BUCHAREST POLYTECHNIC NATIONAL
UNIVERSITY OF SCIENCE AND TECHNOLOGY
DOCTORAL SCHOOL OF ELECTRICAL
ENGINEERING

TEZĂ DE DOCTORAT

- SUMMARY -

CONTRIBUȚII PRIVIND OPTIMIZAREA CUPLAJELOR INDUCTIVE ȘI CAPACITIVE FOLOSITE ÎN SURSELE DE ALIMENTARE ÎN COMUTAȚIE

CONTRIBUTIONS ON THE OPTIMIZATION OF INDUCTIVE AND CAPACITIVE COUPLINGS USED IN SWITCHED MODE POWER SUPPLIES

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CONTENT

LIST OF ABBREVIATIONS

AC / CA - Alternating Current - Alternative Current

DC / CC - Direct Current - Continuous Current

U - Electromotive Voltage

I - Intensity of Electric Current

R - Resistance

L - Self Inductance

M - Mutual Inductance

C - Capacity

G - Conductance

Z - Impedance

X_L - Inductive Reactance

X_C - Capacitive Reactance

T_r - Transistor

ϕ_m - Magnetic Flux

B - Beta - Amplification Factor

F - Frequency

ESR - Equivalent Series Resistance - the equivalent series resistance

LTx - Transmitting coil

LRx - Receiver coil

Rs - Load Resistor

K - Conversion ratio

WPT - Wireless Power Transfer - wireless power transfer

IPT - Inductive Power Transfer - inductive coupling for power transfer

CPT - Capacitive Power Transfer - capacitive coupling for power transfer

PWM / MID - Pulse Width Modulation - Pulse Duration Modulation

AM / MIA - Amplitude Modulation - Impulse Modulation in Amplitude

PFM /FM / MF - Pulse Frequency Modulation - Frequency Modulation

Dc - Duty Cycle - Signal fill factor

Dt - Dead Time - Dead Time

BMS - Battery Management System - Battery monitoring system

SMD - Surface Mounted Device - the component is glued directly to the copper surface

THT - Through Hole Technology - the component pins are inserted through the printed circuit

SOP-8 - Small Outline Integrated circuit - Integrated circuit with 8 terminals

IC - Integrated Circuit – Integrated circuit

PDIP-20 - Plastic Dual In-Line Package - Integrated circuit with 20 terminals

OP-AMP - Operational Amplifier

OSC - Oscillator, signal generator

ADC - Analog to Digital Converter - analog-digital converter

DAC - Digital to Analog Converter - digital-analog converter

SMPS - Switched-Mode Power Supply - Switching power supply

LCC - Coil-Capacitor-Capacitor Connection

LLC - Coil-Coil-Capacitor Connection

VCM - Voltage Controlled Mode - Control in voltage

CCM - Current Controlled Mode - Control in current

MOSFET - Metal Oxide Semiconductor Field Effect Transistor - transistor with field effect

IGBT - Insulated Gate Bipolar Transistor - bipolar transistor with insulated gate

LED - Light Emitting Diode - light emitting diode

ASIC - Application Specific Integrated Circuit - specialized integrated circuit

PCB - Printed Circuit Board - board with printed wiring

EMI - Electromagnetic Interference - electromagnetic interference

MPPT - Maximum Power Point Tracking - extracting the maximum power from the circuit

Np - Number of turns in the primary winding

Ns - Number of turns in the secondary winding

LFO - Low Frequency Oscillator - low frequency generator

VNA - Vector Network Analyzer - vector network analyzer

PREFACE

This thesis represents the result of the research activity from October 2020 - September 2023, with the main field of research being switching power supplies, respectively optimizing the functionality of inductive and capacitive couplings. This was carried out within the Faculty of Electrical Engineering of the Polytechnic University of Bucharest.

I would like to especially thank Mr. Prof. Dr. Eng. Mihai IORDACHE, my PhD supervisor for his involvement and patience.

I also want to thank Mr. Prof. Dr. Eng. Valentin NĂVRĂPESCU for the support given during my master's studies. I would like to thank all the teaching staff at the Faculty of Electrical Engineering of the Polytechnic University of Bucharest who contributed to my development as an engineer, during my master's and doctoral studies.

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Last but not least, I want to thank my family for their support, my father for opening the way to the electrical/electronics field.

