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Experimental Study of the Boost Converter under Current Mode Control

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ABSTRACT

This paper presents the practical analysis of Boost converter operating in continuous conduction mode under current control. We start by theconverter modeling, then experimental results will be exposed where we propose an experimental circuit, to study the influence of the variation of different circuit parameters such as reference current, input voltage and load. We also analyze the control technique performances. The experimental results are given and interpreted in each case.

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1. INTRODUCTION

The experimental study of the DC DC converters improve that they are suffering from ripple hysteresis. Many works are focused on the illumination of the current- ripple hysteresis. Other experimental works studied the nonlinear phenomenon exhibited by DC DC converters such as periodicity doubling, Bifurcation types, intermittency and chaos [1], [2], [3] , [4].

In all switching converters, the inductor current is related to the reference current and the circuit parameters. To obtain a constant inductor current under circuits parameters variation, the solution is the design of circuit that automatically adjust the duty cycle as necessary to obtain the desired inductor current, they are some works interessed by the tension mode control of DC DC converters to track desired output voltage, the paper [5] used the NNC method to decreasing overshoot and reducing settling time in the DC-DC Flyback Converter, otherwise some works used a control methods of DC DC converters to find the MPPT of the PV supply [6].

In our case we propose a new experimental circuit to study the DC DC Boost converter behaviours under circuit parameters variation and to improve the efficiency of this type of converters.
In the first section we present the converter and its model, then simulation and experimental results will be exposed in the second section. In the last part we present the obtained experimental results in the case of Boost parameters variation and we analyze the control technique performances.

2. CONVERTER DESCRIPTION

We choose the current mode control (CCM) as operating mode, in this control mode is we can control both the slow and fat dynamics of the system [7], [8]. The Boost converter is operating in continues conduction mode when the current through the inductor L never falls to zero ($i_L(t) > 0$). In this case we have two configurations related to the position of the switch sw. Figure 1 shows the current mode control of the Boost converter.

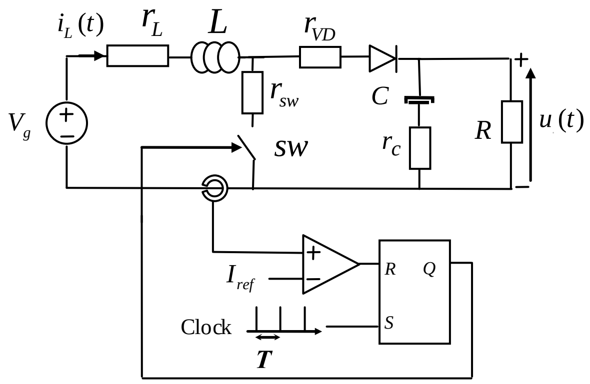


Figure 1. Boost converter under current mode (simplified version)

If T is the clock cycle, the dwells times in the two configurations are respectively $t_1 = dT$ and $t_2 = d^{'}T = (1-d)T$ and the duty cycle $d = t_1/T$ is given by [9]:

$$d(n) = \frac{L}{T(r_L + r_{sw})} \ln\left(\frac{V_{in} - (r_L + r_{sw}) - i_L(n)}{V_{in} - (r_L + r_{sw}) I_{ref}} \right) \tag{1}$$

The system state is expressed as:

$$\dot{x}_i = A_i x_i + B_i U \tag{2}$$

with A_i , B_i the state matrices in the i^{th} configuration.

$$A_1 = \begin{bmatrix} -\frac{1}{C(R+rc)} & 0 \\ 0 & -\frac{r_L + r_{SW}}{L} \end{bmatrix}, \; A_2 = \begin{bmatrix} -\frac{1}{C(R+r_C)} & \frac{R}{C(R+r_C)} \\ -\frac{R}{L(R+r_C)} & -\frac{r_L + r_{VD} + \frac{Rr_C}{R+r_C}}{L} \end{bmatrix}, \tag{3}$$

$$B_{1,2} = \begin{bmatrix} 0 & \frac{1}{L} \end{bmatrix}^t$$

The state is $x = [v_c \; i_L]^t$ (v_c : voltage across capacitor, i_L : inductor current)

The state can be expressed by:

$$X_i(t) = e^{A_i(t-t_0)}(X_i(t_0) + A_i^{-1} B_i V_g) - A_i^{-1} B_i V_g \tag{4}$$

The system model is obtained using (4) to describe the converter behavior in each configuration and using the state final value of the actual configuration, as initial value for the next configuration and so on until obtaining the system response during the whole time rang.

