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Research Article

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Design, Simulation and Realization of Buck Converter

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Abstract This paper present an Embedded system's bench based on power electronic where students cando experiments. We realize a DC-DC power supply with two fixed output 5V and 12V. Buck converter is used to vary the LED's luminosities and DC motor's speed. All this two application are in one box. Potentiometer is used to do the variation.

Keywords Electrical Energy Conversion, Switching of Power Supply Devices, Power Converters

Introduction

For control of power supply or energy conditioning, conversion of electrical power from one form to another is necessary and the switching characteristics of the power devices allow these conversions. Static power converters perform these power conversion functions. A converter can be considered as a switching matrix. The use of cutting in electrical energy conversion, for several years, has allowed the development of DC-DC converters. The fields of application are varied and require some of the following characteristics:

- High efficiency
- Several isolated outputs (supply of electronic cards for microcomputing, measuring devices, etc.)
- Various primary sources of electrical energy, (continuous: 12-24-4 8V,)
- High mass and volume powers (on-board system, welding station, etc.)

The development of new powerful controllable switches allows the high frequency operation of these converters, which has the effect of reducing weight and volume; increase the efficiency of the system.

Two main principles of continuous-DC conversion are used depending on the mode of action on the output variable:

- Pulse width modulation.

  In this mode of action, the setting of the energy transfer is carried out by varying the conduction time of the fixed frequency controllable switch.

- Using resonant circuits

  This mode of action uses the properties of resonant circuits in variable frequency (adjustment of the energy transfer by reactive impedance variation). The main advantage of these converters lies in the fact that the currents and voltages are almost sinusoidal, the switching losses in the switches are small, the resonant circuit behaves like a switching assistance circuit.

Theoretical Calculations

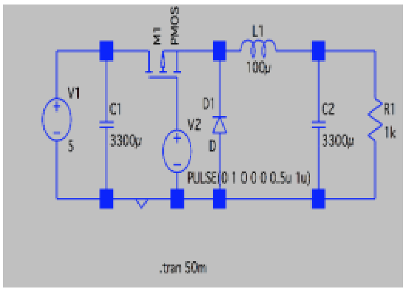

Figure 1: Buck converter diagram

0 < t < DTs

When the transistor is turned ON, the diode is reverse-biased; therefore, not conducting (turned OFF) and the circuit schematic looks like as follows: Ron is the equivalent resistor

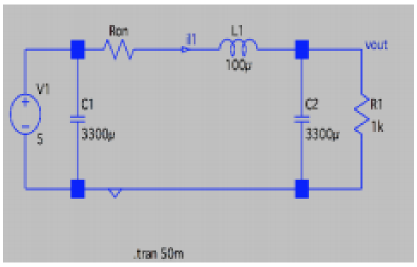

Figure 2: Buck converter diagram when transistor is on

$$vin - Vl1 - Ron * I - Vout = 0$$

then $Vl1 = vin - Ron * I - Vout$ (1)

and

(DTs < t < Ts)

When the transistor is OFF, the Diode is turned ON. The circuit is shown in fig 3:

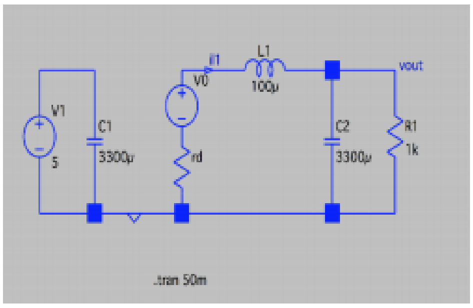

Figure 3: Buck converter diagram when transistor is off

$Vout + Vl1 - V0 - rdI = 0$ (2)

then $Vl1 = -Vout + V0 + rdI$

the average voltage of the inductor is 0 so

$$d * (vin - Ron * I - Vout) + (d - 1) * (-Vout + V0 + rdI)$$

then

$$d * Vin - Vout - I * (Ron + (1 - d) * Rd) + (1 - d) * V0 = 0$$

the dc component of the capacitor current in is 0 therefore $I = \frac{Vout}{Rch}$