I wish to dedicate this thesis to all electrical and electronic enthusiasts.

Thank you very much! Bucharest 2024, Ovidiu-Dorin Lăudatu

1. INTRODUCTION

The research paper is entitled: " Contributions to the Optimization of Inductive and Capacitive Couplings Used in Switching Power Supplies", this comes as a technological advancement of switching power supplies used in the consumer electronics industry.

Most consumer electronic equipment (televisions, computers, monitors, printers, audio systems, mobile phone chargers, laboratory equipment, network equipment, charging systems for electric vehicles, most equipment powered from the national grid, etc.) use power sources switching power supply..

These power supplies are indispensable and offer countless benefits such as: low production costs, considerably reduced size and weight compared to linear power supplies.

The aim of this doctoral thesis is to make significant contributions to the realization of switching power supplies with galvanic separation, by making some design changes on the inductive and capacitive couplings, changes that will translate into benefits in relation to: reducing the cost of production, energy efficiency, improvement of nominal operating parameters and reduction of EMI emissions, etc.

For the development of changes in the structure of the power sources, (changes that were presented in this paper), a series of calculations, simulations of electronic circuits using dedicated programs, as well as laboratory experiments were carried out. In this research paper, most of the satisfactory results obtained from the research conducted have been presented.

1.1. Problem formulation

Most electronic equipment uses switching power supplies, especially equipment powered from the national electricity grid. To ensure a stabilization of the output voltage (if it is a voltage source), or a stabilization of the electric current (if it works in current source mode), it is necessary to introduce a feedback loop between the secondary module of the source and the module in primary source.

This feedback loop can be achieved by:

- Analogue optical coupling, where the signal is transmitted linearly, or digital optical, where the reaction signal is transmitted in the form of pulses (in this case it can be pulses for direct control of the power semiconductor element, or indirectly, through a driver circuit). In the case of the analog optocoupler (which is also the most used), if the optocoupler is defective (the LED inside is destroyed due to overcurrent or high working temperatures) the output voltage or output current will increase considerably, resulting in the destruction the source but also the equipment it supplies.
- coupling , using a pulse transformer in the feedback loop, it can directly drive the power transistors, or it can drive a driver circuit of the transistor or power transistors.

The objectives of this research work are the following:

Improving the performance of switching power supplies with galvanic separation, by:

1. Replacing the ferromagnetic core pulse transformer with:
   - WPT circuit - placement of the primary coil and secondary coil on the PCB path of the electronic module
   - CPT circuit - using the capacity formed by the two paths of the *top* and *bottom PCB circuit* , the dielectric being made of glass-textolite or pertinax.
2. Eliminating the optocoupler (analog or digital with hysteresis), and the pulse transformer with a ferromagnetic core used to close the feedback loop and introducing two couplings:
   - IPT inductive coupling, using two coils made from the PCB trace of the module, without a magnetic core.
   - Capacitive CPT coupling, using two capacitances made from the mod's PCB trace.

   Both couplings use WPT as their communication principle.

The advantages of new contributions are:

- Improving feedback loop response.
- Reduction of energy consumption by entering sleep mode of the primary mode through the digital command from the secondary.
- Reducing energy consumption by eliminating the optocoupler.
- Improvement of nominal parameter variations with operating temperature.
- Reduction of drift voltage.
- Reducing the output ripple.
- Reduction of production cost by eliminating the optocoupler or ferromagnetic core from the magnetic circuit of the feedback loop.
- Reducing the production cost of the impulse power transformer.
-

1.2. Structure and content of the thesis

The research paper is structured in 9 chapters:

CHAPTER 1 INTRODUCTION problems encountered in closed-loop switching power supplies, but solutions to solve them, are briefly presented.

CHAPTER 2 POWER SUPPLY TOPOLOGIES - a brief presentation of the main switching power supply topologies, both with and without galvanic separation, was made. The proposed solutions can be used within these topologies of switching power supplies.

CHAPTER 3 THE CURRENT STATE OF SWITCHING POWER SUPPLIES, a brief presentation of the current technical ways of closing the reaction loops was made, as well as a simulation of the three couplings, optical-inductive-capacitive.

