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Using the Enable Pin in a Linear Regulator as a Voltage Supervisor

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APPLICATION NOTE

INTRODUCTION

The combination of a voltage regulator and a voltage supervisor, shown in Figure 1, is a popular circuit configuration. The addition of the supervisor ensures that the regulated output turns on and off at sufficient input voltages, as well as giving the system the luxury of a safe and ordered startup. An inexpensive alternative, shown in Figure 2, uses the enable pin of a regulator and an external delay network to provide a safe and ordered startup. Unlike the supervisor solution, this circuit does not immediately shutdown the output once it drops below an unacceptable level. Furthermore, since the delay starts directly after the enable pin goes high, there is no insurance that the output will be at the desired regulated output voltage. The circuit proposed in Figure 3 fixes the problems of Figure 2 by cleverly replacing the single resister with a resister divider network.

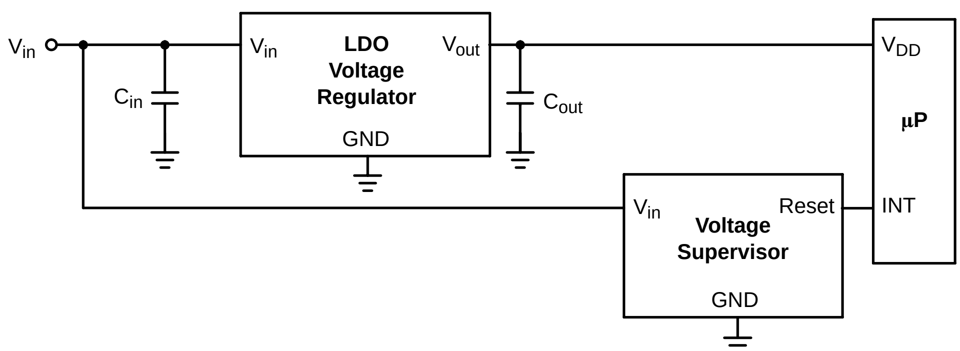

Figure 1. A voltage supervisor can be used with a voltage regulator to ensure a controlled regulated output.

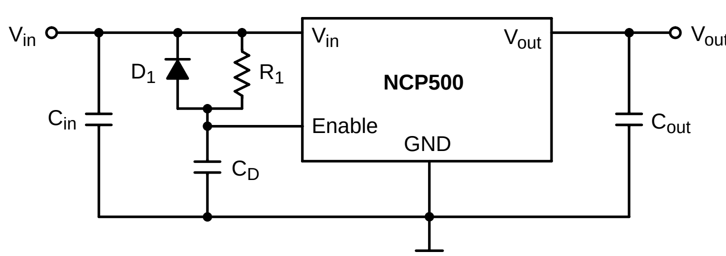

Figure 2. Resistor R_1, capacitor C_1 and diode D_1 provide a startup delay for the voltage regulator's enable pin.

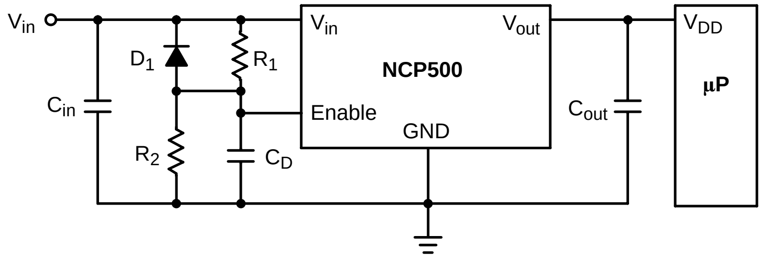

Figure 3. Resistor R_2 serves to raise the switching threshold of the voltage regulator's enable pin. This circuit also has the advantage of not requiring an interrupt pin on the microprocessor.

Circuit Description

The purpose of the resistor divider of Figure 3 is to "trick" the enable pin into turning on at a higher voltage. In most regulators, such as the NCP500, the enable pin is set to a voltage well below the nominal output. As a result, the output will track the input voltage when the enable pin switches from a logic low to logic high. The output and input voltages will be almost identical until the input voltages increases to a level above the dropout voltage of the regulator.

