary pairs in audio amplifiers. This is covered in more detain in AN-948.

Related topics

Gate drive characteristics
MOS-Gate Drivers
Measuring device characteristics