CHAPTER 4 CONSIDERATIONS REGARDING THE OPTIMIZATION OF SWITCHING POWER SUPPLIES. In this chapter, four technical solutions were presented for the optimization of switching sources. The first solution is to replace the ferrite core power transformer with a WPT circuit made from the PCB circuit trace. The second solution is given by replacing the power transformer with a capacitive coupling made from the PCB circuit, for low power sources. The third solution is to close the feedback loop through an inductive coupling made from the copper path of the PCB circuit. The fourth solution is to close the feedback loop using capacitive coupling made using the PCB circuit. These solutions are the subject of the next four chapters.

CHAPTER 5 CONSTRUCTION OF A SWITCHING POWER SUPPLY, HALF-BRIDGE TOPOLOGY USING INDUCTIVE COUPLING, WITH OPEN FEEDBACK - presents the research, design, simulation and physical realization together with experimental results of a power supply using Half-Bridge topology. In this case the source replaces the traditional transformer with an inductive coupling made of two overlapping PCB traces.

CHAPTER 6 CONSTRUCTION OF A SWITCHING POWER SUPPLY, HALF-BRIDGE TOPOLOGY USING CAPACITIVE COUPLING, WITH OPEN REACTION LOOP. In this chapter, research was carried out in the direction of replacing the usual transformer with a ferrite core. Two sources were designed, simulated and physically built using a capacitive coupling made from the PCB circuit.

CHAPTER 7 CONSTRUCTION OF A SWITCHING POWER SUPPLY, FLYBACK TOPOLOGY, WITH CLOSED REACTION LOOP, CLOSING THE REACTION LOOP BY INDUCTIVE COUPLING - research has been carried out to replace the optical coupling with an optocoupler or inductive coupling with a ferrite core transformer , replacing it with an inductive coupling made from the PCB circuit traces. Flyback topology was chosen for the design of the source.

CHAPTER 8 CONSTRUCTION OF A SWITCHING POWER SUPPLY, FLYBACK TOPOLOGY, WITH CLOSED FEEDBACK LOOP, CLOSING THE FEEDBACK LOOP BY CAPACITIVE COUPLING - research was carried out in order to replace the optical and inductive couplings, with a capacitive coupling used to close the loop of reaction in the case of power supplies with galvanic separation. The electronic scheme was designed, calculations and simulations were carried out, as well as the physical construction of the source together with experimental results.

CHAPTER 9 FINAL CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS – is a chapter dedicated to the presentation of the obtained results but also the new research directions that are required based on the obtained results.

1.3. Dissemination of results

1) Mihaela Grib, Ionela Vlad, **OD Lăudatu** , AR Grib, M. Iordache, Hybrid Equivalent Circuit Generation, Carpathian Journal of Electrical Engineering, vol. 15, no. 1, pp. 81-93, 2021.

2) M. Grib, M. Iordache, AR Grib, H. Popescu, **O. Laudatu** and M. Staniloiu, "The Use of Thévenin, Norton and Hybrid Equivalent Circuits in The Analysis and Polarization of Nonlinear

Analog Circuits," 2022 International Conference and Exposition on Electrical And Power Engineering (EPE), Iasi, Romania, 2022, pp. 198-207, doi: 10.1109/EPE56121.2022.9959871.

3) **O. Laudatu** , M. Iordache, M. Stanculescu, L. Bobaru, D. Niculae and O. Drosu, "Wireless Power Transmission System Design. A Practical Approach.," 2023 13th International Symposium on Advanced Topics in Electrical Engineering (ATEE) , Bucharest, Romania, 2023, pp. 1-4, doi: 10.1109/ATEE58038.2023.10108155.

4) D. Niculae, M. Iordache, L. Bobaru, M. Stănculescu, M. Grib and **O. Laudatu** , "Adapting the Impedance of The Signal Transmission Lines," 2023 10th International Conference on Modern Power Systems (MPS), Cluj-Napoca , Romania, 2023, pp. 01-05, doi: 10.1109/MPS58874.2023.10187513.

5) **O. Lăudatu** , M. Iordache, M. Stănculescu, D. Niculae, L. Bobaru and O. Drosu, "Loop Closing of Flyback Switching Power Supply Using Inductive Coupling. Practical Study," 2023 10th International Conference on Modern Power Systems (MPS), Cluj-Napoca, Romania, 2023, pp. 01-04, doi: 10.1109/MPS58874.2023.10187546.