Figure 4 shows a simplified internal diagram of the NCP500 linear voltage regulator. The NCP500 uses a P−channel MOSFET to achieve a low drop out voltage. In addition, the NCP500 contains overcurrent and thermal protection circuits, along with an enable circuit. The enable pin can be used to shutdown the output voltage for power saving modes and to control the powerup and powerdown characteristic of the device. The enable circuit consists of a voltage comparator that determines when the voltage at the enable pin is either larger or smaller than the magnitude of the reference voltage (V_{REF}). The two resistors of the enable circuit determine the hysteresis of the comparator and account for the difference in the switching threshold voltage between the rising and falling voltage.

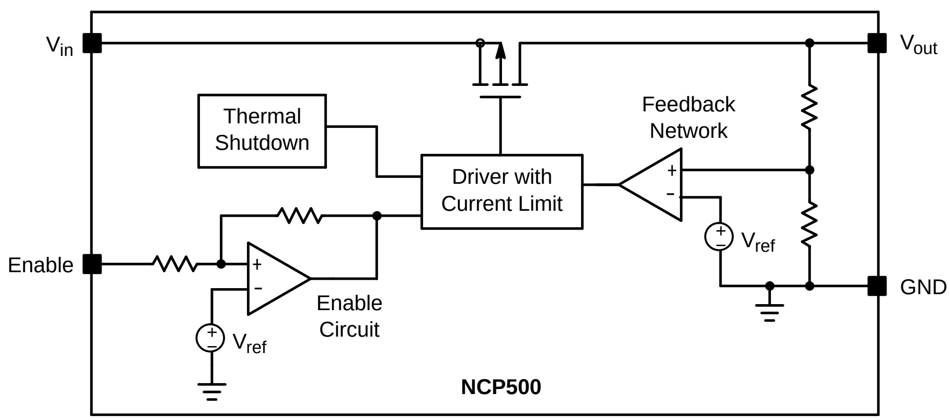

Figure 4. Block Diagram of the NCP500 Voltage Regulator

The values of resistors R_1 and R_2 needed to change the threshold voltage of Figure 3's enable pin can be determined with the equation (1). Figure 3's circuit was tested with values of 27 kΩ and 8.0 kΩ for R_1 and R_2 respectively.

$$V_{IN(TURN-ON)} = [(2 \times V_{EN(RISING)}) - V_{EN(FALLING)}] \times \left(1 + \frac{R_1}{R_2}\right) \quad \text{(eq. 1)}$$

where:

$V_{IN(TURN-ON)}$ = The user defined turn−on voltage. It is suggested that minimum $V_{IN(TURN-ON)}$ should be set to $V_{OUT} + V_{DROPOUT}$ to prevent tracking.

$V_{EN(RISING)}$ = The enable pin's rising trip point.

$V_{EN(FALLING)}$ = The enable pin's falling trip point.

$V_{DROPOUT}$ = The regulators dropout voltage.

Example:

$V_{IN(TURN-ON)}$ = 4.0 V

$V_{EN(RISING)}$ = 0.89 V (Taken from Figure 5)

$V_{EN(FALLING)}$ = 0.85 V (Taken from Figure 5)

$$\frac{R_1}{R_2} \cong \frac{V_{IN(TURN-ON)}}{((2 \times V_{EN(RISING)}) - V_{EN(FALLING)})} - 1 = \frac{4.0}{((2 \times 0.89) - 0.85)} - 1 = 3.3 \qquad \text{(eq. 2)}$$

$$\text{Select } R_2 = 8\ k\Omega, \text{ then } R_1 = 3.3 \times R_2 \cong 27\ k\Omega.$$

It is important to note that Equation 1 only approximates the value of the resistor divider. In the case of the NCP500, the approximation is fairly accurate. In other voltage regulators, the results may vary slightly. The only time a problem will be noticed though, is if the resistor divider is not large enough. This can be easily fixed by increasing the value of R_1. However, it is also important to note that since $V_{IN(TURN-ON)}$ is directly proportional to R_1, increasing R_1 will increase $V_{IN(TURN-ON)}$.