3. PROPOSED EXPERIMENTAL CIRCUIT OF BOOST CONVERTER UNDER CURRENT MODE CONTROL

As presented in Figure 2. We used two operational amplifiers TL084 to obtain the error between the feedback current and the reference current. After that we pass by PI controller, where the control signal must be compared with the triangular signal that can be produced by the ICL8038 circuit to obtain the duty cycle applied on the switch.

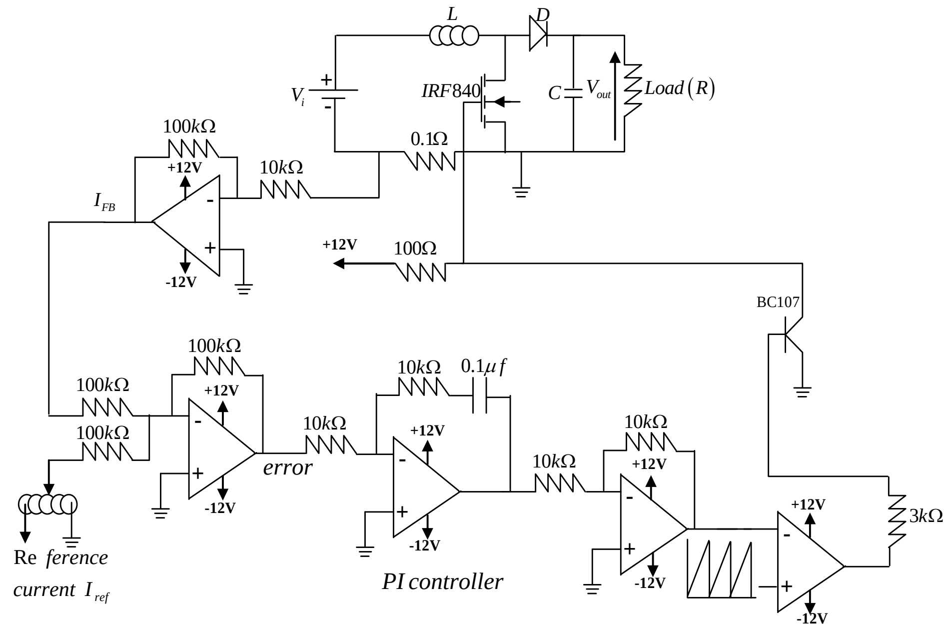


Figure 2. Experimental Boost converter circuit under current mode control

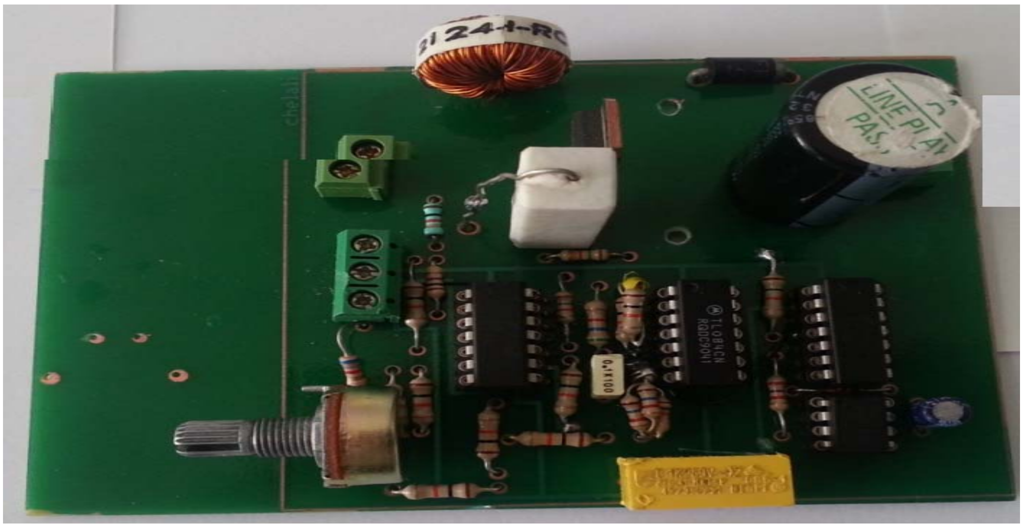


Figure 3. Capted Photo of Experimental Boost converter circuit under current mode control

3.1. Generation of Triangular Signal

We used the driver ICL8038 shown in Figure 4 to generate experimental triangular signal where the frequency is fixed at $10khz$. The values of parameters of the ICL8038 are calculated as fellow: $f = \frac{0.33}{RC}$. Hence, $R = 700\Omega$ and $C = 0.047\mu f$.