6) **O. Lăudatu** , M. Iordache, M. Stănculescu, L. Bobaru, D. Niculae and E. Cazacu, "Loop Closing of Flyback Switching Power Supply Using Capacitive Coupling," 2023 International Conference on Electromechanical and Energy Systems (SIELMEN), Craiova , Romania, 2023, pp. 1-6, doi: 10.1109/SIELMEN59038.2023.10290757

7) **Ovidiu praised,** mihait Iordache, " Comparison of Inductive and Capacitive Couplings Used to Close the Feedback Loop Used in the Switch Mode Power Supplies " , *rev. Rome. Sci. Tech.– Electrotechn. etc Energy.* , Vol. **68** , 4, TWO: https://doi.org/10.59277/RRST-EE.2023.4 , **WOS:001126934500008 ,** Bucharest, 2023, Published: 14.12.2023. pp. 363–368.

8) Ovidiu Lăudatu , Dragoș Niculae, Mihai Iordache, Maria – Lavinia Bobaru, Marilena Stănculescu, " Experimental Analysis of Power Semiconductor Elements Used in Flyback Converters " , *rev. Rome. Sci. Tech.– Electrotechn. etc Energy.* , Vol. 6 9 No.1 (2024): RRST-EE , 1 , https://doi.org/ 10.59277/RRST-EE.2024.1.12 , **WOS:001198252400013,** Bucharest, 2024 , Published: 04.04.2024. pp. 67–72 .

2. POWER SUPPLY TOPOLOGIES

2.1. Introduction

The power supplies ensure the delivery of electric power to the electronic circuits, having very well defined delivery parameters. Power supplies fall into two categories, linear power supplies and switching power supplies.

Linear power supplies offer very good stability of output parameters, very low ripple compared to switching power supplies, but very low energy efficiency. For this reason they are used in most cases, in circuits where the consumed power is relatively low. An example of an adjustable linear power supply can be seen in Fig. 2.1, where a laboratory linear power supply is shown, it was designed to power various laboratory circuits.

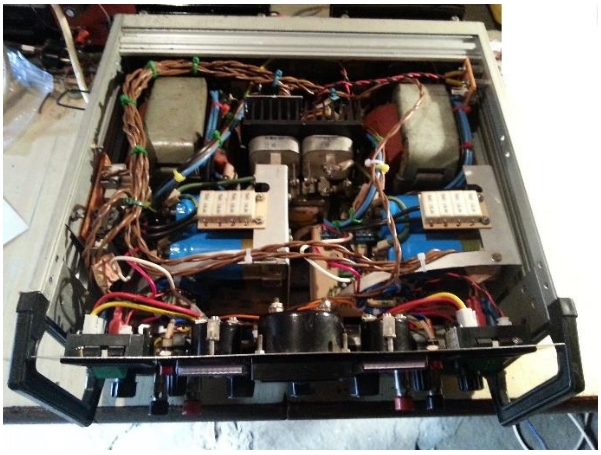


Fig. 2.1 Adjustable linear power supply

Linear power supplies have much lower efficiency compared to switching power supplies. This energy loss is mostly dissipated by the semiconductor elements, in the case of the source shown, by the bipolar transistors connected on the radiator, shown in Fig. 2.2.

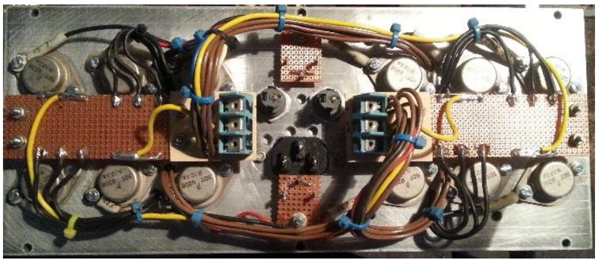


Fig. 2.2 Power supply transistors connected on the heatsink

The basic diagram of a stabilized linear power supply is shown in Fig.2.3. The basic components are: the transformer TR1- has the role of changing the voltage/current parameters, and to ensure a galvanic separation, it works at a low frequency, of the order of Hz; the rectifier bridge BR1- has the role of rectifying the alternating voltage into pulsating direct voltage; capacitor C1 - has the role of keeping the voltage constant, by reducing the ripple; integrated circuit U1 - is a linear voltage stabilizer circuit, with the role of keeping the

VO output voltage stable; C3 - has the role of reducing the ripple value of the output voltage, and improving the response of the feedback loop inside the linear stabilizer circuit.

