Drivers for High Frequency Power Supply

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Abstract – **The reliable and flawless, as well as steady, work of the high-frequency power devices is provided by the way their power switches have been controlled. The present paper treats a development of MOSFET drivers for controlling switch transistor sets of a high frequency power supply designed for induction heating with working frequency of 1÷1.5 MHz and output power of 750 W, transferred on a resonance load.**

Keywords – **Power Supply, Inverter, Induction Heating.**

I. Introduction

There is a large variety of industrial processes that require reliable, low cost, high frequency power for an induction heating. The technologies for welding and soldering of non – ferrous metals with a thickness of microns are impossible without this induction heating [1-5].

The results from the investigation of frequency power supply for soldering of non-ferrous metals with P_{out} = 750 W; f_{in} = 1 ÷1.5 MHz; U_{ps} = 150 V DC are presented in the report.

The soldering of non – ferrous metals is made with an inductor L_{Load} = 3.9 μH compensated in the resonant parallel circuit from a high frequency capacitor C_{Load} = 5.6 nF. The equivalent resonant resistance is $R_e \approx 572\ \Omega$.

The block circuit of the high frequency power supply is shown in Fig. 1. The impedance matching on the load is made by an output transformer with a transformation ration 5:1.

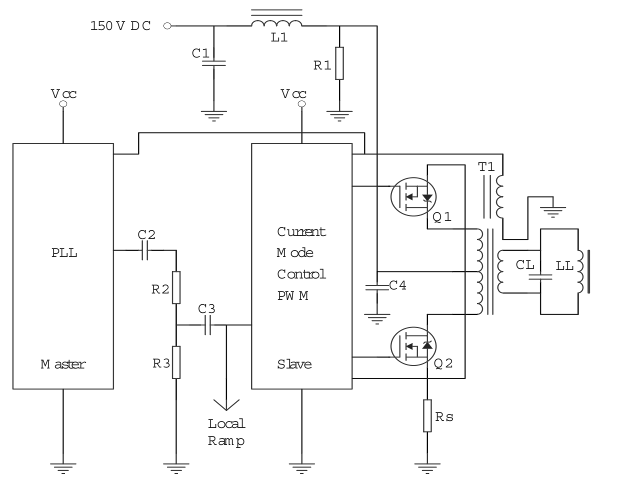

Fig. 1. Block circuit of the high frequency power supply

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A push – pull configuration for inverter is selected. In the simultaneously are introduced voltage and current mode controlled to keep up the output voltage and the output current in the MOSFET switches. The output current is stabilized by pulse width modulation (PWM) system.

II. Operating Principle

The requirement in the induction heating for a higher frequency and an improved efficiency has lead to the need for using MOSFETs. The power MOSFETs have several parasitic elements, capacitance and inductances, with inhibit high speed operation and will affect its switching behavior and its power dissipation. Consequently the type of drive circuitry is very important for the switching one power MOSFETs, the reduction of the power dissipation and the operation at high frequency mode.

The electrical circuits with a push/pull drive circuit and a Power MOSFET are given in Fig. 2.

The modelling and the calculation of the gate driver is presented by the simplified MOSFET model and all associated inter connections. The equivalent electrical circuit is shown in Fig. 3 [6,7], when:

- R_D = 0.54 Ω is the resistance of the driver;
- $R_{G,I}$ = 1.8 Ω I - the internal gate mesh resistance;
- R_C = 0.05 Ω - their interconnection;
- C_D = 81 pF - the capacitance of the driver
- C_C = 50 pF- the capacitance of the interconnection,

