



SIMPLE SWITCHER IMPLEMENTATION IN +5 V AUXILIARY POWER SUPPLY

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Abstract: The Simple Switcher[®] converter implementation in +5 V auxiliary power supply for embedded systems is investigated. The goal is to obtain good and reliable dc-dc power converter. After design of electrical schematic, the power converter is simulated using the WEBENCH[®] on-line simulation tool. Printed circuit board design is explained together with experimental verification of the proposed converter.

Key Words: DC-DC power conversion, Design, Simulation, Student experiments.

1. INTRODUCTION

When designing an embedded system it is of great importance to have robust and reliable auxiliary power supply implemented.

In the early 90s, much of the lower power dc-dc voltage conversion was carried out using linear regulators [1]. The linear voltage regulators are not desirable in modern low voltage design due to poor efficiency and large heat dissipation that often requires heat sinks usage.

Introduction of Simple Switcher term and product by National Semiconductor has changed the low voltage dc-dc switching power supply market in 90s. It was the first family of its kind, where a host of support elements was prepared so that very little power supply expertise was required from potential customers. First of all, the devices included an easy step-by-step guide to enable selection of critical external components. Not only component values were suggested, but also exact component device numbers could be chosen from external components lists included in the datasheets. The need to select a power transistor was reduced to selecting the Simple Switcher regulator with the appropriate current rating. Because the power transistor was included (in the Simple Switcher), the selection process was greatly simplified [1].

Here, the +5 Vdc auxiliary power supply implementation, using the Simple Switcher dc-dc power converter, is presented. This design is a small part of the project that deals with digital drive controller design.

The paper is organized as follows. The first section contains description of auxiliary power supply and the Simple Switcher topology. Next, computer aided design (CAD) issues are explained together with printed circuit board (PCB) design. The second section covers the

converter operating parameters, WEBENCH simulation tool and the simulation results. In the third section, implementation issues and experimental results of the converter performance are reported and analyzed.

2. THE CONVERTER DESIGN

The auxiliary power supply block diagram is shown at Fig. 1. Mains voltage is rectified by diode bridge and connected to DC bus. First, we have buck converter +300/+20 V, based on design with UC3842A, that works at 30 kHz switching frequency. Its output is connected to linear voltage stabilizer 7815 that produces +15 V at its output. Then, we have connection to the Simple Switcher converter based on LM2674 integrated circuit (IC) [2] that gives +5 V at its output. This converter consists of IC U3, schotky diode D21 and inductor L2 with voltage feedback implemented (Fig. 2).

The Simple Switcher operating frequency of 260 kHz is chosen in order to decrease amount of inductance and capacitance required in a given circuit. Control IC LM2674 belongs to third generation of the Simple Switcher family and it is based on MOS internal power switch [1].

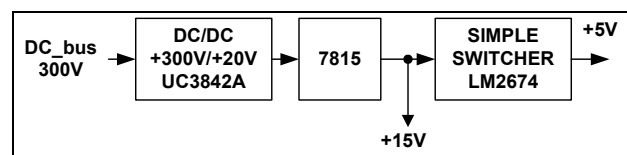


Fig. 1. Auxiliary power supply block diagram

Electric components are chosen in such way that the converter could withstand short circuit at its output. The converter current limit is 0.8 A. Maximum load current of 410 mA is calculated by examination of max consumption of all components within embedded system. The Simple Switcher supplies Microchip dsPIC30F4011 digital signal controller, zener diodes, LM339 comparator, Hall-effect based current sensors ACS704-0xx (3 pcs), MAX232 and FT232BL ICs for RS-232 and USB 2.0 communication, respectively. dsPIC30F core consumption (I_{DD}) varies with supply voltage, temperature and operating frequency and its value is 170 mA (for +5 V, 30 MIPS and +85°C). Total dsPIC30F current accepted was 250 mA (max into V_{DD} pin).

Greatest challenge within design of this converter was how to choose and buy the power inductor. No

heatsink is required for this converter. In addition, most of electrical components used are RoHS compliant.

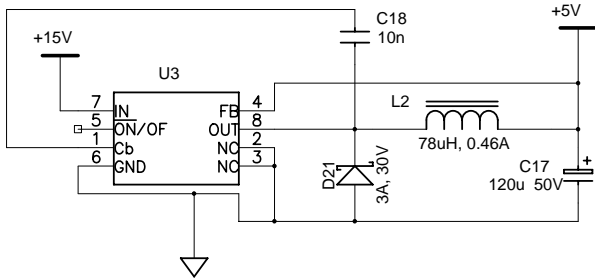


Fig. 2. The Simple Switcher schematic

Electrical schematic (Fig.2) and PCB files are created by program P-CAD[®] (2002 and 2004, trial versions) [3] [4]. Part of PCB top layer showing the converter occupied area is given at Fig. 3. P-CAD is one of the best CAD programs for PCB design that are available today. It is easy to learn and has friendly user interface.