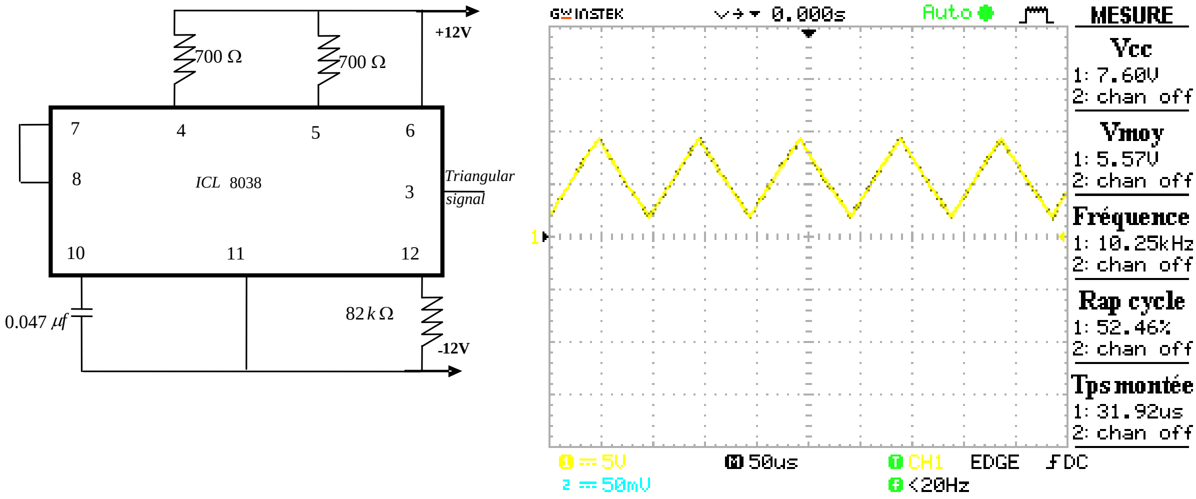


Figure 4. Triangular signal generation by ICL8038 with frequency $10khz$

4. RESULTS AND DISCUSSION

In both cases, the simulation and the experimental study, parameters are: $V_g = 10\text{V}$, $L = 1mH$, $R = 22\Omega$, C=10μF, $r_l = 0.4\Omega$, and the switching frequency $f_{sw} = 1/T = 10KHz$ [10], [11]. We do comparisons between the results obtained by simulation and those obtained by the experimental plant under the variation of reference current, input voltage and the load to analyze the used current mode control performances.

4.1. Original Boost Converter Behaviour

We can remark, in Figure 5, for both cases: simulation and experimental that the inductor current follows the reference current $i_{ref} = 1A$, in the Figure 6 the value of the output voltage in the simulation and experimental is $V_{out} = 14V$.

