Application Hint 29

Protecting Super LDO™ Regulator MOSFETs

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The Problem

A momentary short can increase power dissipation in a MOSFET voltage regulator pass device to a catastrophic level. In the circuit of Figure 1, power dissipation in Q1 is approximately $V_{DS} \times I_{OUT}$, or $(5V - 3.3V) \times 10A = 17W$. If the output of the power supply is shorted it becomes

$$(V_{IN} / R_{DS(on)})^2 \times R_{DS(on)},$$

or an unworkable

$$(5V / 0.028\Omega)^2 \times 0.028\Omega = 892W$$

Even the most conservative heat-sink design will not save the MOSFET.

The Micrel MIC5156, MIC5157, and MIC5158 Super LDO™ Regulator Controllers offer two features that can be used to save the pass device. The first feature is a current limit capability (not implemented in Figure 1). Output current can be limited at a user-defined value, but the function is not the classic foldback scheme. While fixed-value current limiting can reduce shorted-output power dissipation to a manageable level, the additional dissipation imposed by the short can still damage the pass device. When considerable voltage is being dropped by the pass device the short-circuit power dissipation becomes dramatically high.

The second feature offered by the MIC5156/7/8 parts is an error flag. This is an open-collector output which generates a signal if the output voltage is approximately 6% or more lower than the intended value. Since this flag output is asserted logic low in the event of a shorted output, it can be used to control the enable-input pin of the regulator. The regulator can be immediately disabled upon detection of a low-voltage condition.

An Example

Figure 2 implements both the current-limit capability and a control scheme for dealing with shorted outputs. The 2.3mΩ resistor R_S provides for current limiting at about 15A. The current-limit threshold voltage of the MIC5158 is about 0.035V, and 0.035V/15A = 2.3mV. See Application Hint 25 for information on building such resistors using circuit board copper. Since a shorted output may be momentary, the circuitry built around U1 automatically restarts the regulator when a short is removed. Existence of a shorted output is continually monitored; the system will protect the pass device for an indefinite time. When a short exists the regulator is enabled for a very brief interval and disabled for a much longer interval; power dissipation is reduced by this duty cycle, which can be arbitrarily designed.

Circuit Description

Schmitt-trigger NAND gate A is used to control a gated oscillator (gate B). Resistors R5 and R6, diode D3, and capacitor C5 provide oscillator timing. With the values shown the enable time is about 110µs approximately every 2.25ms. This provides a healthy 1:20 on/off ratio (5% duty cycle) for reducing power dissipated by the pass device. Diode D2 keeps C5 discharged until gate A enables the oscillator. This assures that oscillation will begin with a full-width short enable pulse. Different enable and/or disable time(s) may be