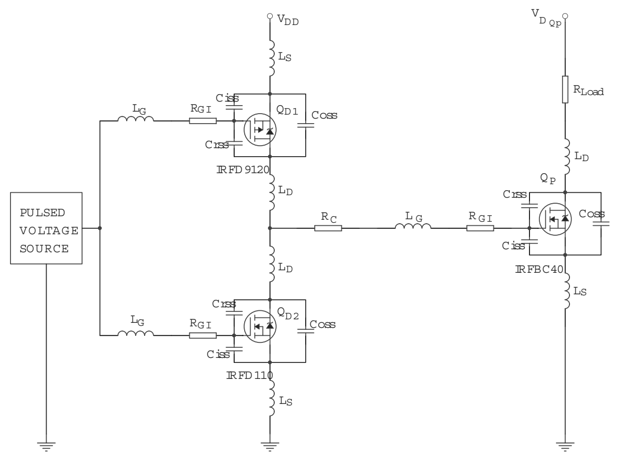

Fig. 2. Electrical circuit – a push/pull drive circuit and a power MOSFET

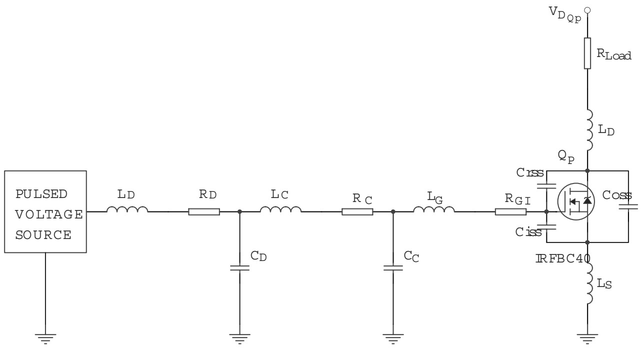

Fig. 3. Equivalent circuit of the driver

- C_{iss} = 1300 pF- the internal capacitance of the Power MOSFET;
- C_{rss} = 30 pF - reverse transfer capacitance;
- L_G = 7.5 nH - the inductance of the gate;
- L_S = 7,5 nH - the inductance of the source;
- L_D = 10 nH - the inductance of the driver;
- L_C - the inductance of the interconnection.

III. Calculation

From the theoretical model and equations, given in [8,9], the next calculation we have:

- resistance of the circuit

$$R_L = R_D + R_C + R_{GI}\ , \tag{1}$$
$$R_L = 0,54 + 0,05 + 1,80 = 2,39\ \Omega\ ;$$

- capacitance of the circuit

$$C_{FET} \cong C_{iss} + C_{rss}\frac{\Delta\left(V_{DS} - V_{GS}\right)}{\Delta V_{GS}}, \tag{2}$$
$$C_{FET} = 1300 + 30\frac{600-8}{8} = 3520\ pF,$$

$$C_L = C_{FET} + C_C + C_D = 3651\ pF\ , \tag{3}$$
$$C_L = 3520 + 50 + 81 = 3651\ pF\ ;$$

- gate switching time

$$T_r = 2R_L C_L, \tag{4}$$
$$T_r = 2\cdot 2.39\cdot 3.651\cdot 10^{-9} = 17.45\ nS\ ;$$

- inductance of circuit

$$L_L \cong \left(\frac{2T_r}{\pi\sqrt{C_L}}\right)^2 =$$
$$= \left(\frac{2\cdot 17.45\cdot 10^{-9}}{\pi\sqrt{3.651\cdot 10^{-9}}}\right)^2 = 33.8\ nH \tag{5}$$

- corrected rise time

$$T_{r(corrected)} \cong \sqrt{\left(\frac{\pi\sqrt{L_L C_L}}{2}\right)^2 + \left(2R_L C_L\right)^2} =$$
$$= \sqrt{\left(\frac{\pi\sqrt{33.8\cdot 10^{-9}\cdot 3.65\cdot 10^{-9}}}{2}\right)^2 + \left(2\cdot 2.39\cdot 3.85\cdot 10^{-9}\right)^2}$$
$$= 24,67\ nS \tag{6}$$

- gate current

$$I_{Gpk} \cong \frac{C_L\cdot V_{DD}}{T_{r(corrected)}} = \frac{3.65\cdot 10^{-9}\cdot 8}{24.67\cdot 10^{-9}} = 1.18\ A \tag{7}$$

- gate drive voltage

$$V_{Gpk} \cong \frac{I_{DS}}{g_{fs}} + V_{TH} + R_G I_{Gpk} + L_L\frac{I_{Gpk}}{T_r} =$$
$$= \frac{5}{6.1} + 4.2 + 2.39\cdot 1.18 + 33.8\frac{1.18}{24.67} = 9.46\ V\ , \tag{8}$$

g_{fs} - forward transconductance;

- gate power dissipation

$$P_{Gd} = C_{(FET)}\times V_{DD}^2\times f_s = 0.337\ W \tag{9}$$

IV. Experimental Results

The experimental results from the simulation model core shown in Fig. 4. *Protel 99 SE* for the simulation is used. Gate and

Drain voltages are given in Fig. 5.

