

APPLICATION NOTE 969

High-Power Voltage Regulator Has Low Dropout Voltage

Abstract: A very low dropout regulator is built from a MAX1622 high-side charge pump, an n-channel MOSFET, and an operational amplifier reference combination. Dropout voltage can be in the 10s of mV.

The positive voltage regulator of **Figure 1**, featuring an N-channel MOSFET pass element, maintains 5V regulation $I_{OUT} = 1A$ with inputs as low as 5.02V. MOSFETs with low $R_{ds(ON)}$ are key to this application because the dropout voltage is proportional to $R_{ds(ON)}$. Fortunately, high-power MOSFETs with extremely low $R_{ds(ON)}$ are both inexpensive and readily available.

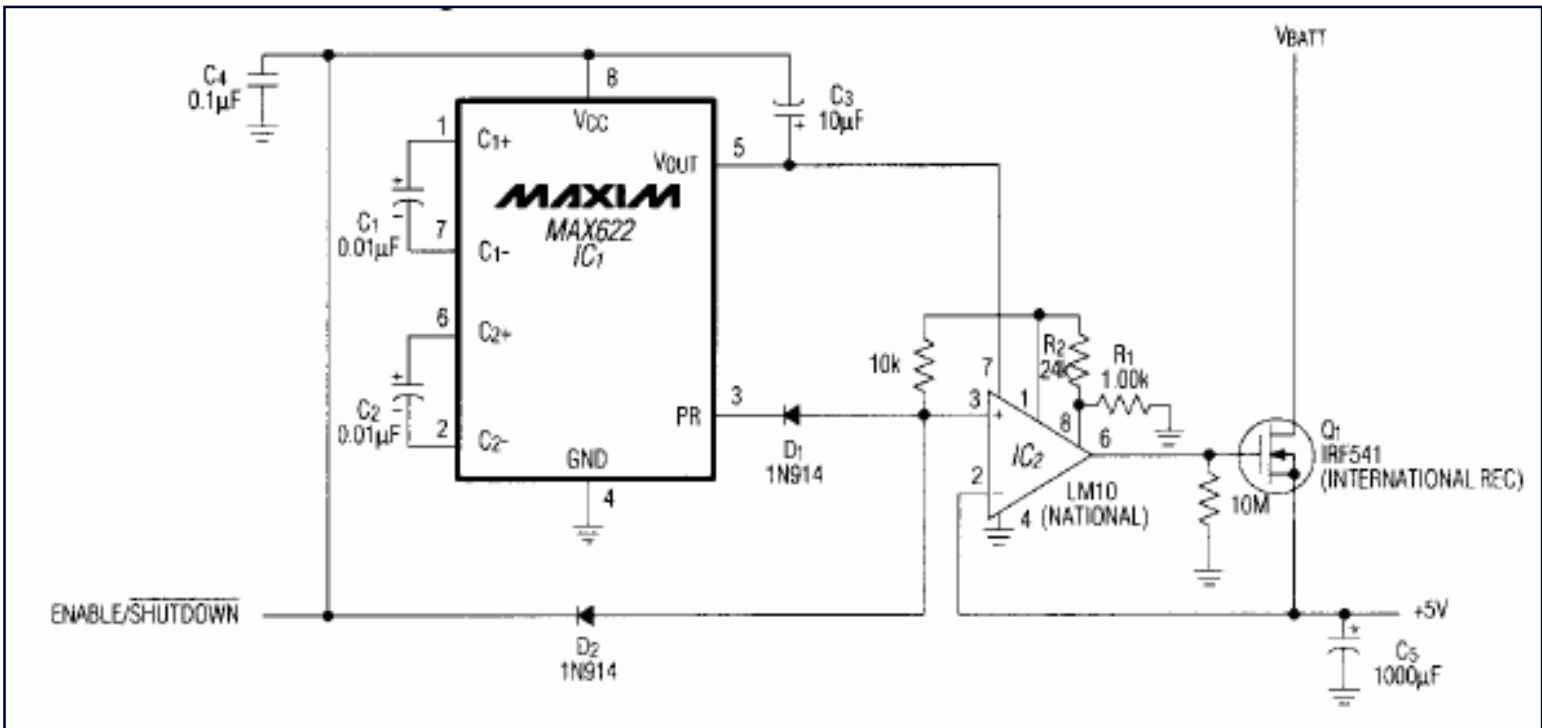


Figure 1. IC₁ generates a high-side voltage ($V_{BATT} + 11V$) that helps drive the N-channel pass transistor in this high-power, low-dropout, positive voltage regulator.