In the data sheet the enable thresholds are usually specified in one of two ways: a minimum and maximum range guaranteed by design or with typical values that go along with the minimum and maximum range. For most applications, the typical threshold values will be more applicable. If the threshold values are not specified, they can be easily found by testing a few parts beforehand. It should also be stressed that Equation 1 is not dependent on just the value of the rising threshold. The rising threshold itself does not take into account the hysteresis, $V_{EN(RISING)} - V_{EN(FALLING)}$, of the enable pin's comparator circuit. Without adding the value of the hysteresis to the value of the rising threshold, there would be no guarantee that the output would turn−off at the proper value.

The delayed input provided by the voltage supervisor is useful for applications dealing with microprocessors. It ensures that the system has a safe and ordered startup before turning on. The circuit in Figure 3 provides a similar function as a voltage supervisor IC by combining the external setup in Figure 2 with the resister divider calculated in Equation 1. The user can define the appropriate delay time based on their application by using R_1 and C_D as the RC time constant. A diode is added in parallel across R_1 to quickly discharge C_D if the voltage falls below the "new" enable threshold formed by R_1 and R_2.

Special attention in particular should be paid to R_1, since it along with C_D will determine the turn−on delay time for the regulator. Ideally the value of C_D should be in the range of 0.01 μF and 0.47 μF. A larger magnitude capacitor will increase the discharge time. Hence, a large capacitor reduces the effectiveness of this circuit to function as a voltage supervisor. Moreover, a smaller capacitance requires less board space.

The following table compares the features of four different controlled output solutions using a voltage regulator. Another possible solution, not shown, combines a voltage regulator with a voltage detector. Detectors are very similar to supervisors; however, a supervisor contains an integrated powerup delay circuit.

Table 1. Voltage Regulator Solutions

Circuit	Advantages	Disadvantages	Reference Figures
Voltage Regulator with enable pin	• Enable pin saves power consumption	• No delay at powerup • V_{OUT} tracks V_{IN} on rising and falling edges	Figure 5
Voltage Regulator with input delay (R_1, C_D, and D_1)	• Turns on at $V_{OUT(NOMINAL)}$ (assuming sufficient delay time)	• No safety feature to ensure that delay time is sufficient • V_{OUT} tracks V_{IN} on falling edge	Figure 2 Figure 6
Voltage Regulator + Voltage Supervisor	• Turns on at $V_{OUT(NOMIMAL)}$ • Delay at powerup • Warning signal prior to shutdown • Turns off immediately after insufficient V_{IN}	• Requires an interrupt pin on the microprocessor • 2 IC solution	Figure 1
Voltage Regulator with input delay and resistor divider (R_1, R_2, C_D, and D_1)	• Low cost solution • Does not require extra pin on microprocessor • Turns on at $V_{OUT(NOMIMAL)}$ • Delay at powerup • Turns off immediately after insufficient V_{IN}	• Requires four discrete parts • No warning signal prior to shutdown	Figure 3 Figure 7

Test Results

Figure 5 shows the output of the NCP500 linear regulator configured with the enable pin connected to V_{IN}. The points of inflection on the output voltage curve represent the enable trip points. It is clear that the output is tracking the input on both the rising and falling edges. Figure 6 shows the improvement of adding the external delay network on the rising edge. The falling edge of the output, nonetheless, still continues to track to the input voltage.

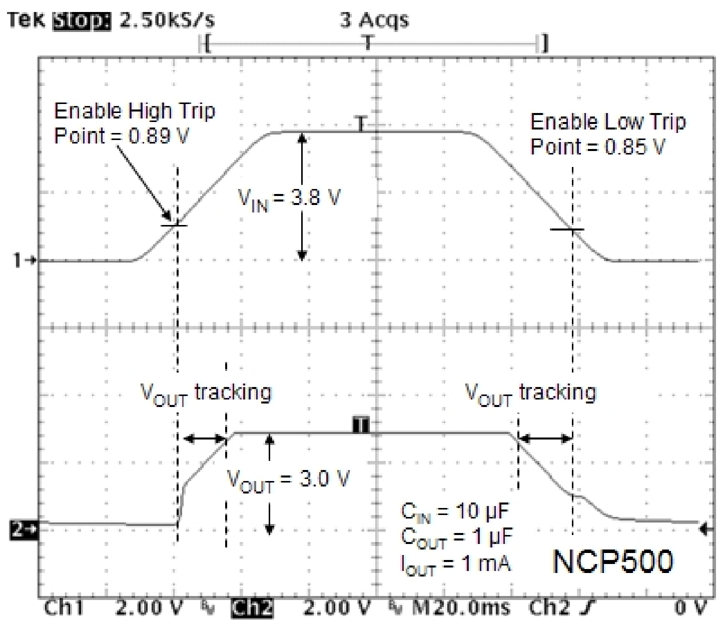

Figure 5. Regulator circuits that connect the enable pin to the input voltage have a problem. The output voltage will track the input voltage during the turn−on and turn−off time of the regulator.

