BUCK AND BUCK-BOOST DC-DC CONVERTERS

I. OBJECTIVES

a) To visualize the waveforms for the voltages and currents from the dc-dc converter circuits (Buck and Buck-boost).
b) To determine the parameters of the output voltages for the dc-dc converters.

II. COMPONENTS AND INSTRUMENTATION

We use the experimental assembly from Fig. 3, equipped with an IRF9130 transistor (enhanced p – channel MOS transistor), a diode, an inductor, resistors and capacitors of different values. The positive voltage supply is applied from a dc voltage supply, and the command voltage is obtained from the signal generator. We use a dual channel oscilloscope to visualize the signals, and a multimeter to measure the dc values.

III. PREPARATION

P1. Buck converter (Step – down)

The output voltage of the Buck converter is lower than the input voltage.

- For the circuit in Fig.1, supplied with V_I=10V, controlled with a rectangular signal v_{cmd} from the function generator, with an amplitude of 10V, frequency 33KHz and a duty cycle δ=50%, draw the waveforms of the following signals:
    - $v_{I(t)}$, $v_{cmd}(t)$, $v_{D3}(t)$, $v_O(t)$;
    - $i_{I(t)}$, $i_{D3}(t)$, $i_{L1}(t)$, $i_{C1}(t)$.
- Write the relationship between V_O and V_I and find the value of V_O for V_I=10V and duty cycle δ=50%. The duty cycle is computed as $\delta=T_L/T$, where T_L represents the time during which the control signal is 0V (control transistor M1 is in conduction state) and T is the period of the signal.

P2. Buck-Boost converter (Step – down/step – up)

The output voltage of a Buck – Boost converter has an inverted polarity compared with the input voltage.

- For the circuit in Fig. 2, supplied with V_I=10V, controlled with a rectangular signal v_{cmd} from the function generator, with an amplitude of 10V, frequency 20KHz and a duty cycle δ=50%, draw the waveforms of the following signals:
  - $v_{I(t)}$, $v_{cmd}(t)$, $v_{L2}(t)$, $v_O(t)$;
  - $i_{I(t)}$, $i_{D3}(t)$, $i_{L2}(t)$, $i_{C2}(t)$.
- Write the relationship between V_O and V_I and find the value of V_O for V_I=10V and duty cycle δ=50%.

IV. EXPLORATIONS AND RESULTS

1. Buck converter

1.1. Waveforms

Exploration

- Supply the circuit in Fig.1 with V_I=10V and connect a load resistance R_{L1}=50Ω. You will do this by connecting *J2* with *J3*, *J4* with *J5*, *J7* with *J8*, *J11* with *J12* and *R1* closed.

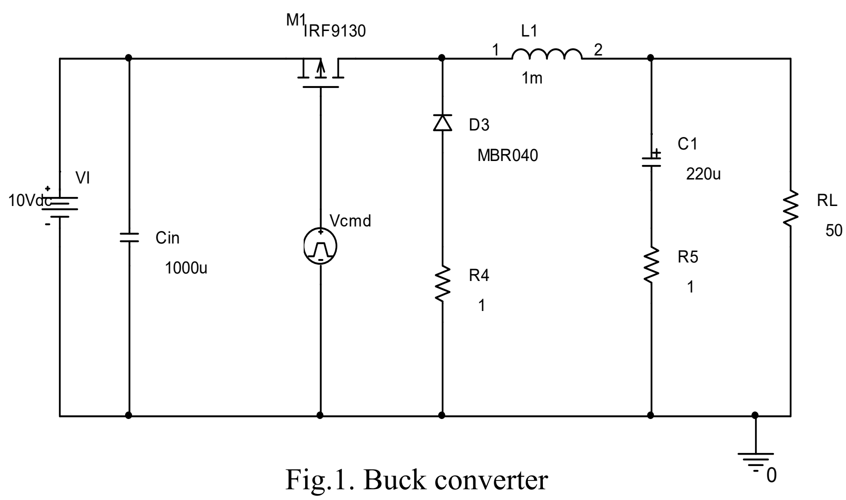

Fig.1. Buck converter

- In the gate terminal of the control transistor M_1, apply a rectangular signal v_{cmd} from the function generator, with an amplitude of 10V, frequency 33KHz and a duty cycle δ=50%.