The LM10 (IC₂) combines a precision op amp with a voltage reference and variable-gain buffer. External resistors configure the buffer for a gain of 25, boosting the .02V reference to a regulated 5V at pin 1. By comparing this 5V reference with the regulated output (V_{OUT}), the internal op amp produces an error voltage that drives the MOSFET's gate. Powered by the high-side power supply (IC₁), the LM10 is able to deliver a gate drive of $V_{CC} + 11V$ (approximately 16V). At $I_{OUT} = 5A$, the resulting dropout voltage is under 400mV with an IRF541 MOSFET, and under 100mV with an SMP60N06 (**Figure 2**).

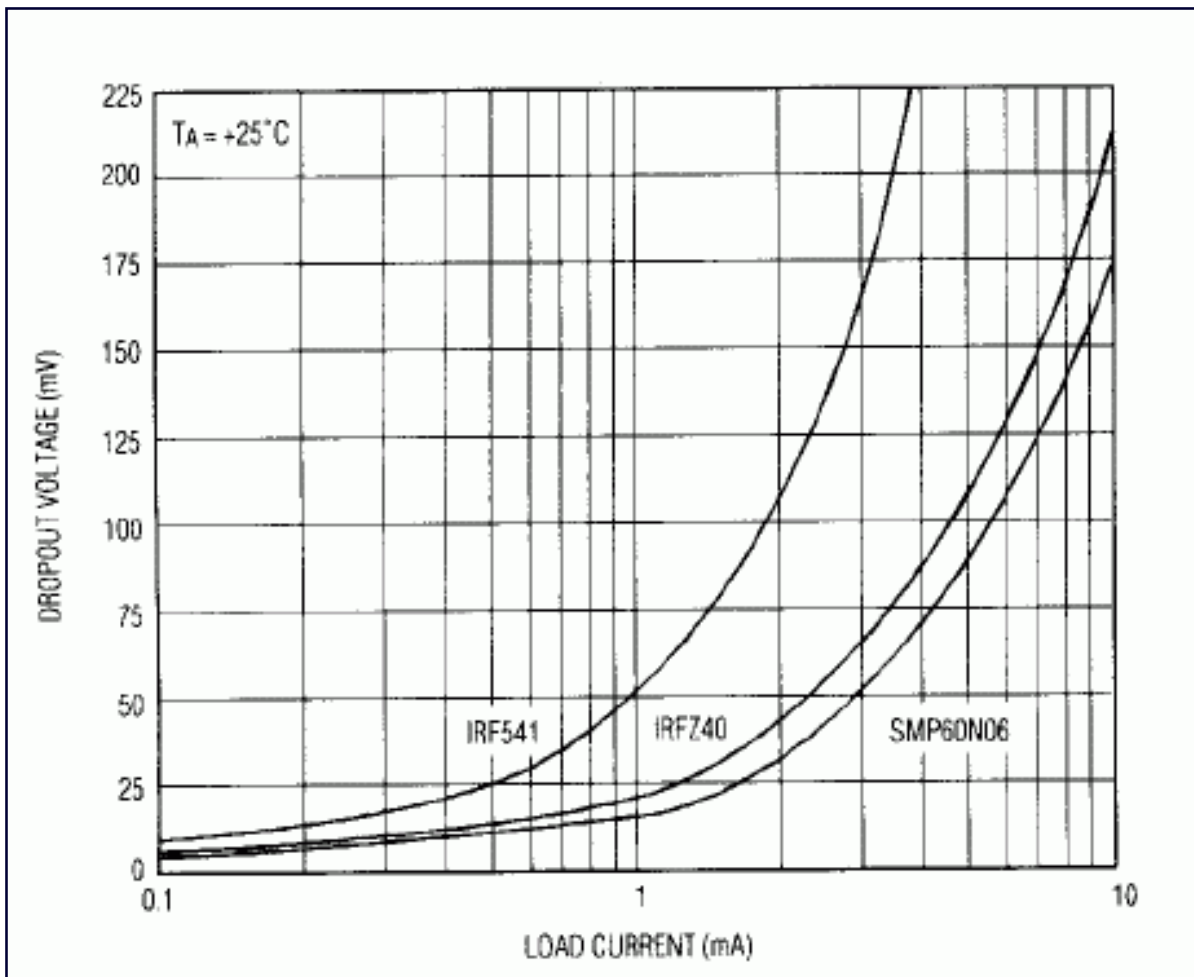


Figure 2. Dropout voltage (a function of load current) can be reduced by choosing a MOSFET with lower $R_{ds(ON)}$.

