TB081

Soft-Start Controller For Switching Power Supplies

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OVERVIEW

This technical brief describes a microcontroller based Soft-Start Controller circuit for a switching power supply.

Start-up is a stressful time for the power driver section of a switching power supply. Because the output voltage is initially zero, the feedback error initially jumps to its maximum. The large feedback error then drives the loop filter to its limit, which drives the power switching transistors in the driver section of the power supply at their maximum rating. This condition continues until the output voltage of the power supply approaches its nominal value.

If the load being driven by the power supply is capacitive, the problem is exaggerated due to the large transient currents required to charge the capacitive load. In extreme instances, the repeated high stress of start-up can result in catastrophic failures in the driver section, typically, the power MOSFET transistors or the power rectifiers.

Soft-start circuits alleviate this problem by ramping up the output of the power supply at a slower rate. The reduced rate limits the initial error and the overall drive of the system is reduced. Typically, soft-start is accomplished in one of two ways. The first system ramps the reference voltage into the error amplifier from zero to its nominal value. This eases the output voltage up at a slower rate, reducing the drive requirements on the driver section of the power supply. The second system places a limit on the output of the loop filter, limiting the drive demands on the driver section of the power supply. Unfortunately, both of these systems require control of signals that are not normally accessible in single-chip-solution power supply designs.

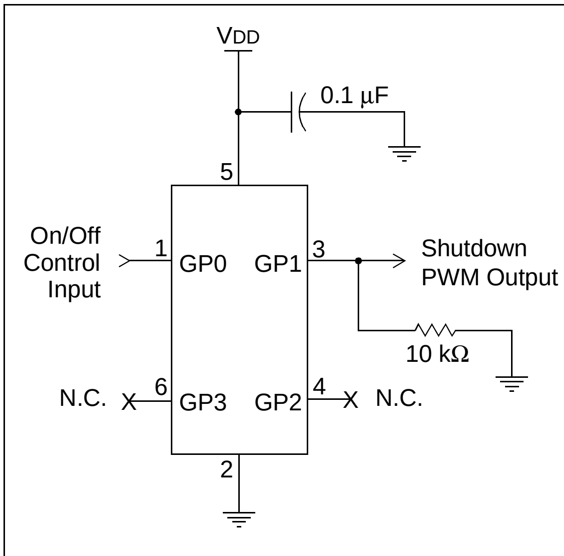
The circuit described in this document takes a different approach. It operates by toggling the shutdown control of the power supply controller with a ramping Pulse Width Modulation (PWM) signal. The result is an on/off cycling that runs the power driver section at its maximum, although not continuously. Over the course of the soft-start, the amount of time that the output driver section is allowed to operate increases from 0 to 100%. The result is a burst-mode ramp-up of the output with only limited stress on the power supply power chain. Because the circuit uses an existing control within the IC or a simple enable control on the power drive section, the circuit can be applied to almost any switching power supply circuit.

IMPLEMENTATION

Hardware

The hardware for the soft-start circuit consists of three components; a PIC10F200 microcontroller, a 0.1 uF capacitor and a 10 kΩ pull-down resistor. The ramping PWM function is implemented entirely in software requiring only the GP1 pin on the microcontroller (see Figure 1). The GP0 pin operates as a control input to the circuit.

FIGURE 1: SOFT-START CIRCUIT SCHEMATIC

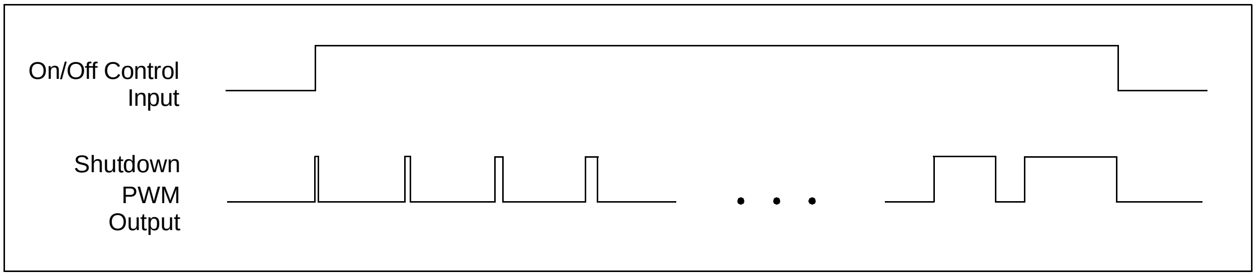


Note: Assumes SOT-23 packaging.

The two connections to the microcontroller are the On/Off Control input and the Shutdown PWM output. Initially, the Shutdown PWM output is held low until the On/Off Control input goes high. Once the input is high, the PWM output begins its ramp from 0 to 100%, incrementing the duty cycle following each pulse output. Once the output reaches 100%, the output is held high until the On/Off Control input falls, indicating a power-down for the power supply. In response to the low On/Off Control input, the PWM output is again pulled low and held low until either the control input is raised or the circuit completely powers down.

Figure 2 shows a general timing diagram for the soft-start circuit and its response to high and low levels on the On/Off Control input.