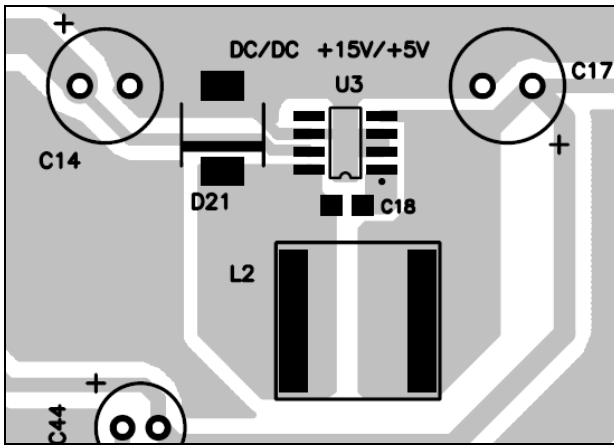


Fig. 3. The Simple Switcher PCB top layer

When designing the PCB the standard IPC-2221 [5] is used as a guideline together with some general guide [6] and LM2674 documentation [7]. According to [5] designed PCB belongs to B4/A6 design type that is usual for commercial use under normal environmental conditions. This means that designed PCB complies with minimum spacing requirements (electrical clearance), between electrical conductors, depending of AC or DC voltage peaks between that conductors (Table 6-1 in [5]).

Component layout, electrical conductors' routes and digital ground planes are chosen in such a way that electromagnetic interference (EMI) problems are minimized.

3. SIMULATION

The Simple Switcher operating values are given in Table 1. They are calculated for following input specifications: input voltage +15 V (min/max=14/16 V), output voltage +5 V, output current 0.41 A and ambient temperature 25 °C. Under these conditions the converter works in continuous conduction mode (CCM) which means that inductor current never goes to zero. From Table 1. one could see that designed converter has good stability and moderate efficiency; power dissipation is very low as well as output voltage ripple.

The simulation model is built using the WEBENCH on-line simulation tool and the operating parameters are calculated using it [8]. This software tool is free and it is located at Web site www.nsc.com. Such a tool is very useful when designing a power converter because it simplifies designer's task and shorts time needed for device development. The WEBENCH enables a designer to simulate a switch mode power supply design. This helps designers to select external components for the design as well as to optimize a circuit for its end application, saving time and money compared to an iterative approach on a lab bench [9]. Similar design tools are very popular nowadays and they could be found with other IC manufacturers too (e.g. Fairchild and TI).

Table 1. The Simple Switcher operating parameters

Frequency	260 kHz
Bandwidth	12 kHz
Phase margin	92.6 deg
Duty-cycle	34.6%
Steady state efficiency	83.5%
IC junction temperature	38.1 °C
IC power dissipation	0.13 W
Peak-to-peak ripple voltage	22 mV
Total output power	2.0 W

Also, using WEBENCH the converter behavior is simulated and the results are given in Fig.4–Fig.8. Bode plots are given at Fig. 4. and they show excellent converter performance. The values of bandwidth and phase margin are given in Table 1.

Results of transient simulations at input and load sides of converter are shown at Fig. 5. and Fig. 6, respectively. From these figures, we could see that output voltage traces demonstrated good dynamic behavior of the converter under transients with settling times in range 0.2–0.3 ms.

Startup simulations are shown at Fig. 7. and Fig. 8. From these figures, we could see that output current and voltage are entering steady state after 1.8 ms which is very good. Large input current (Fig. 8) during short period of time (less than 100 μ s) is expected and this happens due to charging of empty capacitors.