- Visualize the waveforms of the following signals:
  - the control voltage $v_{cmd}(t)$ and the voltage on R_4, $v_{R4}(t)$, between *J13* and *GND* (R_4 acts like a current transducer for $i_{D3}(t)$);
  - the control voltage $v_{cmd}(t)$ and the voltage on R_5, $v_{R5}(t)$ between *J14* and *GND* (R_5 acts like a current transducer for $i_{C1}(t)$);
  - the control voltage $v_{cmd}(t)$ and the output voltage $v_O(t)$. The output voltage is measured between *OUT* and *GND*, for *J14* connected to the ground.

Results

- Draw the waveforms for $v_{cmd}(t)$, $v_O(t)$, $v_{L2}(t)$, $i_{RL}(t)$, $i_{C1}(t)$, $i_{L1}(t)$, $i_{D3}(t)$ and $i_I(t)$.

1.2. Verifying the relationship between the input and the output voltage

Exploration

- Visualize the control voltage $v_{cmd}(t)$ and the output voltage $v_O(t)$, for R_{L1}=50Ω and compute V_O/V_I.
- Modify the value of the input voltage and the amplitude of the control voltage to 8V. Measure once again the output voltage and the variation of the output voltage, Δv_O, and recompute V_O/V_I.

Results

- The value of V_O/V_I for V_I=10V.
- The value of V_O/V_I for V_I=8V.

1.3. Variation of the output voltage ripple Δv_O with load resistance

Exploration

- For the circuit in Fig.1. with R_{L1} apply once again v_{cmd} with a duty cycle δ=50%. Copy the values for v_O and Δv_O obtained in section 1.2.
- At the output, replace the load resistance R_{L1} with R_{L2} = 75Ω, by disconnecting *R1* and connecting the jumper on the *R2* position. Visualize the control and the output voltages, measure the output voltage v_O, as well as the variation of the output voltage, Δv_O.

Results

- The values of V_O and Δv_O for δ=50% (copied from section 1.2.)
- Draw the waveforms for v_{cmd} (t) and $v_O(t)$, for R_{L2}.
- The values of V_O and Δv_O for R_{L2}.

2. Buck-Boost converter

2.1. Waveforms

Exploration

- Supply the circuit in Fig.2 with V_I=10V and connect a load resistance R_{L1}=200Ω. You will do this by disconnecting all the jumpers and connecting *J1* with *J2*, *J5* with *J6*, *J8* with *J9*, *J10* with *J11* and *R3* closed.

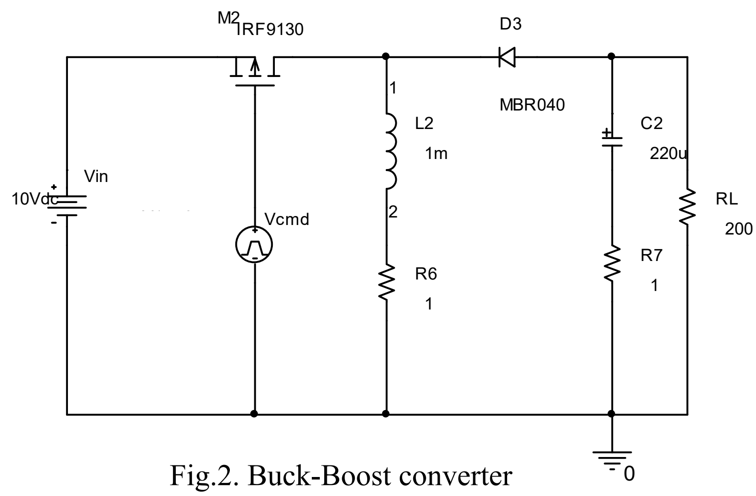

Fig.2. Buck-Boost converter

- In the gate terminal of the control transistor M_2, apply a rectangular signal v_{cmd} from the function generator, with an amplitude of 10V, frequency 20KHz and a duty cycle δ=50%.
- Visualize the waveforms of the following signals:
  - the control voltage $v_{cmd}(t)$ and the voltage on R_6, $v_{R6}(t)$, between *J13* and *GND* (R_6 acts like a current transducer for $i_{L2}(t)$);
  - the control voltage $v_{cmd}(t)$ and the voltage on R_7, $v_{R7}(t)$ between *J14* and *GND* (R_7 acts like a current transducer for $i_{C2}(t)$);

- the control voltage $v_{cmd}(t)$ and the output voltage $v_O(t)$. The output voltage is measured between *OUT* and *GND*, for *J14* connected to the ground.