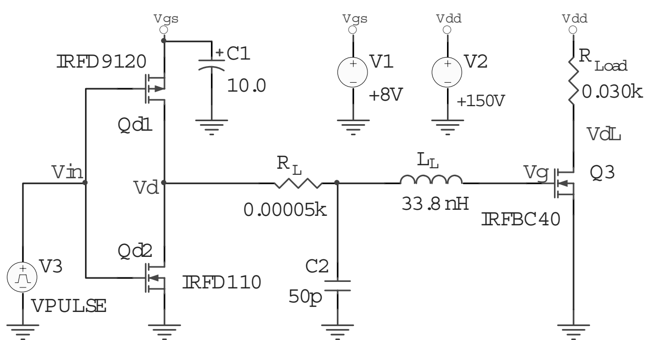

Fig. 4. The simulation model

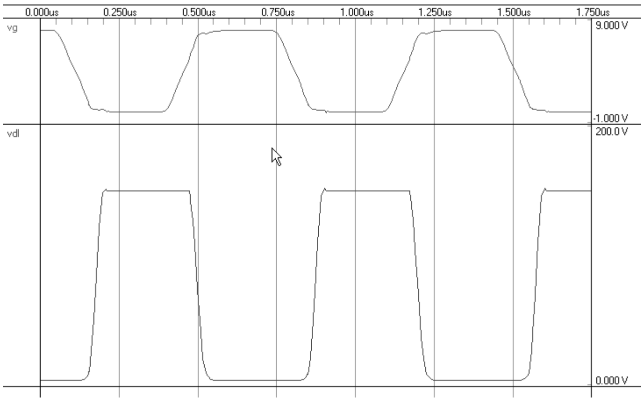

Fig. 5. Waveforms V_{GS} and V_{DS}

The load of drive is R_L = 2.39 Ω, L_L = 33.8 nH and maximum frequency 1,5 MHz. The load of the power MOSFET is R_{Load} = 30 Ω. The driver works steadily as the optimal switch times given by the company producing MOSFET transistors have been reached at.

At inductivity increased to a definite value, a sudden driver hesitation appears follower by unsteady work. The same can be observed when the value of the resistor R_L is increased. This is shown in Fig. 6.