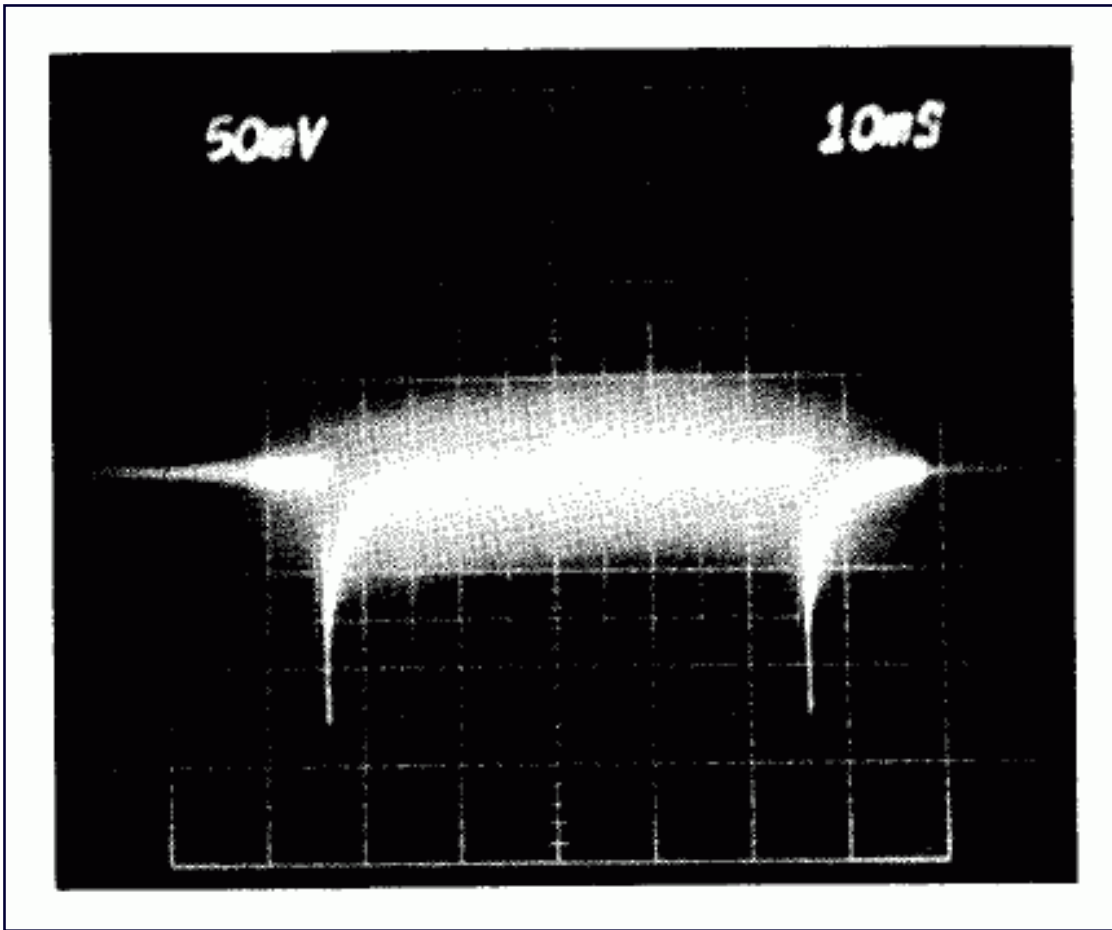


Figure 3. The Figure 1 circuit's transient response to a 1A, 20Hz pulsed load is less than 150mV ($C_5 = 1000\mu\text{F}$).

Gate current (leakage) in the MOSFET, unlike base current in a bipolar transistor, does not change with the load current. Therefore the operating supply current in Figure 1, drawn only by the MAX622 and LM10, is independent of load current and relatively independent of V_{BATT} (Figure 4). During shutdown, the circuit's only supply current is that due to leakage across the pass transistor.

The ENABLE/active-low SHUTDOWN input controls the regulator: applying V_{BATT} turns it on, and pulling the input to ground turns it off. The ENABLE/active-low SHUTDOWN signal must source at least 2mA. Diode D_2 speeds the turn-off time following a shutdown command. If shutdown is not required, you can eliminate D_2 and connect the terminal directly to the battery or unregulated supply.