then

$$d * Vin - Vout - \frac{Vout}{Rch} * (Ron + (1-d) * Rd) + (1-d) * V0 = 0$$

then

$$Vout + \frac{Vout}{Rch} * (Ron + (1-d) * Rd) = d * Vin + (1-d) * V0$$

finaly

$$Vout = \frac{d * Vin + (1-d) * V0}{1 + \frac{1}{Rch} * (Ron + (1-d) * Rd)}$$

there for if we suppose that diode and mofset are ideals (Rd=0,V0=0 and Rd=0) ,
the output voltage will become:

$$Vout = d * Vin$$

relation between input current and output current

0<t<DTs

$$iin = I1$$

DTs<t< Ts

$$iin = 0$$

Then the average input current is:

$$Iin = D * I1$$

The dc component of capacitor current is 0, therefore $I1 = Iout$

so

$$Iout = \frac{Iin}{D}$$

Simulations

We use LTISPICE to do the simulation then we can obtain the voltage and current curves.

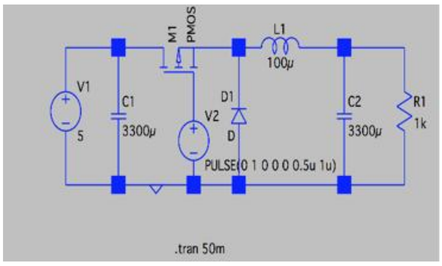

Figure 4: buck converter diagram

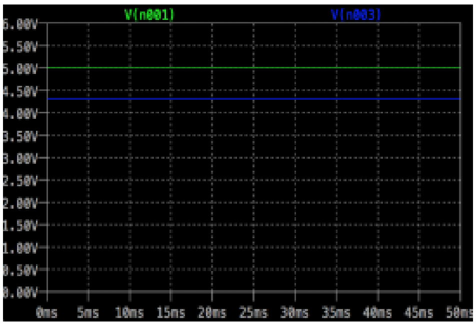

Figure 5: Input (green) and output(blue) voltage

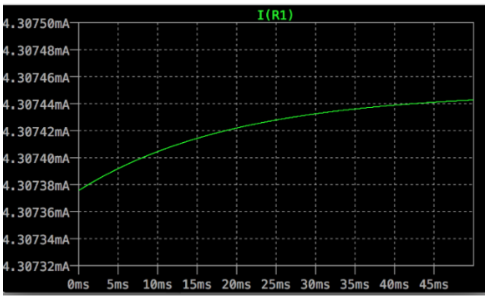

Figure 6: Load current

Figure 7: inductor current

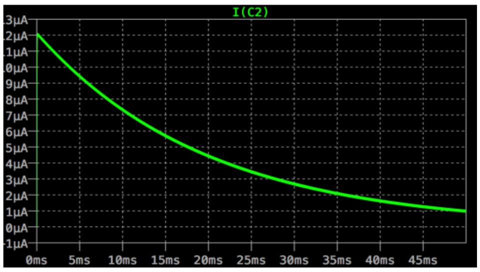

Figure 8: Capacitor current

Figure 9: Input current

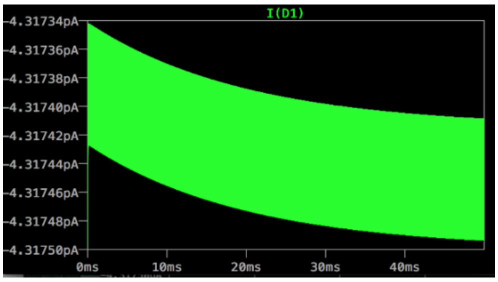

Figure 10: diode current

Applications of DC DC Converters

In many industrial applications, it is necessary to convert a DC power source to voltage fixed in a variable voltage direct current source. A DC-DC converter converts directly from DC to DC and is simply called a DC converter. A DC converter can be considered as a DC equivalent to an AC transformer with a continuous rotation rate. As a transformer, it can be used to reduce or reinforce a DC voltage source.