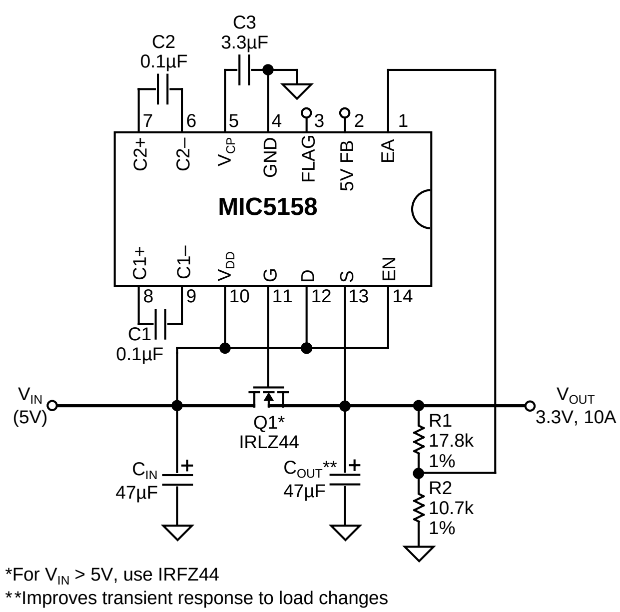


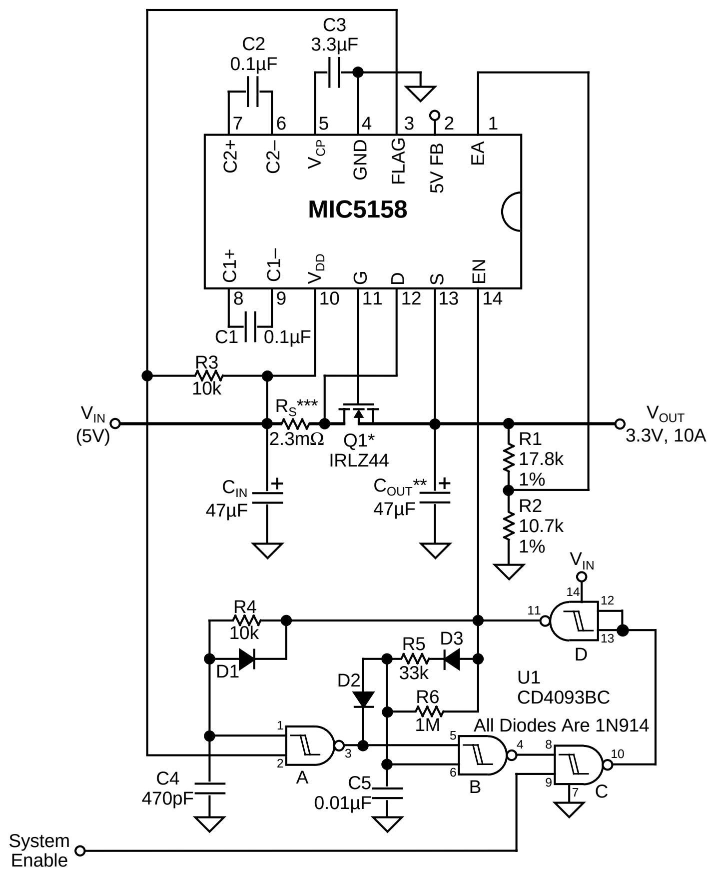
Figure 1. Simple 10A, 5V to 3.3V, Voltage Regulator

appropriate for some applications. Enable time is approximately k1×R5×C5; disable time is approximately k2×R6×C5. Constants k1 and k2 are determined primarily by the two threshold voltages (V_T+ and V_T–) of Schmitt-trigger gate B. Values for k1 and k2 (empirically derived from a breadboard) are 0.33 and 0.23, respectively. Component tolerances were ignored.

Getting Started

The MIC5158 produces a brief logic-low error-flag output at start-up because when first enabled the output voltage is zero. Notice that the protection circuitry provides a system enable input. Use of this input is optional; it should be tied to V_{IN} if not required. Since the output of gate B is logic high when the oscillator is disabled, a logic-high system enable input enables the MIC5158, which immediately produces the brief logic-low flag output mentioned above. Since the power supply output may or may not be shorted, it is desirable to wait and see. The required wait-delay timing is implemented by Resistor R4, capacitor C4, and diode D1. The leading-edge of the regulator enable signal is delayed (before application to gate A) for about 4ms, to attempt to span the width of the logic-low flag that is generated during a normal (non-shorted) regulator start-up. Providing enough delay time to span the time of the flag may not always be practical, especially when starting with high-capacitance loads. If the logic-low flag is longer than the delayed enable input to gate A, the oscillator will cycle through its on/off duty cycle and the circuit will again attempt a normal start-up. This will result in a slowing of the regulator turn-on, but this is not usually objectionable because it reduces turn-on surge currents.

After start-up the logic-high inputs to gate A hold the oscillator off and the system remains enabled as long as no error flag is generated. If the flag is generated due to a short, the MIC5158 remains enabled only for the time of the oscillator enable pulse and is then immediately disabled for the duration of the oscillator cycle. As long as the short exists the oscillator runs and the system monitors the flag to detect removal of the short; meanwhile the MOSFET is protected, and the system again starts when the short is removed.



*For V_{IN} > 5V, use IRFZ44
**Improves transient response to load changes
$$***R_S \approx \frac{0.035V}{I_{LIMIT}}$$

Figure 2. Short-Circuit Protected 10A Regulator