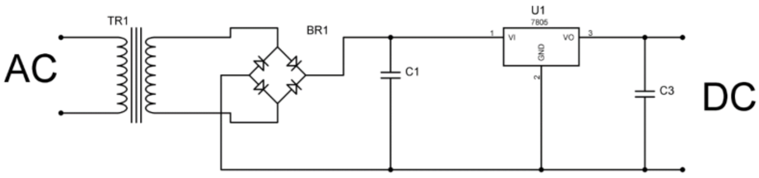


Fig. 2.3 Diagram of a power supply with linear voltage stabilizer

Switching power supplies are power electronic equipment that ensure the delivery of electrical power to consumers at a very good efficiency compared to linear power supplies. As a construction, they are more complex and require a greater number of electronic components. They are called switching power supplies because they operate at medium to high frequencies, on the order of KHz-MHz, for this reason they need an oscillating circuit to generate that operating frequency.

An example of a switching power supply can be seen in Fig. 2.4, the power source comes from a DVD.

Fig. 2.4 Switching power supply

The basic electronic diagram of a switching power supply can be seen in Fig. 2.5.

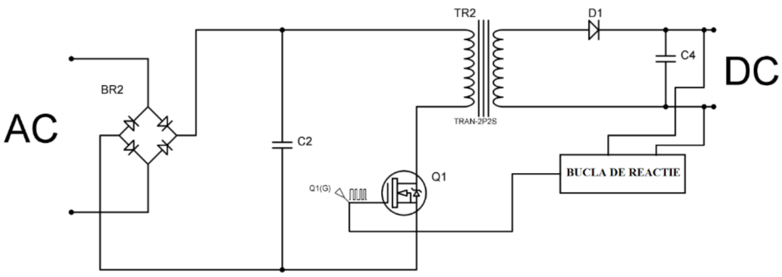


Fig. 2.5 Principle diagram of a switching power supply

2.2. Classification of switching power supplies

Switching power supplies are divided into several categories, depending on:

1.Galvanic separation:

- With galvanic separation, inductive through a transformer or capacitive through a capacitor
- Without galvanic separation, using coil or capacitor (charge pump)

2.How to order power semiconductors:

- MID/PWM duration pulse modulation
- MIA/AM pulse amplitude modulation
- MF/FM frequency pulse modulation

3.Impulse and Rectification Command:

- Asynchronous - when the oscillator generates a single signal, necessary for the control of the power transistor, the voltage rectification is carried out by the diode, uncontrolled, when the value of the forward bias voltage exceeds Uf-the forward bias voltage of the diode, it varies depending on the type of diode. For this reason, the power supply is called asynchronous, because the rectification in the secondary and the pulse in the primary are not synchronized.
- Synchronous - when the generator generates a control pulse/pulses for the module in the primary, but also a control pulse/pulses for the rectification module in the secondary, the rectification being carried out in this case with power transistors, it being necessary to introduce a Dt between these pulses . In this case the pulses from the primary and secondary are synchronized.

4.Feedback loop:

- Closed loop - when there is a communication link between the secondary module and the primary module, it can be with galvanic isolation, or without galvanic isolation
- With open loop - when the output parameters of the source are not stabilized, the command is made according to the value of the current in the primary module.

5.Feedback loop command:

- VCM - pulse control is performed according to the value of the amplitude of the output voltage or voltages
- CCM - command is based on source output current or drain/collector-transformer/coil current if operating in open loop.

3. CURRENT STATE OF SWITCHING POWER SUPPLIES

3.1. Introduction

In modern electronics, power supplies use a high-frequency transformer, with a material called ferrite in the composition of the magnetic circuit, to transmit the electrical power from the primary module to the secondary module. The transformer provides galvanic separation between the primary and secondary side of the power supply.

