TB093

Multiple PWM Output Soft-Start Controller For Switching Power Supplies

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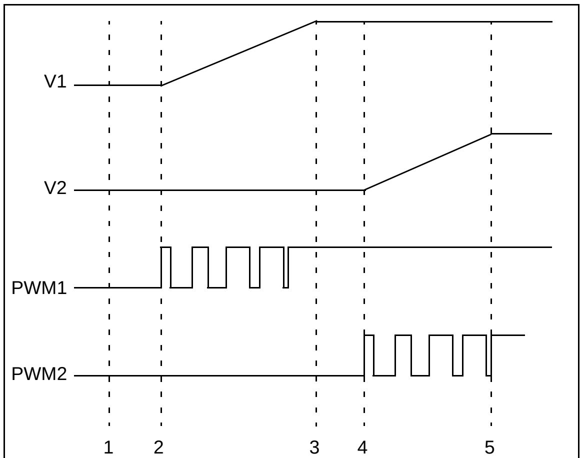
OVERVIEW

This Technical Brief describes a microcontroller-based soft-start controller for power supplies in systems with multiple voltages.

Sometimes applications have devices with multiple voltage requirements (e.g., core voltages, I/O voltages, etc). The sequence in which these voltages rise is important. A common requirement is that one voltage must rise and stabilize before another voltage.

The circuit described in this document operates by using Pulse Width Modulation (PWM) to slowly increase the amount of time the power supply is allowed to operate. The circuit will first increase the duty cycle of one PWM output from 0% to 100% to allow the first voltage to rise. It will then pause and increase the duty cycle of the second PWM output from 0% to 100% to allow the second voltage to rise, as shown in Figure 1. While doing this, an active-low shutdown pin will be polled to ensure that the voltage on the under-voltage lockout pin is above 0.6V.

FIGURE 1: TIMING DIAGRAM

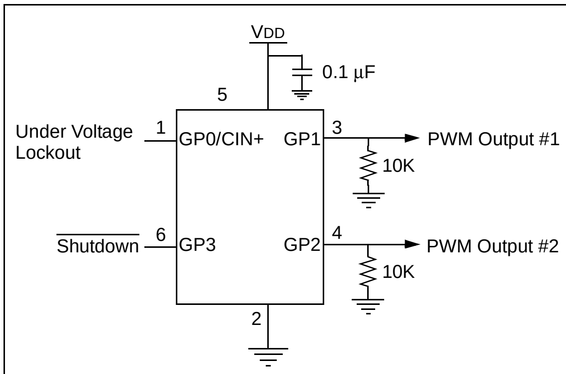


1. Start-up conditions met
2. Initial delay
3. PWM Ramp #1 complete
4. Between PWM delay
5. PWM #2 complete

HARDWARE

The hardware for the soft-start circuit is fairly simple, as shown in Figure 2. The 0.1 μF capacitor is used for decoupling, and the two 10k pull-down resistors are used to ensure that the PWM outputs will never be floating. The ramping and delay functions are implemented entirely in software and the GP1 and GP2 pins provide the two PWM outputs. The CIN+ (GP0) pin provides an under-voltage lockout, and the GP3 pin provides a shutdown for the soft-start controller. The under-voltage lockout uses the on-board comparator of the PIC10F206 to compare the input on the CIN+ pin against the internal 0.6V reference.

FIGURE 2: SOFT-START CIRCUIT SCHEMATIC



Note: Assumes SOT-23 Packaging.

The soft-start sequence will not begin until both of the following conditions are met:

1. The voltage on CIN+ (GP0) rises above 0.6V
2. The shutdown pin (GP3) is held at VDD

Once these conditions are met, the sequence begins and the first PWM output begins to ramp from 0% to 100%, resulting in the output being held high. The second PWM will ramp from 0% to 100% and both PWM outputs will be held high until either one of the two conditions above are not met.