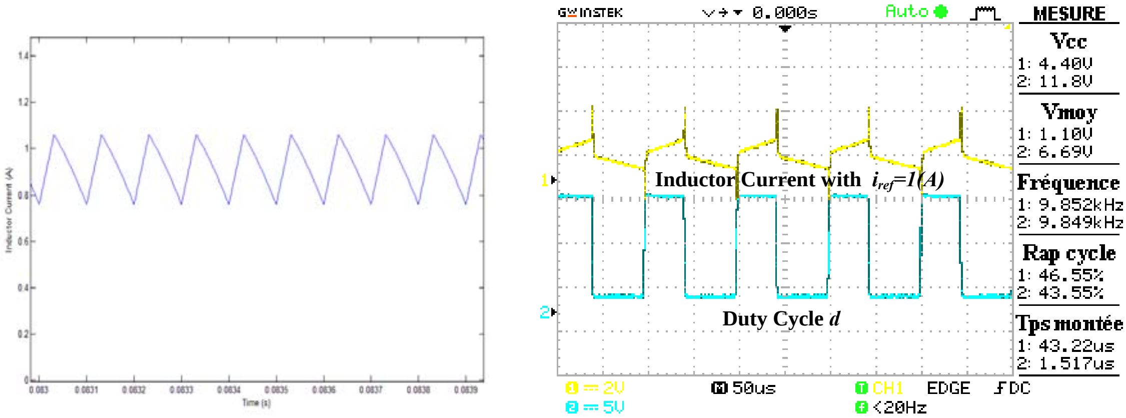


Figure 5. Experimental and Simulation of inductor current

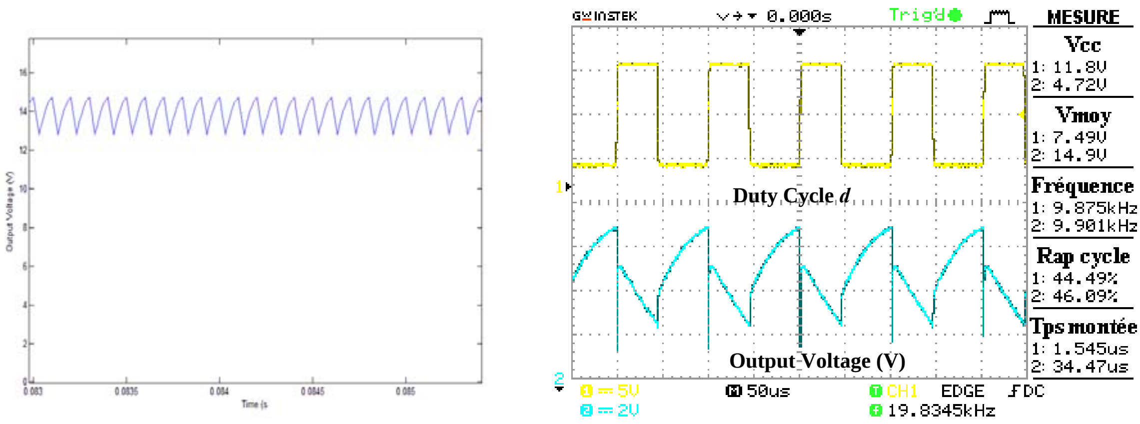


Figure 6. Experimental and Simulation of Output voltage

4.2. Variation of Reference Current

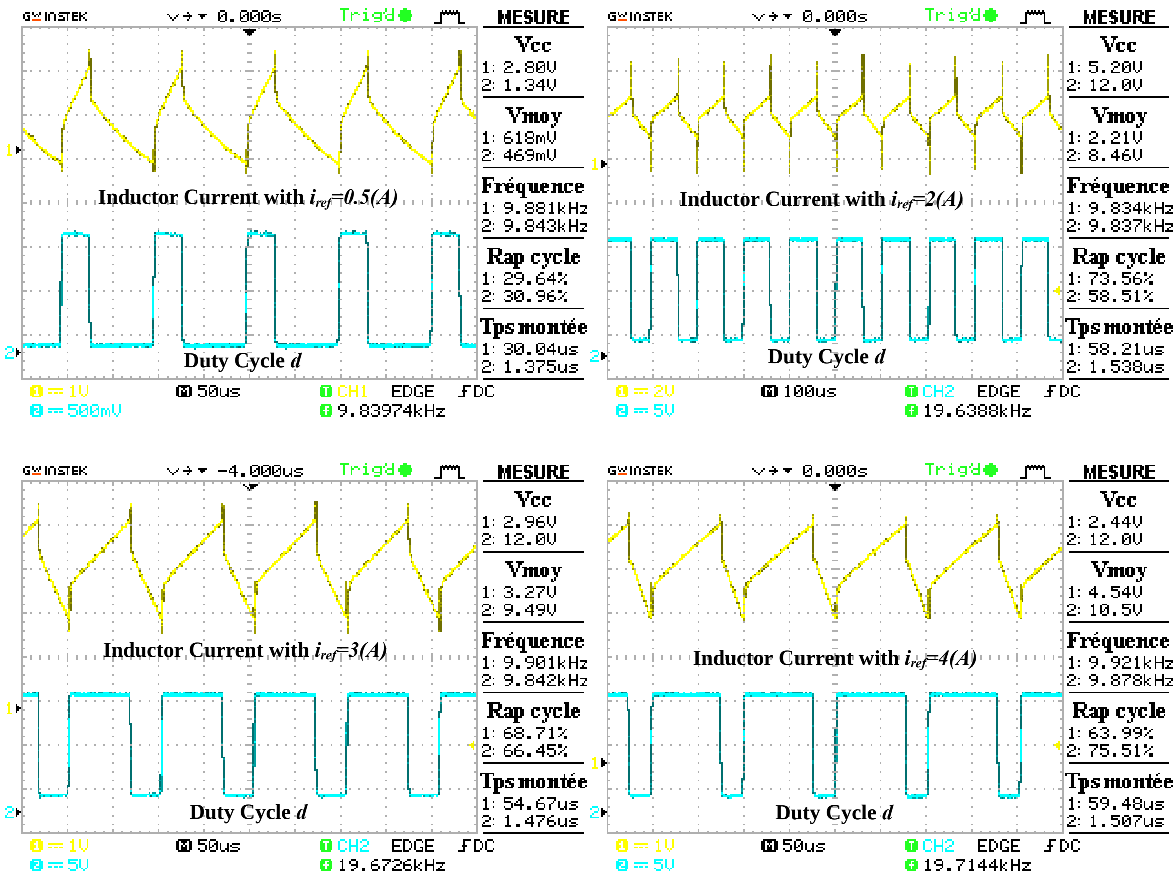


Figure 7. Experimental variation of reference current i_{ref}

