Application Hint 20

Introduction to the Super LDO™ Regulator

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A brief review of the significant changes in IC linear regulators leads to the Micrel Super LDO™ Regulator and highlights its important advantages.

Basic NPN Regulators

Economical high-current regulators continue to employ the original space-efficient NPN transistor for the pass element (see figure 1a). The NPN regulator allows high device output currents, but the large input to output voltage drop that results from operating the NPN as an emitter follower often requires a substantial heat sink.

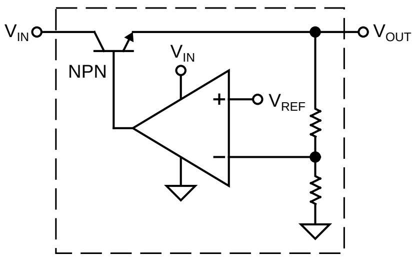

Figure 1a. NPN Monolithic Regulator

PNP Low-Dropout Regulators

Demand for a large reduction in dropout voltage resulted in the introduction of the LDO (low dropout) regulator. The LDO's reduction of the input to output voltage drop was achieved by using a PNP transistor as the pass element (see figure 1b). Because a PNP requires substantially more die area than an electrically similar NPN, early LDO regulators were offered with relatively low output current capabilities. These LDO regulators also required large ground (or quiescent) currents to drive the PNP transistor which resulted in low efficiency.

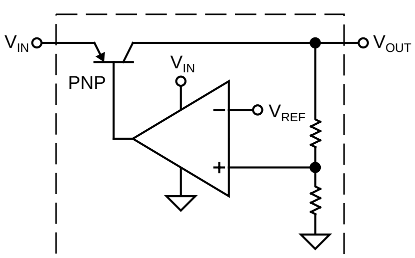

Figure 1b. PNP Monolithic Regulator

Advances in silicon fabrication, such as Micrel's Super ßeta PNP™ technology, made higher current, with reduced ground current, LDO regulators technically and economically feasible . LDO regulators are now available with output currents rivaling those using the NPN as the pass element.

P-Channel Improved-Efficiency Regulators

The need for higher efficiency regulators for battery powered equipment has led to monolithic regulators which use a P-channel enhancement-mode MOSFET as the pass element (see figure 1c). The P-channel MOSFET dramatically reduces ground current, but even more than with the PNP, requires a large die area for even low output current regulators. P-channel MOSFET are typically 2.5 times the size of an equivalent N-channel MOSFET. Another drawback when using this regulator is the dramatic increase of MOSFET on resistance at low input voltages, further limiting its maximum output current capability.

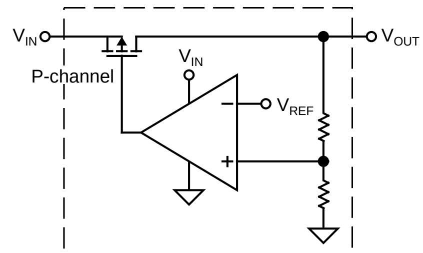

Figure 1c. P-Channel Monolithic Regulator

High-Output Low-Dropout Regulators

Managing moderate to high output currents can be accomplished using a dedicated control IC to drive an external pass element.

The external pass element offers the designer two advantages unattainable with the monolithic approach: First, because the control circuitry is separate, the pass element's die area in a given package can be increased. This results in lower dropout voltages at higher output currents. Second, the junction-to-case thermal resistance is much less allowing higher output currents before a heat sink is required. As with the monolithic approach, for equal die areas, a PNP transistor offers the lowest dropout voltage, a P-channel MOSFET the lowest ground current, and the NPN transistor the lowest cost.

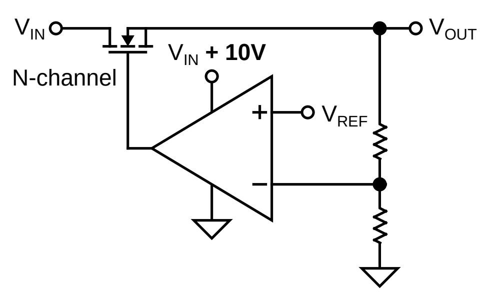

Figure 2. N-Channel Regulator

The most attractive device for the external pass element is the N-channel power MOSFET (see figure 2). Discrete N-channel MOSFET prices continue to decrease (due to high volume usage), and the race for lower and lower on resistance works in the customer's favor. The N-channel MOSFET, like the P-channel MOSFET, reduces ground current.

With device on resistance now below 10mΩ, dropout voltages below 100mV are possible with output currents in excess of 10A. Even lower dropouts are possible by using two or more pass elements in parallel.

Unfortunately, full gate-to-source enhancement of the N-channel MOSFET requires an additional 10V to 15V above the required output voltage. Controlling the MOSFET's gate using a second higher voltage supply requires additional circuitry and is clumsy at best.

Micrel's New Super LDO Family

Micrel's Super LDO Regulator family consists of three regulators which control an external N-channel MOSFET for low dropout at high current. Two members of the family internally generate the required higher MOSFET enhancement voltage, while the other relies on an existing external supply voltage.