SOFTWARE

Two software solutions have been provided. The first software solution (which is further described below) uses decrement loops to provide the software delay. The second software solution uses the same method found in Technical Brief TB081, “*Soft-Start Controller for Switching Power Supplies*”, (DS91081), for producing software delays using a jump table.

This particular solution will control the $\overline{\text{shutdown}}$ pins of two power supplies in order to provide a user specifiable soft-start time. The delay between PWM outputs and before soft-start begins can be customized by the user. Furthermore, the design provides both an active-low shutdown pin and an under-voltage lockout pin. The timing is controlled by four definitions:

Solution 1

This software solution uses decrement loops to provide software delay. It is relatively simple and consists of a small number of sections which will execute sequentially under normal conditions. (See the flow diagram in Figure 3).

1. An initialization section, which presets variables and configures peripherals
2. A loop which waits until both soft-start conditions are met
3. A delay before soft-start begins
4. First ramping PWM routine to generate output pulses
5. A delay before the second soft-start begins
6. Second ramping PWM routine to generate output pulses
7. A final loop which ensures that both soft-start conditions are met

The initialization section is used to set GP1 and GP2 as outputs, GP3 as an input and enables the comparator so that CIN+ (GP0) can be used to detect an under voltage condition.

The first loop checks the status of the $\overline{\text{shutdown}}$ pin and the comparator output. If a shutdown or under-voltage condition exists, the microcontroller will be held in a wait state. Once both conditions for soft-start have been met, the microcontroller begins to execute the software to generate the ramping PWM.

The ramping PWM signal is generated by a software delay. The PWM output is varied by setting a variable and decrementing until it reaches zero. The variables DutyCycleHigh and DutyCycleLow are used to control the PWM ramp. Initially DutyCycleHigh is set to zero and DutyCycleLow is at maximum. With each iteration, DutyCycleHigh is incremented while DutyCycleLow is decremented.

The resolution of the PWM is around 3 µs; that is, every iteration the PWM signal’s high time will increase by 3 µs, and the low time will decrease by 3 µs. The under-voltage and shutdown conditions are continuously monitored, allowing the soft-start to be aborted.

After the first PWM output ramp has completed, a software delay is used to provide a small amount of time until the second PWM output ramp begins. The second ramp functions just as the first and will be aborted if the soft-start conditions are not met.

Finally, the software holds both outputs high and continuously checks for shutdown or under-voltage conditions.

- **PWM1_STEPS** – Determines the number of steps to use to bring the first ramp from 0% to 100%. Increasing the number of steps will increase the amount of time needed for the ramp to complete. (See Equation 1 below to calculate the amount of time the PWM ramp will take.)
- **PWM2_STEPS** – Determines the number of steps to use for the second ramp.
- **INITIAL_PAUSE** – Determines the number of steps to pause after the soft-start conditions are met before the first ramp begins (see Equation 2).
- **BETWEEN_PAUSE** – Determines the number of steps to pause after the first ramp has completed before starting the second ramp.

The approximate length of the PWM ramp is shown in Equation 1.

EQUATION 1:

$$(Number\ of\ steps)^{\wedge}2 * 3\ \mu S$$

The approximate length of the delays can be determined as shown in Equation 2.