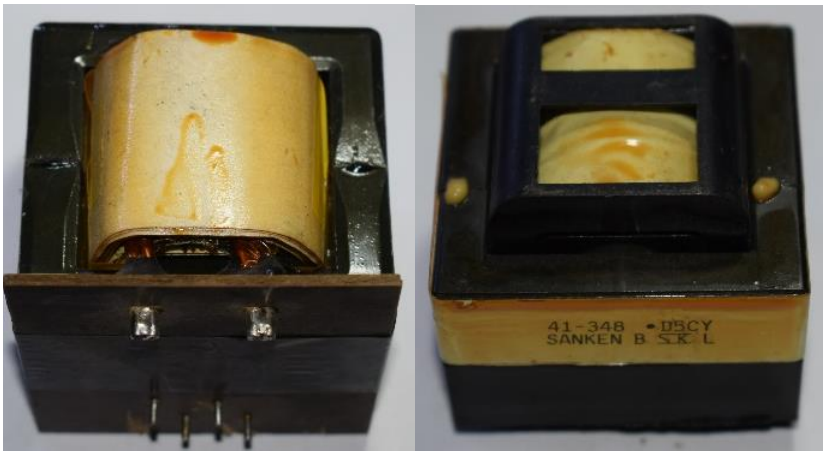


Fig. 3.1 Power transformers used in Full-Bridge and Flyback topology

Closing the reaction loop is achieved through two ways of transmission:

- Optical - analog using an optocoupler composed of an LED diode on the secondary side, and a bipolar transistor on the primary side. In most cases this is controlled by a controlled Zenner diode (TL431)

Fig. 3.2 EL817 optocoupler

- digital using an optocoupler that is composed of an emission LED, powered by the secondary module of the source and a transistor that can control an operational amplifier with class AB amplifier at the output, or can control a circuit that has an integrated hysteresis loop.

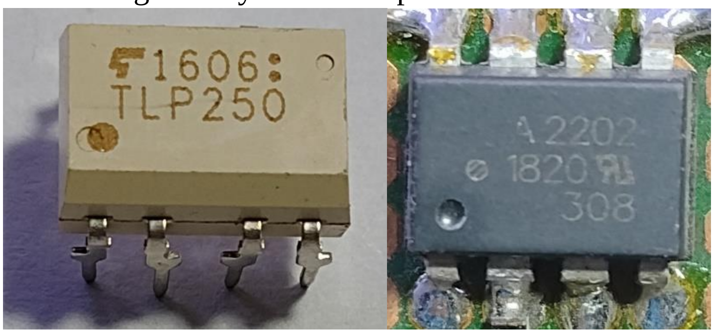


Fig. 3.3 Digital optocouplers

- Inductive - using a pulse transformer Fig.2.26 having the magnetic circuit composed of a ferrite core, it can transmit the control pulses from the secondary to the primary, or it can directly feed the power transistors Fig.2.26, in this case it is necessary to implement a power sources in separate switching with the role of keeping the control circuit in the secondary powered.

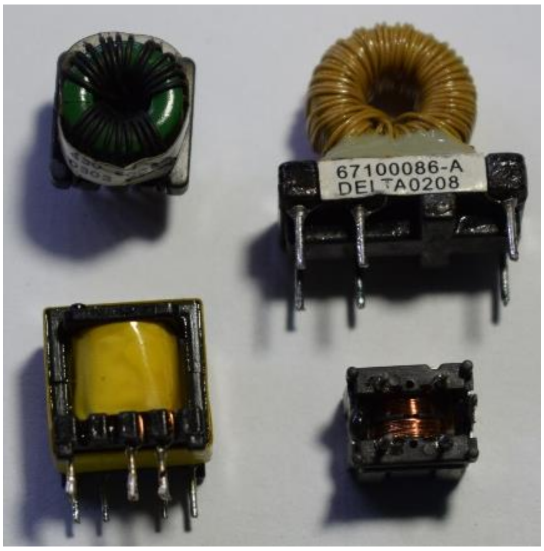


Fig. 3.4 Pulse transformers used to close the feedback loop or control power transistors

3.2. Proposed solutions

To make the power supply more efficient, reducing the physical dimensions, I propose replacing the power transformer Fig.3.1 with:

-Inductive coupling-transformer without magnetic circuit made of ferrite, this being made on the PCB path of the printed circuit using several layers of the PCB circuit, or making two coils (coil for primary and coil for secondary) glued on the layer of PCB.

- Capacitive coupling - using the capacitance formed between the copper layers of the PCB, to transmit the electrical power to the secondary module.

