HEXFET® Power MOSFETs In Low Dropout Linear Post-Regulators

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Advances in switched mode power conversion techniques have made it possible to achieve significant improvements in the efficiency, reliability, size, weight and cost of power supplies. Power supplies today are available in a wide variety and range of output voltages, of which the most common are +5V and ±12V supplies targeted towards boards containing a mix of digital and analog devices. Typically, the 5V output represents the bulk of the output power and, hence, the control loop is closed around this output. For well designed power supplies, the open loop output impedance is low enough so that the change in pulse width due to total load change is approximately 10% maximum at constant input voltage. This change in pulse width causes a 10% change in the unregulated 12V outputs. Thus, linear post regulators are frequently used to keep the 12V outputs within specification for critical analog loads such as AD converters and precision op-amps. The loads are typically low current (approximately 1A) and low overhead voltages are desired. Three terminal fixed voltage regulators such as LM78XX, LM79XX offer an easy solution to this problem because of their simplicity. Their popularity is limited, however, due to two major drawbacks:

1. Remote voltage sensing is not possible; as a result, compensation for wiring voltage drops cannot be made.
2. Being implemented in bipolar technology they need a high input/output differential voltage which generates heat, lowers efficiency, and severly limits the output current.

Due to these shortcomings, International Rectifier HEXFET power MOSFETs find wide application in the design of low voltage dc linear regulators. In this application, as in others, they offer many advantages such as:

1. The current required for a low forward drop is nearly zero while bipolar devices require hundreds of milliamps.
2. The intrinsic reverse diode in the HEXFET protects the device when it is reverse biased while bipolars require an additional device.
3. The resistive characteristics of the HEXFET power MOSFET are most suited for a low dropout linear regulator. This is the prime advantage they have over bipolars as shown in Figure 1a. Bipolars behave like a constant voltage source in series with a variable voltage source, as shown in Figure 1b. This imposes a minimum dropout voltage limit on the regulators equal to the constant voltage value (e.g., 0.25 volts for