DC-DC converters are widely used for the control of traction motors in electronic automobiles, trams, Marine lifting gear, forklifts and mine transporters. They offer smooth control of acceleration, high efficiency and fast dynamic response. DC-DC converters can be used in regenerative braking of DC motors to provide energy, which results in energy savings for frequent stop systems.

DC converters are used in DC voltage regulators used in conjunction with an inductor, to generate a DC source, particularly for the current source inverter.

Realisation

A Power Supply with Two 12V and 5V Outputs

The role of DC voltage power supply is to supply the voltages and currents necessary for the operation of electronic circuits with the minimum of residual ripple and the best possible regulation. They must, moreover, often limit the current supplied in the event of overload as well as the DC voltage which it delivers, this in order to protect fragile components. There are ways various to produce a stable DC voltage from an AC voltage.

Only two methods are frequently used:

1. Linear stabilization.
2. Stabilization by cutting

Both have their pros and cons. The switching power supply is mainly used in the field of powers of 100W and more. A power supply is a circuit transforming the AC mains voltage into a low voltage DC voltage. A mains supply consists of a transformer, a rectifier, a filter and a stabilization / regulation as required.

A voltage regulator is an element which makes it possible to stabilize a voltage, and which is necessary for electronic assemblies which need a voltage which does not fluctuate, even if only a little. A voltage regulator can be made up of a set of conventional components (resistors, zener diodes and transistor for example), but it can also be of the "integrated" type and contain all that is necessary in a single case, to facilitate its use.

A diode bridge has four diodes for filter capacitors and diodes to display the two 5v and 12v DC outputs.

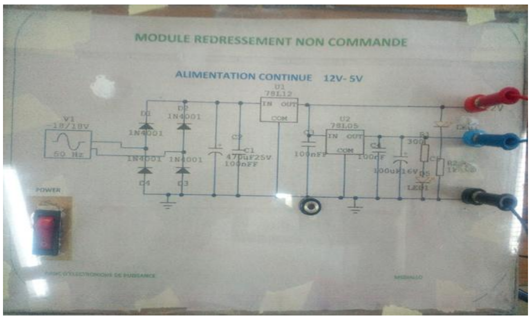

Figure 11: DC power supply 5V -12V

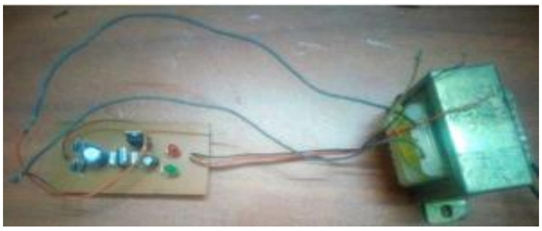

Figure 12: Detailed view inside the box

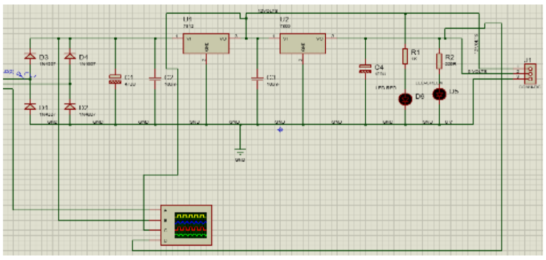

Figure 13: DC power supply diagram realized on proteus

Buck Converter

The buck converter transforms a fixed DC voltage into a lower supply voltage adjustable by the user. For example, a buck converter can be used as a speed variator for DC motors. It consists of a switch transistor, a diode, an inductor and a capacitor. To make it very simple, imagine a light bulb and a switch. You can either turn on the bulb or turn it off. It seems difficult to vary its brightness (dim it) and yet ... Now imagine that with your hand (very fast!), You can turn on and off the bulb very quickly, so quickly that it has neither time to fully light up, or time to completely extinguish. The brightness of the bulb will be intermediate because it is an average over time. The voltage the bulb receives is intermittent. It is "chopped" by the switch. This is the principle of the buck converter.