We remark in Figure 7 experimental results that when increase the reference current, the duty cycle (channel two) increase to obtain an inductor current close to the reference.

4.3. Variation of Input Voltage

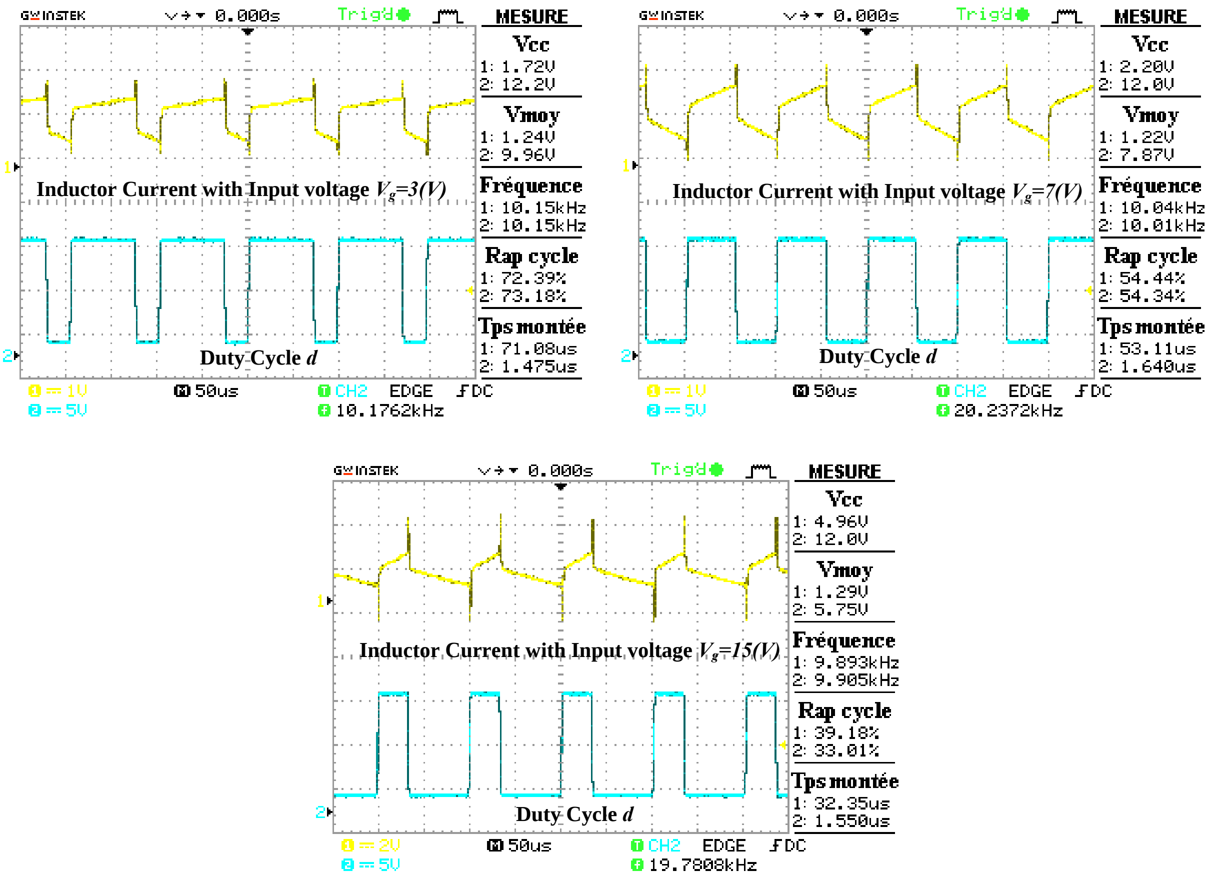
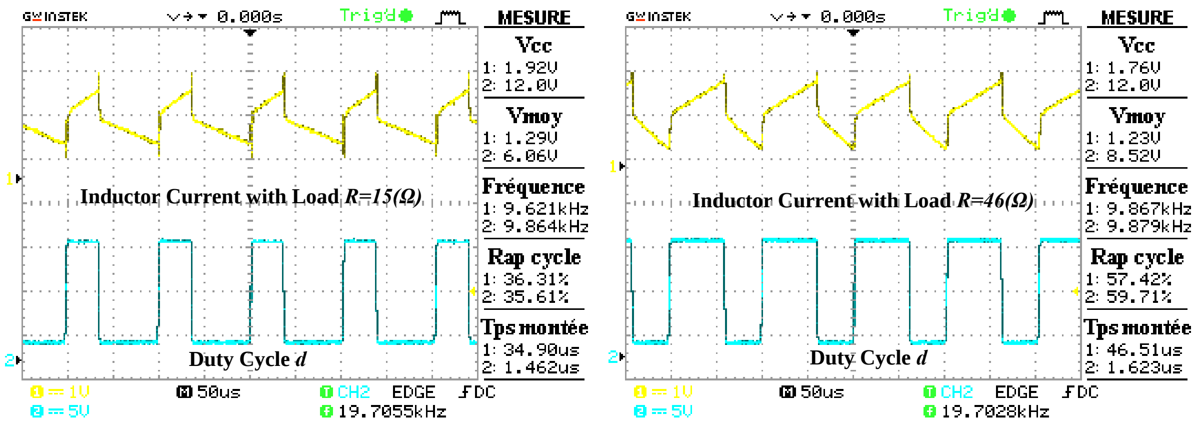