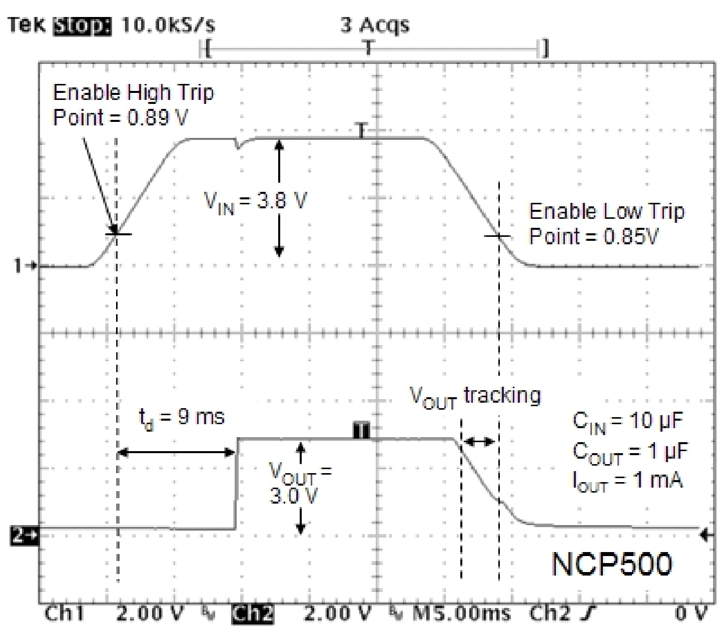

Figure 6. Adding the circuitry in Figure 2 eliminates the problem of the output tracking on the rising edge.

Figure 7 shows further improvement when resistor R_2 is added to the delay network. The schematic of this circuit is shown in Figure 3. It is evident that the output now turns on and off appropriately and that a sufficient delay has been provided. Furthermore, this solution offers the advantage of eliminating the requirement of an extra pin on the microprocessor. The only thing that this circuit lacks in performance in comparison to the supervisor solution is its lack of a waning signal.

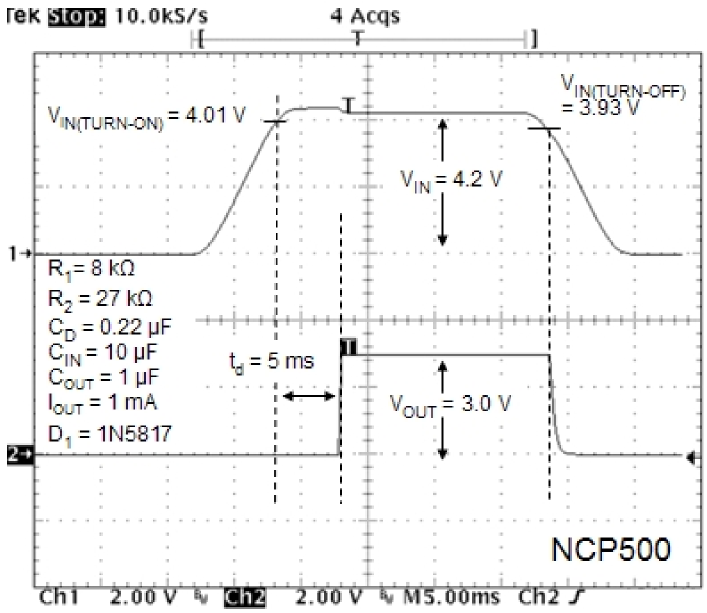

Figure 7. The circuit in Figure 3 turns on only after a sufficient input voltage is reached and shuts down immediately after the input becomes insufficient.

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