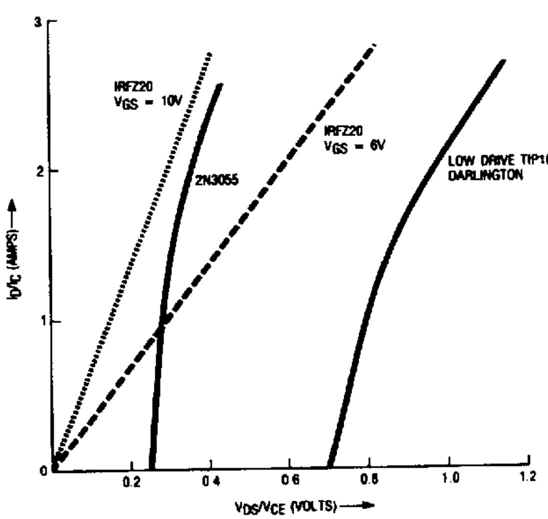


Figure 1a. An approximate comparison of output characteristics

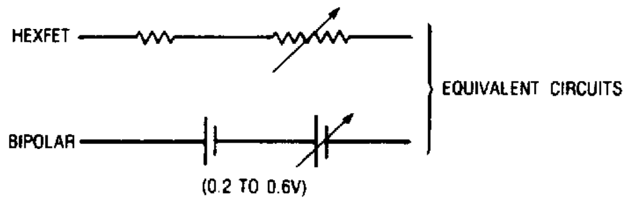


Figure 1b. Output equivalent circuits

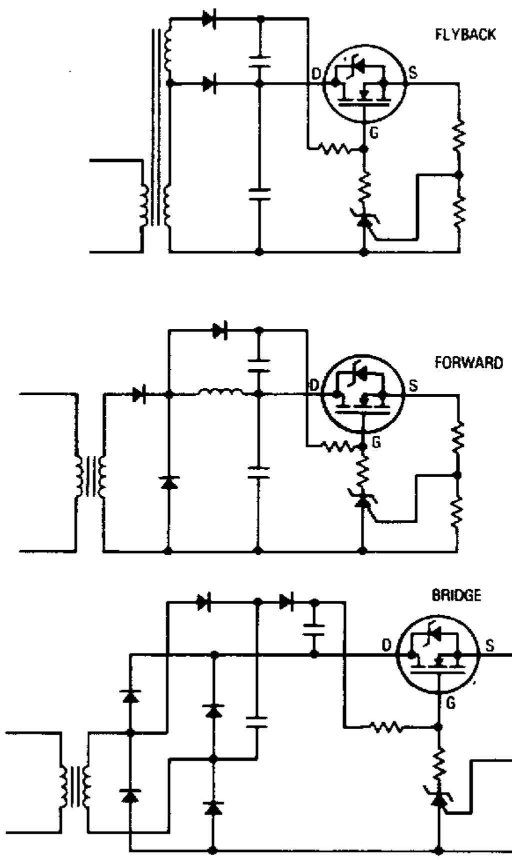


Figure 2. Bias supply generation

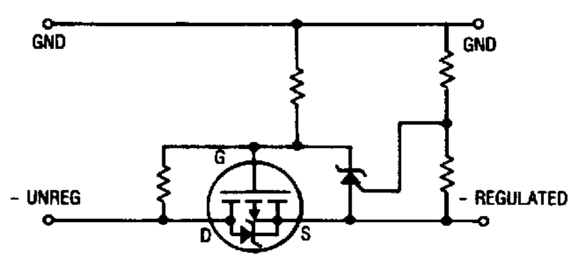


Figure 3. Negative voltage regulator

the 2N3055A). As the 2N3055A requires a large base current, a Darlington such as the TIP100 may be used which further increases the overhead voltage of the TIP100 to about 0.7 volts.

4. As power MOSFETs are majority carrier devices, they have no storage time. This is important as low dropout applications require operation near the saturation region for a bipolar. Circuit transient response is therefore better than that of a bipolar regulator. An example of this is shown in Figure 5.

5. A low dropout bipolar regulator has a gain of more than one and, therefore, is more prone to instability and negative resistance than a MOSFET low dropout regulator, which is unconditionally stable due to its less than unity gain.

6. HEXFETs can take up to four times their rated currents in transient overloads while bipolars are normally limited to 1.5 times the rated current.

The only disadvantage that N-channel power MOSFETs have when used as a high side switch is that they need a bias supply of approximately 10 volts above the positive rail. Fortunately, as the input drive currents are very low, the bias supply can be generated from the switching power supply itself. A few charge pump possibilities have been detailed in Figure 2. These circuit use an IRFD020 in a 4-pin HEXDIP, and at 1 amp has a drop of a mere 150 millivolts, while the 2N3055 at 1 amp would have a drop of 0.3 volts. The control element used is an TL431 3-terminal inexpensive voltage controlled current sink used as an adjustable shunt regulator. A negative voltage regulator is shown in Figure 3. The principle of operation is the same for the circuits in Figures 2 and 3, namely, that if the output voltage tends to increase, the I(sink) through the controller increases. This causes a decrease in the gate source voltage allowing the output to remain in regulation. Experimental results of a breadboarded regulator along with the components are shown in Figures 4 a and b. A comparison with an LM317 linear regulator in the steady state (Figure 4b) illustrates the low dropout advantage of HEXFET regulators. The transient response of both regulators is compared in Figures 4 (a, b, c, d) which reveals that the HEXFET regulator has a much smaller average output error. Simple current limiting can be achieved by