FIGURE 2: SOFT-START CIRCUIT TIMING



Software

The software is relatively simple, consisting of four sections:

1. An initiation section, which presets variables and configures peripherals.
2. A delay section, which waits for the rise of the On/Off Control input.
3. The ramping PWM routine, which generates the output pulse and increments the duty cycle.
4. A second delay section, which waits for input to fall.

These sections execute sequentially, wrapping around from section 4 to section 1 if the On/Off Control input should fall and then rise again. Figure 3 shows a flow chart of the software's operation.

The initialization section configures the GPIO port for the single input and output of the circuit. It also sets the Configuration Word register to configure the Watchdog Timer.

The first delay monitors the state of the On/Off Control input, holding the microcontroller in a wait condition until the input goes high. Once high, the section releases the microcontroller to the ramping PWM section of the software.

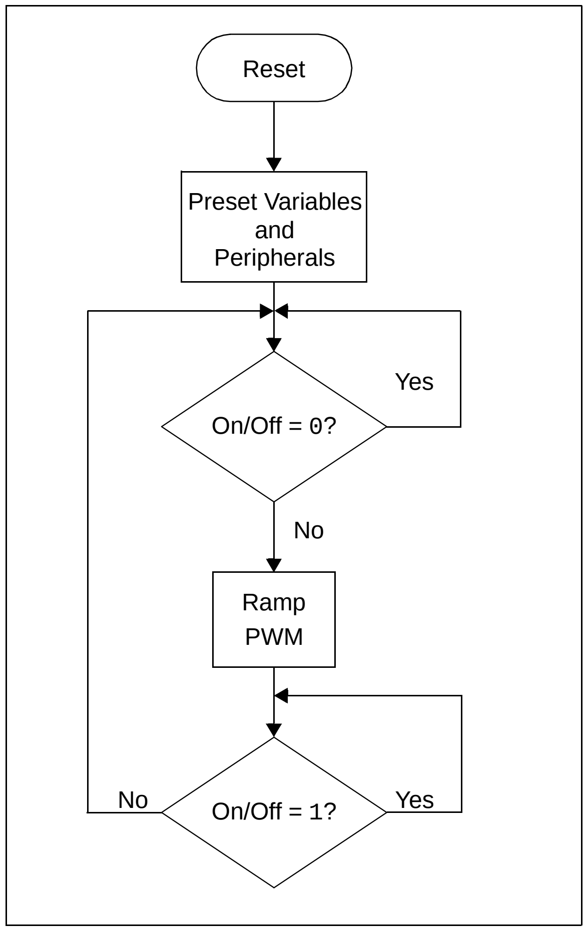
The ramping PWM section produces a high and low pulse based on simple software delays implemented through a computed jump table. The table consists of repeated bit set and bit clear commands. By jumping to different starting points within the table, different timing delays are generated.

The high and low periods of the pulse are controlled by two variables, DutyCycleHigh and DutyCycleLow. The PWM ramp begins with DutyCycleHigh = `0` and DutyCycleLow equal to the period of the PWM pulse. Following the generation of each pulse, DutyCycleLow is decremented and DutyCycleHigh incremented. When DutyCycleHigh reaches zero, the ramp is complete and the software releases the microcontroller to the second delay-for-input section of the software.

Additional logic polls the On/Off Control input during the ramp-up, aborting the ramp if the input returns low.

Like the first delay, the second delay also holds the microcontroller in a wait condition pending a change in the On/Off Control input. The difference is, this delay holds until the On/Off Control input is pulled low. When this occurs, the software clears the PWM output and jumps back to the first delay. The microcontroller then waits in the first routine for the soft-start cycle to begin again.

FIGURE 3: SOFTWARE FLOW CHART



The timing of the soft-start function is controlled by the PWM_STEPS definition at the top of the software source listing. Equation 1 determines the specific value for PWM_STEPS that will achieve the desired ramping start-up time.

EQUATION 1:

$$PWM\_STEPS = [\sqrt{T+25} - 5]$$

T = Ramp time in microseconds

For improved reliability, the Watchdog Timer is enabled to monitor the software operation. Two clear Watchdog commands are present in the software, one in the initial wait for input routine and the second in the second wait for input routine. To speed up the ramping PWM code, a Watchdog Timer Reset was ommitted. This requires the Watchdog time-out be greater than the maximum ramp time. The maximum ramp time is limited by the size of the table that can be accessed by the 8-bit Special Function Register (SFR) Program Counter Low (PCL). This limits the maximum table size as 121 steps, resulting in a maximum possible ramp time of 15.8 µs. Therefore, the worst case Watchdog time-out must be greater than 15.8 µs. Given the worst case, Watchdog time-out is typically 9 µs, then a prescaler value of 2:1 will insure that the Watchdog will not time out during the maximum ramp time.

CONCLUSION

Combining microcontrollers with power supply circuits can produce solutions that both reduce a design's complexity and cost, while implementing new features and functions not available in the original design.

This technical brief has described one such solution, a soft-start circuit with a programmable ramp period. The resulting circuit not only creates a soft-start function that is not dependant upon an RC time constant, it also provides a Shutdown input for external control of the supply.

Note 1:	Flash memory usage is variable, depending on the soft-start period.
2:	RAM memory requirements are 2 bytes.
3:	The software assumes a PIC10F20X part.

NOTES:

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