All members of the Super LDO Regulator family have a 35mV current limit threshold, ±2% nominal output voltage setting, and a guaranteed 3V to 36V operating voltage range. All family members also include a TTL compatible enable/shutdown input (EN) and an open collector fault output (FLAG). When shutdown (TTL low), the device draws less than 1µA. The FLAG output is low whenever the output voltage is 6% or more below its nominal value.

The MIC5156

The MIC5156 Super LDO Regulator occupies the least printed circuit board space in applications where a suitable voltage is available for MOSFET gate enhancement. To minimize external parts, the MIC5156 is available in fixed output versions of 3.3V or 5V. An adjustable version is also available which uses two external resistors to set the output voltage from 1.3V to 36V.

The MIC5157 and MIC5158

For stand-alone applications the MIC5157 and MIC5158 incorporate an internal charge-pump voltage tripler to supply the necessary gate enhancement for an external N-channel MOSFET. Both devices can fully enhance a logic-level N-channel MOSFET from a supply voltage as low as 3.0V. Three inexpensive small value capacitors are required by the charge pump.

The MIC5157 output voltage is externally selected for a fixed output voltage of 3.3V, 5V or 12V.

The MIC5158 output voltage is externally selectable for either a fixed 5V output or an adjustable output. Two external resistors are required to set the output voltage for adjustable operation.

Computer Power Supply Application

Figure 3 shows a typical 3.3V and 5V computer power supply application. The MIC5156 provides regulated 3.3V using Q1 as the pass element and also controls a MOSFET switch for the 5V supply.

When the 3.3V output has reached regulation, the FLAG output goes high, enhancing Q2, which switches 5V to Load 2. This circuit complies with the requirements of new microprocessors that require the 5V supply input to remain below 3.0V until the 3.3V supply input is greater than 3.0V.

An optional current limiting sense resistor (R_S) limits the load current to 12A maximum. For less costly designs, the sense resistor's value and function can be duplicated using one of two techniques: A solid piece of copper wire with appropriate length and diameter (gauge) makes a reasonably accurate low-value resistor. Another method uses a printed circuit trace to create the sense resistor. The resistance value is a function of the trace thickness, width, and length.

3.3V, 10A Regulator Application

Figure 4 shows the MIC5157's ability to supply the additional MOSFET gate enhancement in a low dropout 3.3V, 10A supply application. Capacitors C1 and C2 perform the voltage tripling required by the N-channel logic-level MOSFETs. As with any linear regulator, improved response to load transients is accomplished by using output capacitors with low ESR characteristics. The exact capacitance value required for a given design depends on the maximum output voltage disturbance that can be tolerated during a worse case load change. Adding low value (0.01µF to 0.1µF) film capacitors (such as Wima MKS2 series) near the load will also improve the regulator's transient response.

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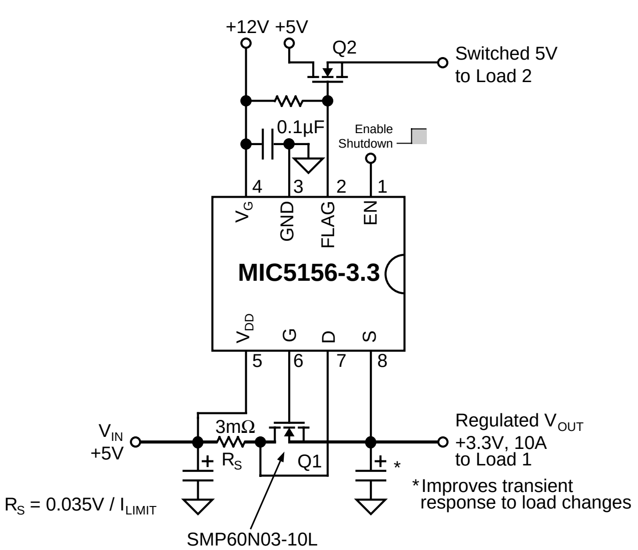

Figure 3. Microprocessor Supply

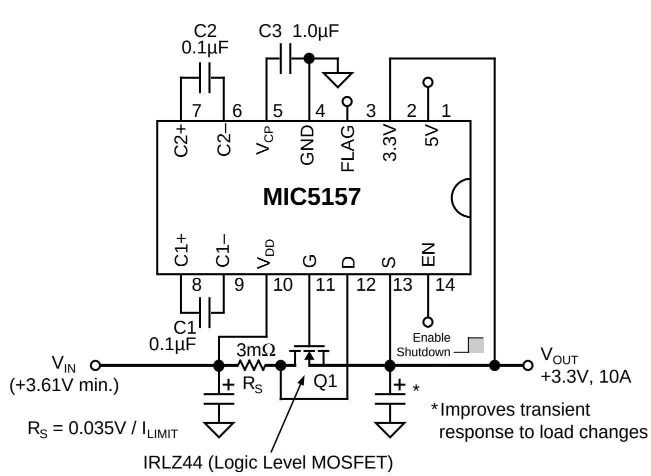

Figure 4. N-Channel Regulator