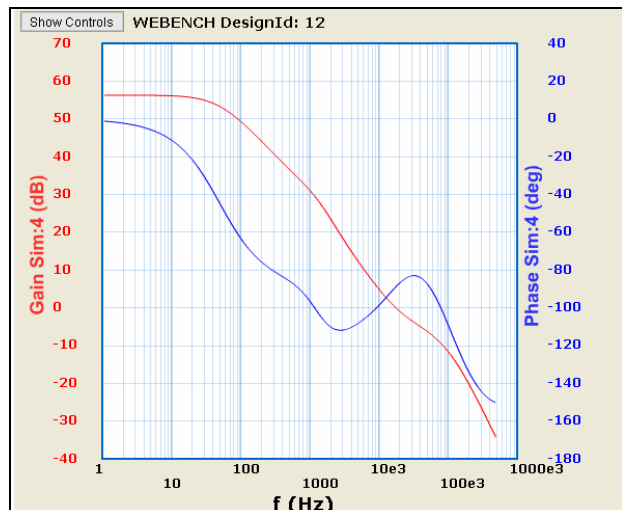


Fig. 4. Bode plots of the Simple Switcher converter

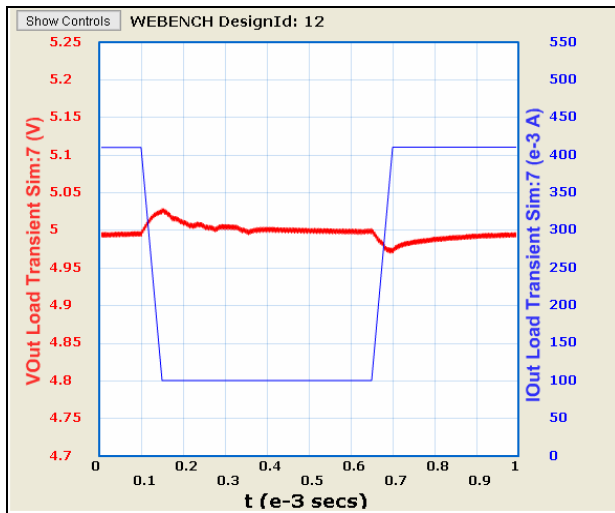


Fig. 5. Load transient simulation (load current step change from 100 mA to 400 mA)

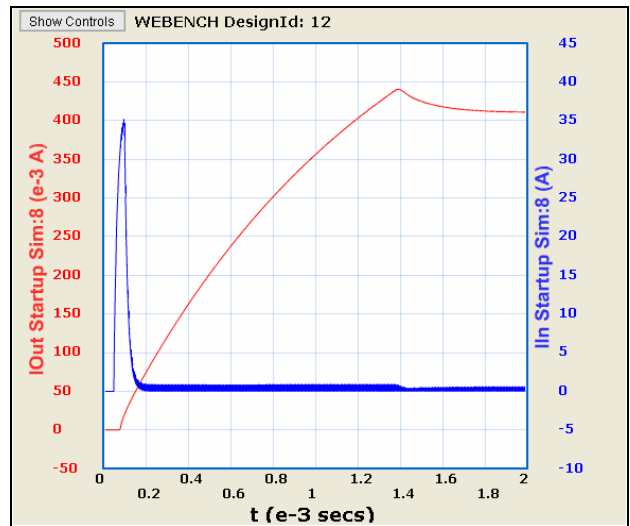


Fig. 8. Startup simulation (input and output currents)

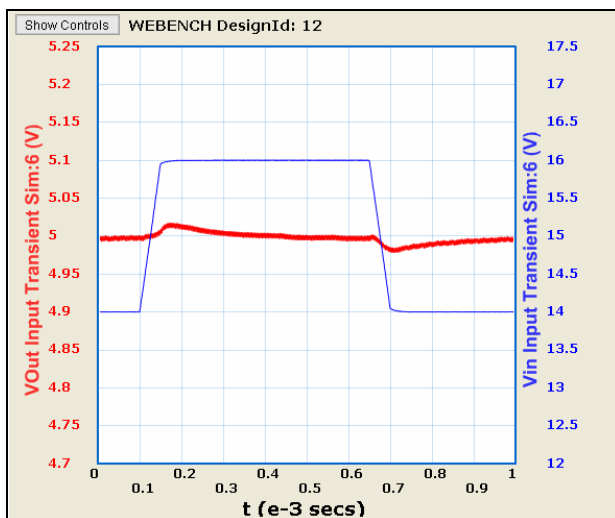


Fig. 6. Input transient simulation (input voltage step change from 14 V to 16 V)