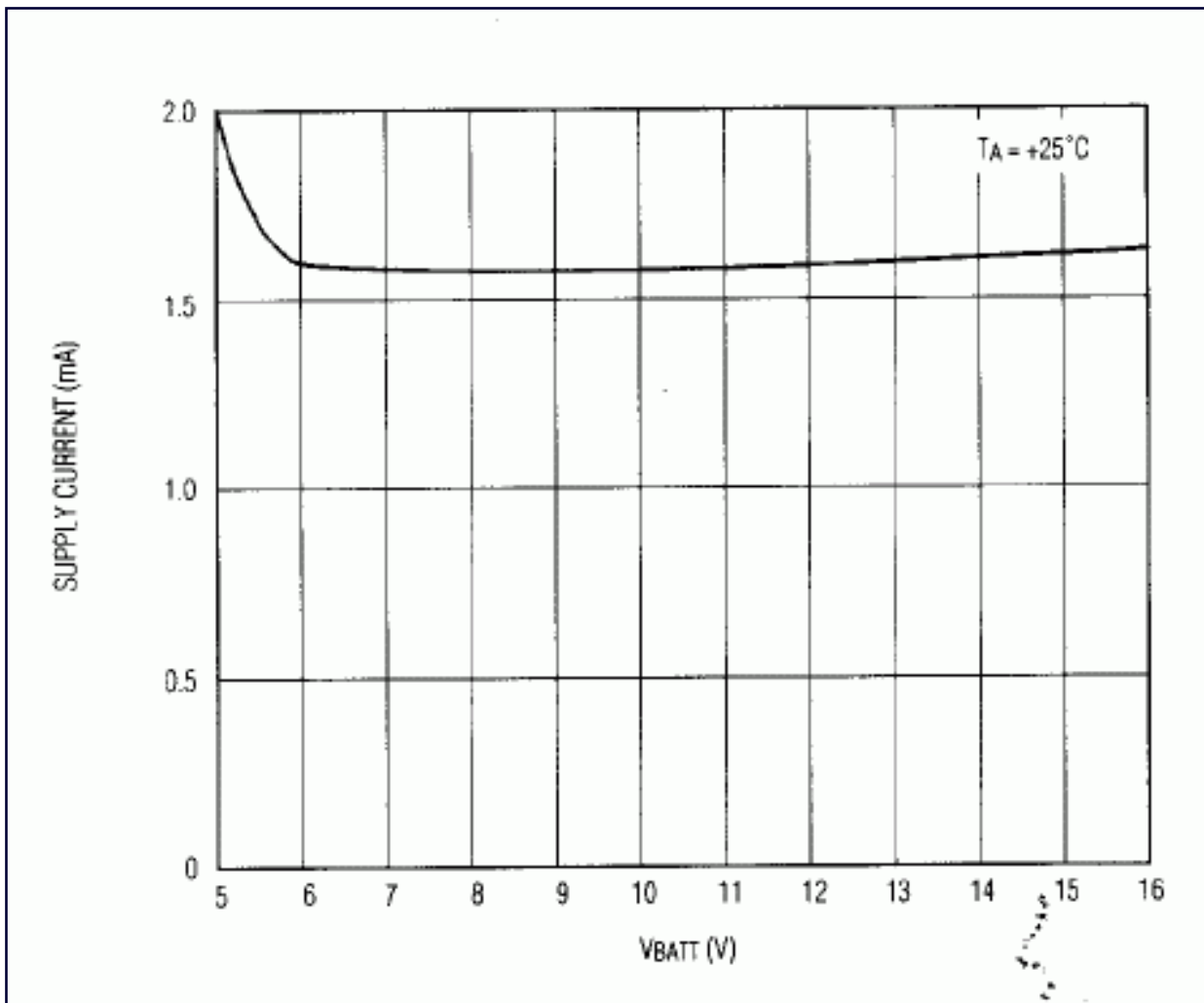


Figure 4. Supply Current for the Figure 1 circuit is independent of V_{BATT} .

At power-up with the regulator enabled, the PR output of IC₁ remains low, holding the MOSFET off by depressing the reference voltage at the non-inverting input of IC₂. The regulator thus remains off until the gate-drive voltage rises to an acceptable level, typically $V_{CC} + 8.5V$.

The output capacitor C₅ stabilizes the output voltage against load changes. A value of 1000μF, for instance, reduces the transients produced by a 1A load, pulsed at 20Hz, to less than 150mV (**Figure 3**). If the load is relatively constant, you can reduce or eliminate C₅. The output voltage depends on R₁ and R₂:

$$V_{OUT} = 0.2 [(R_1/R_2) + 1]$$

Input voltage may range as high as 16.5V but a lower level produced by five NiCd cells in series (for example) offers high efficiency. Efficiency is only 72% at first, when the freshly charged NiCd stack measures about 7V. But the stack drops to 6V during the first 5% of it's discharge and remains there for the next 80% of discharge. As a result, the regulator exhibits 82% efficiency over most battery's discharge period.

A stack of four NiCd cells gives even greater efficiency. Setting V_{OUT} to 4.75V and assuming a ±10% tolerance, the circuit can achieve 98.9% efficiency over 80% of the battery's discharge. Efficiency actually increases as the stack approaches it's 4.5V end-of-life potential.

Application Note 969: <http://www.maxim-ic.com/an969>

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Related Parts

MAX622: [QuickView](#) -- [Full \(PDF\) Data Sheet](#)

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