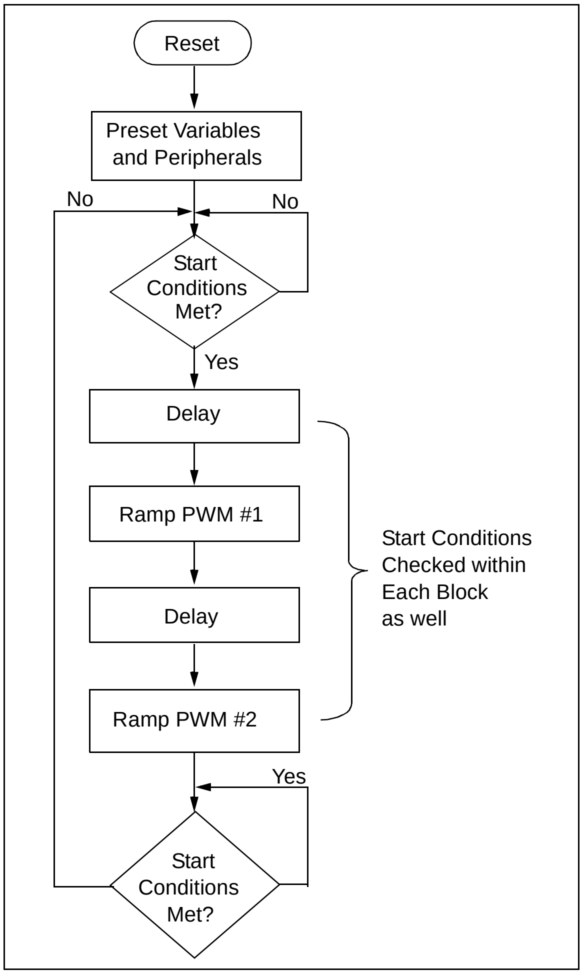
EQUATION 2:

$$(Number\ of\ steps + 1) * 750\ \mu S$$

If either of the delays is set to zero, the software will skip the delay portion completely and there will be no added software delay.

Note:	These timing equations assume that a 4 MHz oscillator is being used.

FIGURE 3: SOFTWARE FLOWCHART



Solution 2

This software solution uses jump tables to generate the PWM output.

One of the advantages of this method is the fact that the PWM steps are smaller. The high time will increase by 1 µs every iteration, and the low time will decrease by 1 µs. However, the disadvantage is the fact that the PWM ramp-up time is limited to 118 steps, resulting in a maximum ramp-up time of less than 13 ms. The maximum ramp-up time for the other software solution is around 400 ms, not including the delays between ramps.

The code used for this solution was taken and modified slightly from Technical Brief TB081, "*Soft-Start Controller for Switching Power Supplies*" (DS91081). As described in this Technical Brief, the maximum size of the jump table is limited by the size of the table that can be accessed by the 8-bit Special Function Register (SFR) Program Counter Low (PCL). For the given software, that limits the maximum sum of steps to 118 (e.g., PWM1_STEPS + PWM2_STEPS = 118).

In order to maximize the size of the jump table, any sections of software that are not related to the jump table have been moved to the memory address, 0x100. This higher memory contains all the initialization procedures used before and after the jump table, and contains the delays between PWM ramps. Should either of the added software delays be set to zero, the code will be skipped entirely and there will be no added software delay.

Please refer to Technical Brief TB081, "*Soft-Start Controller for Switching Power Supplies*" (DS91081) for more information on implementing a soft-start controller using jump tables.

To download the complete source code, for both software solutions, go to Microchip's web site at www.microchip.com.

CONCLUSION

Systems with multiple voltages can benefit from small microcontrollers, such as the PIC10F206. The PICmicro® MCU can be used to control the sequence in which the voltages in the system are allowed to rise. They can be added to an existing design with a minimal increase in complexity or cost.

This particular solution will control the $\overline{\text{shutdown}}$ pins of two power supplies in order to provide a user specifiable soft-start time. The delay between PWM outputs and before soft-start begins can be customized by the user. Furthermore the design provides both an active-low shutdown pin and an under-voltage lockout pin.

MEMORY USAGE

Memory usage for the first software solution (using software decrement loops) is 4 bytes RAM and 49 words Flash memory. Because the memory usage is so small, this application could easily be implemented on a PIC10F204 which is more cost effective than the PIC10F206.

Memory usage for the second software solution is 4 bytes RAM. The amount of Flash memory that is required is as follows:

EQUATION 3:

$$63+(PWM1\_STEPS * 2-1)+(PWM2\_STEPS * 2-1) \text{ words}$$

The number of PWM steps will determine the size of the jump table. Because of this, memory usage will vary with the number of PWM steps.

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