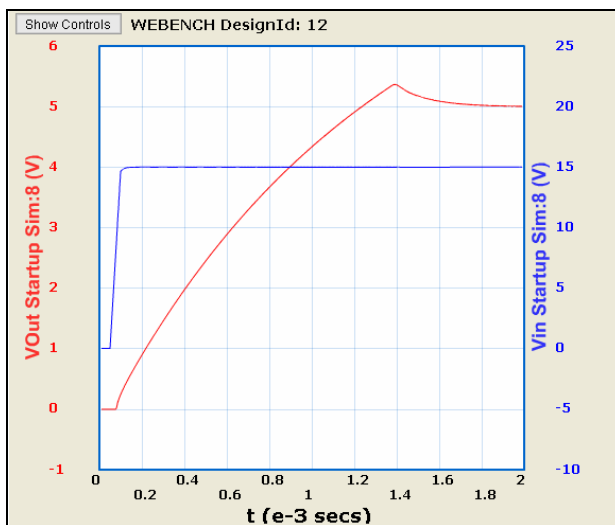


Fig. 7. Startup simulation (input and output voltages)

4. IMPLEMENTATION AND VERIFICATION

Finally, designed converter is assembled. Total number of assembled systems was three. The converter photo is given at Fig. 9. In Table 2, PCB technical and technological parameters are summarized. Unit mil (or thou [6]) stands for mili inch (25.4 μm) and its use is common when designing PCBs. From Table 2. one can see that copper layer of 100 μm is used because the embedded system is intended to drive three phase AC motors up to 750 W.

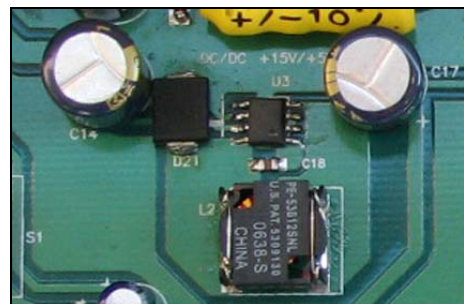


Fig. 9. The photo of implemented converter

In order to verify the designed converter performance simple experimental setup was prepared. It consisted of assembled embedded system (no dsPIC30F mounted), variable resistor (connected to +5 V pin header) and Amper-meter for DC current measurement. DC voltages and frequency are measured by digital multimeter. For temperature measurements I used infrared thermometer Fluke IR62.

Table 2. PCB technical and technological specifications

Material	FR-4, thickness 1.5–1.6 mm
Copper thickness	100 μm
Number of layers	Two
Hot air leveling	Done
Electro test 0–200 Vdc	Done
Min/max line width	30/100 mil
Min distance line-to-line	12 mil
Min distance from GND (copper pour plane)	40 mil

Experimental results are given in Table 3. First, I put embedded system into operation with no resistive load at +5 V pin header and relevant data are taken (second column). Then resistor values are changed in order to get appropriate DC current values at +5 Vdc pin, $I_{(+5V)}$ and relevant values are measured (rest of Table 3). Load current values examined were: 400 mA (operational), 500 mA (nominal) and 600 mA (20% overload). During tests output voltage (V_5) remained within tolerances as well as switching frequency (f_{sw}). Maximum temperature rise above ambient temperature was roughly 36 °C (schotky diode with 20% overload) which is very good.

Table 3. *Experimental results*

$I_{(+5V)}$ [mA]	No load	400	500	600
V_{15} [V]	14.74	15.03	15.03	15.03
V_5 [V]	4.99	4.98	4.97	4.97
f_{sw} [kHz]	266.9	266.3	266.1	265.9
T_{sch_diode} [°C]	31.0	43.6	51.2	61.4
T_{simple_sw} [°C]	30.6	45.2	52.6	54.4
$T_{inductor}$ [°C]	28.8	34.8	38.6	41.8
T_{amb} [°C]	25.4	25.4	25.6	25.6

In Table 3. V_{15} stands for converter input voltage, V_5 is output voltage and f_{sw} is switching frequency. Remaining four rows contains temperatures of schotky diode, the Simple Switcher control IC, power inductor and ambient, respectively.

5. CONCLUSION

The Simple Switcher dc-dc converter implementation in auxiliary power supply is investigated with goal to design and make good power converter for embedded systems applications.

The converter design issues are explained covering both electrical and PCB design aspects. The simulation model is built using the WEBENCH on-line simulation tool. Using this tool converter is simulated and operating parameters are calculated. Also, using WEBENCH the converter design is optimized and appropriate components are chosen. The "Simple Switcher" design concept with accompanied software tool justified its name "simple" while working on this project.

Experiments demonstrated that the Simple Switcher dc-dc converter performance were very good. Therefore, its use is highly recommended in the +5 V switching power supply applications.

In future work one could try to implement the Simple Switcher converter with different topology for the first dc-dc converter stage in order to reduce total area of the auxiliary power supply.

6. REFERENCES

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