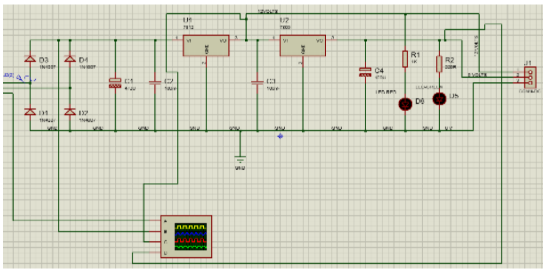

Figure 13: DC power supply diagram realized on proteus

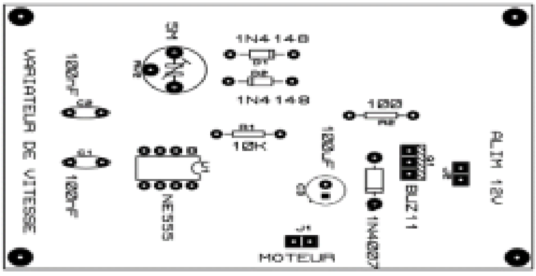

Figure 14: Positioning of DC power supply's components on the printed circuit board

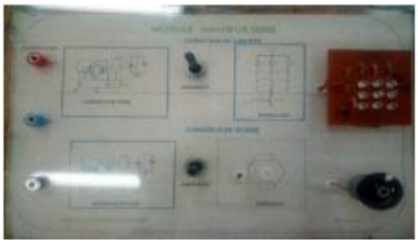

Figure 15: Box containing two inverters

Figure 16: Realization diagram on proteus

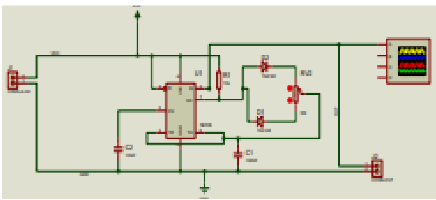

Figure 17: Disposition of led on circuit printed board

Figure 18: 3D disposition of DC DC converter's components

Direct Current Motor Speed Variator

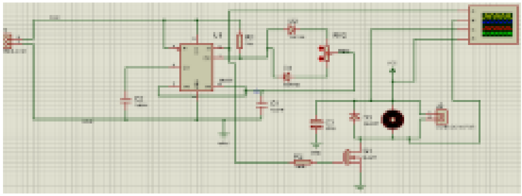

Figure 19: DC motor's speed variator diagram realized on proteus

Figure 20: 3D view of the disposing of DC DC conveter's components on printed circuit card

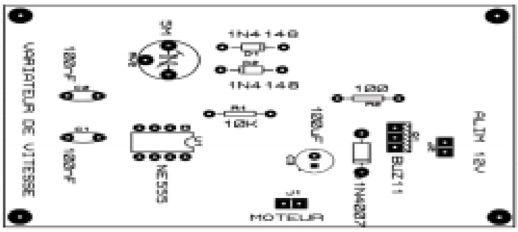

Figure 21: Disposing of DC DC conveter's components on printed circuit card

Conclusion

Nowadays, DC DC converters are of paramount importance in electrical and electronic applications. They make possible to produce speed variators of DC motors, brightness variation, voltage and current regulators for solar batteries or for any other load. They are also used to regulate the rate of generation of hydrogen by fuel cells. Associated with microcontrollers, the DC DC converters can regulate the voltage and the current of the charges remotely in front of a screen or with a smartphone.

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