DC/DC Power Supply Module 4

2 Channel Soft-Start

Application Report

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Contents

Abstract

On May 2022 I finish the design of this module. Professional power supplies include among other characteristics, the capacity to tolerate load dumps and reverse polarity protection to protect sensitive electronic components. They also include one or more buttons depending on the channel's quantity, to connect or disconnect the loads from the output without turning off the supply.
Along this document you will find all the information of the design process and all the details taken into account to provide a reliable circuit with two channels that can connect up to two power supplies and control them independently.

What is a Soft-Start?

A soft-start has the characteristic of gradually increase the current from cero to the value specified in the supply, so the voltage increases in a constant rate protecting the devices and the electronic components from the damage caused by instantaneous high input current.
Figure 1 shows where the module is placed. If load is connected backwards or disconnected while the supply is on, or if VOUT falls 90% of VIN the soft start protects both the power supply and the load by complete isolation.

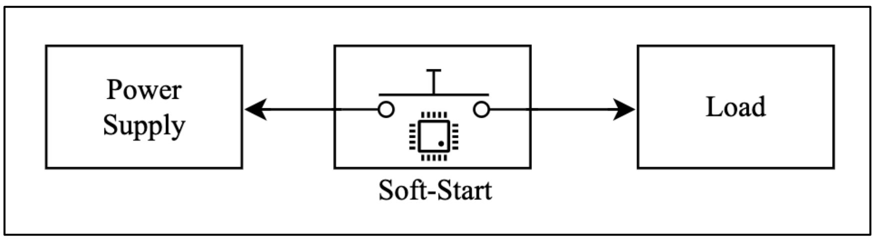


Figure 1 – Module Placement

Module Characteristics

Multiple Voltages

Across the design of the module, I realize it was necessary to use multiple power sources. Additionally, I will use this abbreviations for a better document understanding:

- V_{IC1} voltage input of IC1
- V_{IC2} voltage input of IC2
- V_{IC4} voltage input of IC4
- V_{SCH1} power supply to use at ch1
- V_{SCH2} power supply to use at ch2

IC1 (REG1117FA-5.0/500) [1] is a voltage regulator that supplies +5V. V_{IC1} is +12V via J4 connector. I add reverse polarity protection to this input using a P-Channel Mosfet (IC6) and place a 1A fuse (F1) to protect it from an overcurrent scenario. You can use any auxiliary +12V output of your power supply or use another power source for V_{IC1}.

On the other side, IC2 (MAX16126TCA+T) [2] is a load-dump/reverse-voltage protection ic.
V_{IC2} can be either via J1 connector using V_{SCH1}, or from the output of IC1. According to the datasheet minimum input voltage of IC2 is 3V. In order to provide a permanent voltage above this value when the power supply output is below 3V, I use a ORing diode using schottky types (D1, D2). Same applies to IC4 (MAX16126TCA+T). Can be powered either using V_{SCH2} via J1 connector or from the output of IC1 using an ORing diode (D3, D4). See (ORing Diode with two voltages sources).

Noise Filtering

You may notice that IN pin of IC2 and IC4 has a 100Ω resistor (R22, R23 respectively) and a capacitor (C4, C11) of 0.1uF connected. I use them to create a RC Low Pass Filter to reduce EMI. With this two values and using this formula $f_c = 1 / 2\pi RC = 1 / 2\pi \times 100\Omega \times 0.1uF = 15.923KHz$ we obtain the point at which frequencies above it will be attenuated. According to FCC [3], the EMI frequency range that concern us goes from 9KHz to 30MHz based on the CISPR Publication 11.
Most of the component arrangement and special considerations like this when designing the board, I took from the evaluation kit [4].

Mosfet Selection

In order to output the voltage coming from V_{SCH1} or V_{SCH2}, IC2 and IC4 switches two mosfets (IRLR2908TRPBF) [5] respectively (IC2-Q1,Q2), (IC4-Q4,Q5). I decided to use them due its low $R_{DS(on)}$ (28mΩ) and max current capability (30A). By placing them in a back-to-back configuration

we complete isolate the load from the power supply, so if there's a problem at the output no current will flow back to the supply.
At 4A and 25°C, we can obtain an approximated value of the mosfet power dissipation by using this formula $P_D = I_{LOAD}^2 \times R_{DS} = 4^2A \times 0.028\Omega = 0.448W$ with R_{DS} the resistance between drain and source.
To protect mosfet gates I use 15V Zener diodes, (Z1, Z2) connecting the cathode to gate and the anode to source.

How Soft-Start is Achieved

IC2 and IC4 uses an internal charge pump to raise the gate-source voltage of the mosfets above the minimum threshold so they start conducting with minimum on-state resistance. The value of the capacitors C3, C10 determine the rate of rise of the voltage on the gates.
Using 0.22uF (220nF) caps and knowing that the charge-pump current is 180µA (specified on MAX16126TCA+T datasheet), by using this formula we have: $dV / dt = I_{CPUMP} / C_{C3/C10} =$
$180\ \mu A / 220nF = 818\ V/s$. This value tells us that if we want to power-up a capacitive load of for example 680uf, peak input current will be limited at 818 x 680 = 556mA.