Figure 8. Experimental variation of input voltage

We remark in Figure 8, that when we decreases the input voltage the inductor current decreases, so the duty cycle (channel two) increase to obtain an inductor current close to the reference current.

4.4. Variation of Load



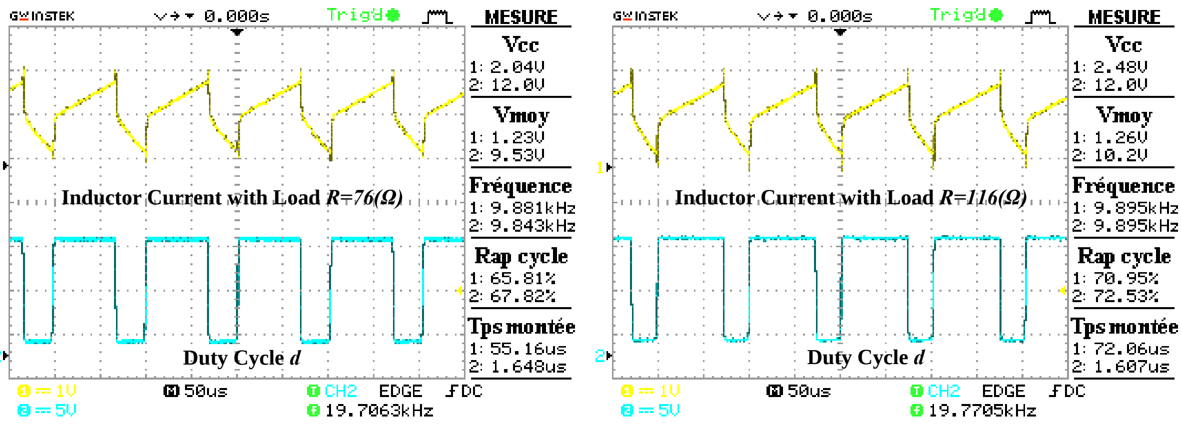


Figure 9. Experimental variation of load

We remark in Fig.9, that when we increase the load the inductor current decreases, so the duty cycle (channel two) increase to obtain an inductor current follow the reference.

5. CONCLUSION

In this paper an experimental circuit of DC-DC converter under current-mode control is analysed. The obtained experimental results were compared to those of simulation which confirms the efficiency of the proposed experimental circuit to study the different behaviors of the Boost converter under diffrents parameters variationsuch as the eference current, the input voltage and the load.

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