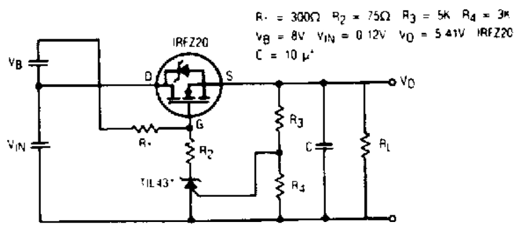


Figure 4a. Breadboard regulator

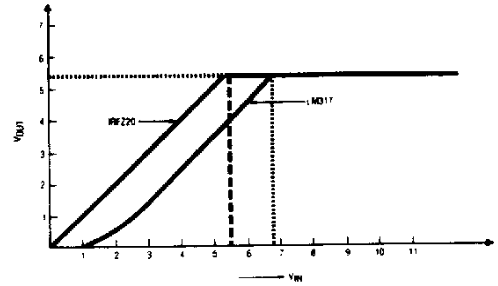
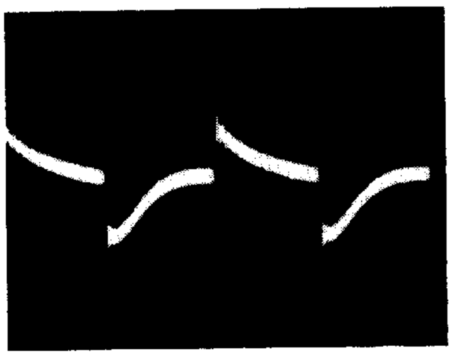


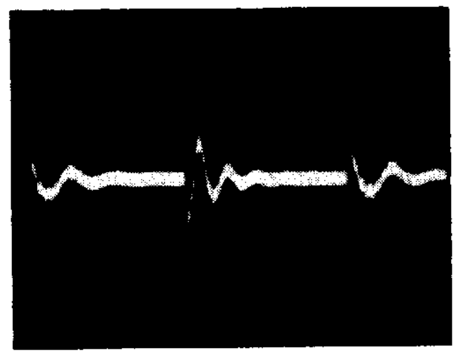
Figure 4b. Comparison of regulators

LM 317 REGULATOR



(a) With 10 µF output filter capacitor

IRZ20 REGULATOR



(b) With 10 µF output filter capacitor

LM 317 REGULATOR

(c) Without output capacitor

IRFZ20 REGULATOR

(d) Without output capacitor

Figure 5. Transient response comparison of regulators (load change of 1 mA to 500 mA)

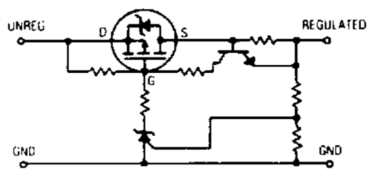


Figure 6. Current limit implementation

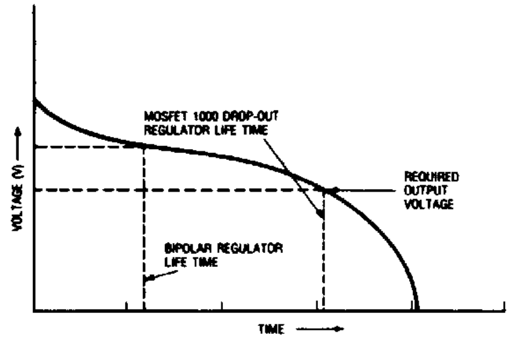


Figure 7. Battery operated equipment lifetime comparison

using a few additional components as detailed in Figure 6.

Low dropout regulation is especially important in battery operated equipment in terms of useful battery life. As Figure 7 shows, an instrument with a bipolar voltage regulator would have a shorter life time as it would need an input-output differential of at least 0.2 to 0.6V. This is much more than a HEXFET regulator requires, which would regulate down to a few tens of millivolt of differential voltage. Depending on the slope of the battery voltage profile, a sizeable increase in equipment life could result.

In summary, International Rectifier HEXFET power MOSFET devices offer an excellent alternative to bipolars as low drop-out linear regulators chiefly because of the HEXFET's resistive output characteristics and high input impedance. □