Undervoltage and Overvoltage Protection

MAX16126TCA+T monitor the input voltage using a resistive arrangement between TERM and UVSET pins. When IN voltage is below the programmed threshold, voltage on GATE pin goes low and the mosfets turn off. When voltage goes above the threshold, GATE voltage goes high and mosfets turn on.
Since I didn't want that IC2 and IC4 turn off by an undervoltage scenario, instead of using a resistive arrangement, I use the +5V output of IC1 and resistors R6, R17 of 10KΩ connected to UVSET pin.
For overvoltage the principle is the same, voltage on IN pin is monitored and mosfets are turned off if the value on it is above the programmed threshold. MAX16126TCA+T has auto-retry mode, meaning that if an overvoltage occurs, every 150ms a retry attempt to restore voltage on gate pin is made until the overvoltage condition disappear.
For threshold configuration, I set a value bigger than the max voltage output of V_{SCH1} and V_{SCH2} (in my scenario 20V) using this formula:
For IC2: $V_{OVTH} = ((R7 + R8 + 700\Omega) \times V_{TH}) / R8 = ((165K\Omega + 10.7K\Omega) \times 1.225V) / 10K\Omega = (175.7K\Omega \times 1.225V) / 10K\Omega = 21.52V$
For IC4: $V_{OVTH} = ((R18 + R16 + 700\Omega) \times V_{TH}) / R16 = ((165K\Omega + 10.7K\Omega) \times 1.225V) / 10K\Omega = (175.7K\Omega \times 1.225V) / 10K\Omega = 21.52V$
where 700Ω is the typical on-resistance of the TERM switch and $V_{TH} = +1.225V$ for the OVSET threshold.

Handling Channels Status

I use two pushbutton on/off controllers IC3, IC5 (MAX16054AZT+T) [6] with a single switch debouncer and built-in latch, each one for one channel. The controllers tell IC2 or IC4 to shut down or turn on the mosfets by driving SHDN pin high or low.

To enable a channel, the controller generates a logic signal that makes OUT pin go high, and OUT complementary pin go low. To toggle the signal high or low I use SPST Pushbutton Switches (S1,S2) with 2 led diodes included. By default, they illuminate on red but when they are press-down change to green to show the channel is active. The output state on the pins remains latched till the pushbutton is released/opened. When released, pins revert to the initial state and switch color goes back to red.

There are two mosfets (Q3, Q6) connected each one to one channel via resistors R10, R11. When any channel changes its state from enabled to disabled, OUT complementary pin goes high and turn on the mosfet, making output connect to ground via respective resistor. Any capacitor in the load will be safely discharged to ground. It’s important to select an appropriate wattage for R10 and R11 based on the maximum output voltage of the power supply used.

Circuit Simulation

ORing Diode with two voltages sources

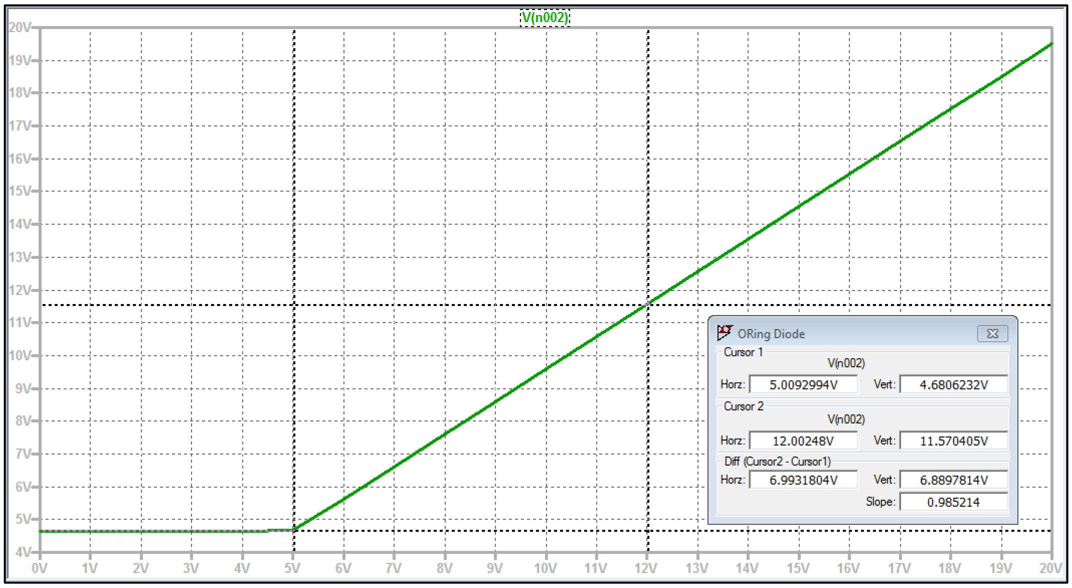


Figure 2 – ORing voltage output

Figure 2 shows how the ORing diode behaviors with 2 voltage sources:

- V_{S1}: +5V emulating voltage output of IC1.
- V_{S2}: 0-20V emulating voltage output of the power supply used.