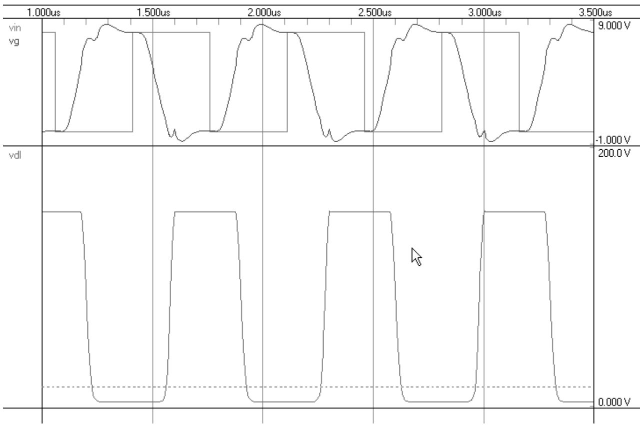

Fig. 6. Unsteady work of the driver

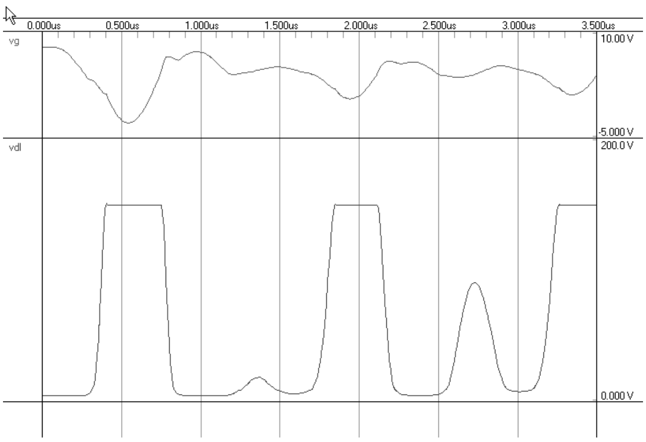

Fig. 7. Breakdown regime of the drive

The impedance increase in the Gate circuit R_L, C_C and L_L, as a result of poor design of a print chip and a poorly executed assembly, may lead to unsteady work of the driver as a whole , an oscillation of harmonious frequency in the driver circuit and destruction of the converter in general. Such a working regime is shown in Fig. 7.

Table 1. Power Consumption of Gate Drive

F[MHZ]	0,8	0,9	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7
P[mW]	180	203	225	248	270	293	315	338	360	383

The research work carried out for the power released in the Gate of the powerful transistor show that the gate depends linearly on the working. The dependence $P_G = f(F)$ is given in Fig. 8.

On the basis of the research conducted, a sample model of the High Frequency Power Supply for induction heating was designed, having output power P_{out} = 750 W; f_{out} = 1÷1.5 MHz; U_{PS} = 150 V DC working with resonance load L_{Load} = 3.9 μH; C_{Load} = 5.6 nF, with equivalent resistance $R_e \approx$ 572 Ω. He work forms demonstrating the driver's work are shown in Fig. 9.

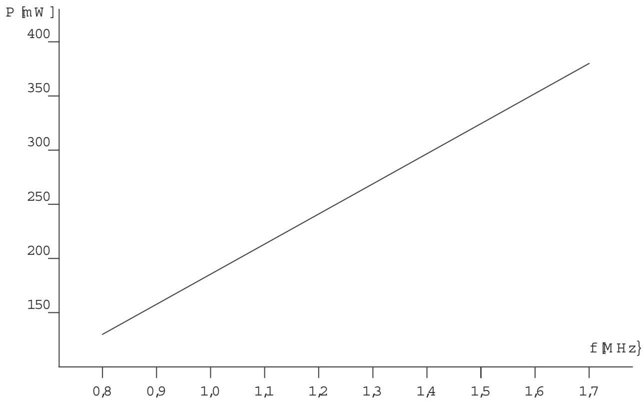

Fig. 8. Dependence $P_G = f(F)$

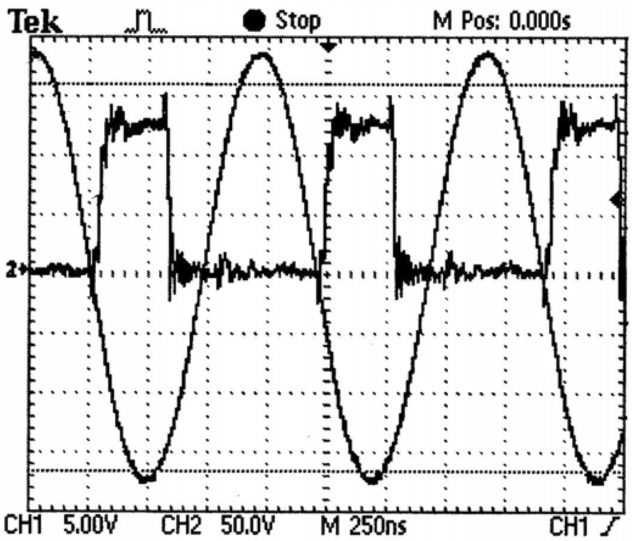

Fig. 9. U_{GS} and U_{Load}

V. Conclusion

The reliable and flawless work of the High Frequency Power Supply depends exceptionally on the precise drivers design. Drivers control the powerful switches, as the reduction of the parasite components appearing as a result of incorrect construction and assembly are of great importance.

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