Results

- Draw the waveforms for $v_{cmd}(t)$, $v_O(t)$, $v_{L2}(t)$, $i_{RL}(t)$, $i_{C2}(t)$, $i_{D3}(t)$, $i_{L2}(t)$ and $i_I(t)$.

2.2. Verifying the relationship between the output and the input voltage

Exploration

- Visualize the control voltage $v_{cmd}(t)$ and the output voltage $v_O(t)$, for R_{L1}=200Ω and compute V_O/V_I.
- Modify the value of the input voltage and the amplitude of the control voltage to 8V. Measure once again the output voltage and the variation of the output voltage, Δv_O, and recompute V_O/V_I.
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Results

- The value of V_O/V_I for V_I=10V.
- The value of V_O/V_I for V_I=8V.

2.3. Variation of the output voltage ripple Δv_O with load resistance

Exploration

- For the circuit in Fig.2 with R_{L1} apply once again v_{cmd} with a duty cycle δ=50%. Copy the values for v_O and Δv_O obtained in section 2.2.
- At the output, replace the load resistance R_{L1} with R_{L2} = 250Ω, by disconnecting *R3* and connecting the jumper on the *R4* position. Visualize the control and the output voltages, measure the output voltage v_O, as well as the variation of the output voltage, Δv_O.

Results

- The values of V_O and Δv_O for δ=50% (copied from section 2.2.)
- Draw the waveforms for v_{cmd} (t) and $v_O(t)$, for R_{L2}.
- The values of V_O and Δv_O for R_{L2}.

REFERENCES

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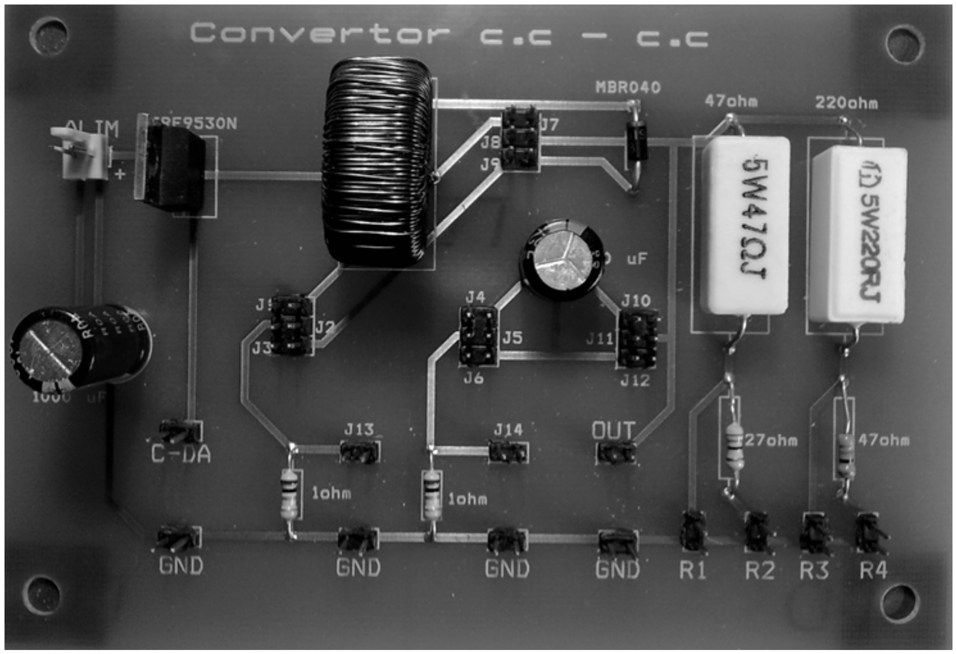

Fig. 3. Experimental assembly