After making a linear voltage sweep from 0 to 20V you can see that for voltages below 5V the source that takes priority is V_{S1}, but as long as this value increases, the priority is taken by V_{S2}. Note that the resultant voltage showed on green, it's the value of the voltage source minus the forward voltage of the schottky diode. You can see an example at the selected points on the graphic.

Conclusions

After finish making the module, I start to test it with different types of loads.
I consider the design offers all the basic functionalities and bring enough confidence on the protections included to guarantee that both the power supply and the load are protected if something goes wrong.
Good soldering skills and a decent soldering station is required when soldering IC2 and IC4, taking into account their dimension and type of package (3mm x 3mm, 12-Pin TQFN Package).

References

[1] “REG1117: 800mA and 1A Low Dropout Positive Regulator 1.8V, 2.5V, 2.85, 3.3V, 5V, and Adjustable” [Online]. Available: https://www.ti.com/lit/ds/symlink/reg1117.pdf?ts=1706985085829&ref_url=https%253A%252F%252Fwww.google.com%252F (Accessed: Jan. 24, 2024).

[2] “MAX16126/MAX16127 - Load-Dump/Reverse-Voltage Protection Circuit” [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/max16126-max16127.pdf (Accessed: Jan. 24, 2024).

[3] “Federal Communications Commission FCC 02-157,” May 30, 2002. [Online]. Available: https://docs.fcc.gov/public/attachments/FCC-02-157A1.pdf (Accessed: Jan. 24, 2024).

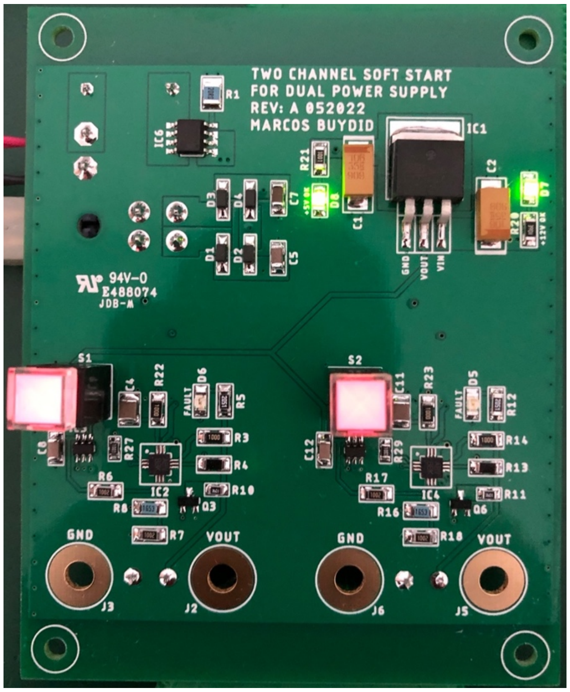
[4] “MAX16126/MAX16127 Evaluation Kits” [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/max16126evkit-max16127evkit.pdf (Accessed: Feb. 3, 2024).

[5] “IRLR2908PbF IRLU2908PbF” [Online]. Available: https://www.infineon.com/dgdl/Infineon-IRLR2908-DataSheet-v01_01-EN.pdf?fileId=5546d462533600a40153566cdace2681 (Accessed: Feb. 4, 2024).

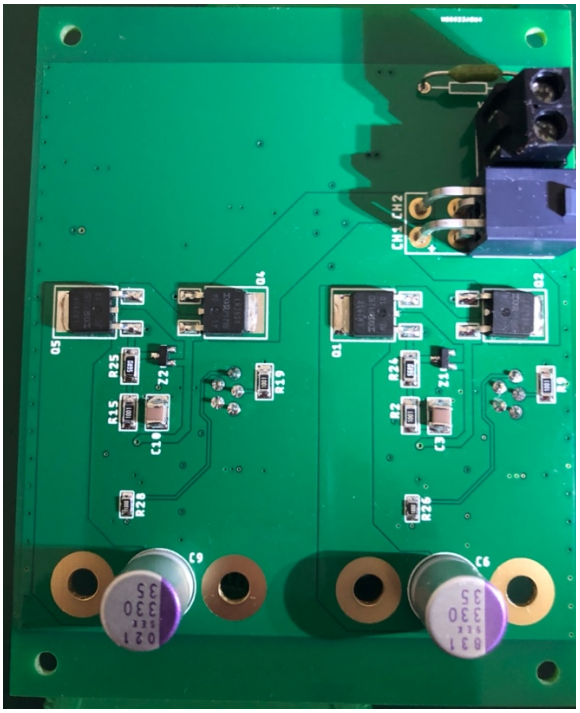
[6] “MAX16054 On/Off Controller with Debounce and ±15kV ESD Protection” [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/max16054.pdf (Accessed: Feb. 10, 2024).

Annexes

Finish Assembly Photos



Module Front View



Module Back View

Revision History

Date	Version	Changes
Mar-2024	1	First version