To reduce the response time of the feedback loop, I suggest replacing the optocoupler and ferrite core transformer with:

-Inductive coupling - closing the digital feedback loop by means of two coils built on the circuit's PCB path, top and bottom.

- Capacitive coupling - the closing of the digital feedback loop is achieved by means of two capacitors made from the circuit's PCB path, the pertinax having the role of dielectric and insulating material, the material from which the PCB board is built.

4. OPTIMIZATION CONSIDERATIONS FOR SWITCHING POWER SUPPLIES

To optimize power supply dimensions, manufacturing costs, stand-by efficiency, and variable load response, I propose **four design changes:**

4.1. Modification 1 - Inductive couplings replacing the power transformer

Replacing the ferrite core high frequency transformer with an inductive coupling made from coils made from the multilayer PCB circuit trace.

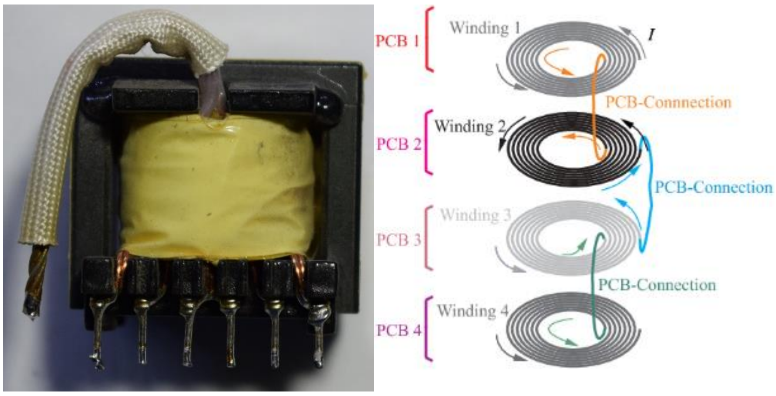


Fig. 4.1 Replacing the transformer with WPT coils [7]

In Fig.4.1 is represented the power transformer from a switching power supply, and the 3D design of the coils made on the PCB circuit, coils that replace the transformer.

4.2. Modification 2 - Capacitive couplings replacing the power transformer

In the case of switching power supplies with galvanic separation of very low powers, of the order of 1-10W, the power transformer with a ferrite core can be replaced with a capacitive coupling, made from the copper layers of the PCB printed circuit.

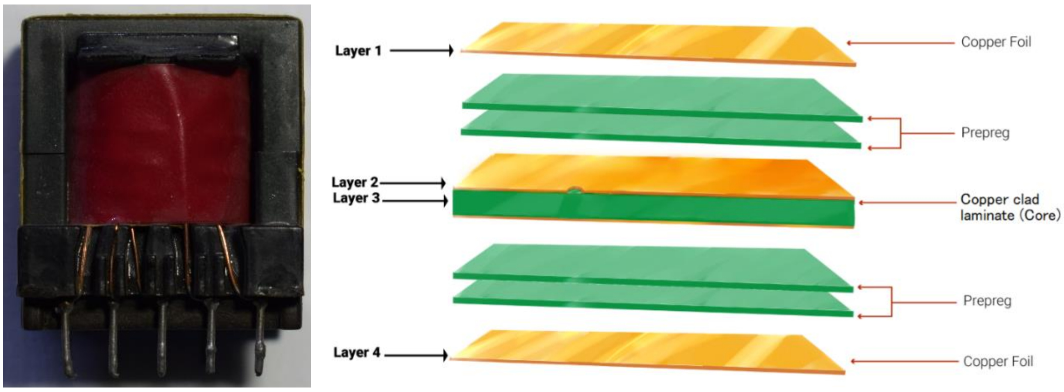


Fig. 4.2 Replacing the transformer with capacitive couplings made from the PCB route [8]

Fig.4.2 shows the power transformer from a switching power supply and the 3D section of a PCB printed circuit. The capacitance formed between the copper layers of the PCB circuit ensures the transmission of electrical power from the primary module to the secondary module.

4.3. Modification 3 - Inductive couplings used in the feedback loop

To improve the response of the feedback loop, in the case of power supplies with galvanic separation, I propose replacing the optocoupler and the pulse transformer with an inductive coupling made of two coils arranged on the top and bottom, on the PCB printed circuit. Thus we can provide galvanic separation, we can improve the response of the feedback loop, all at a low cost.

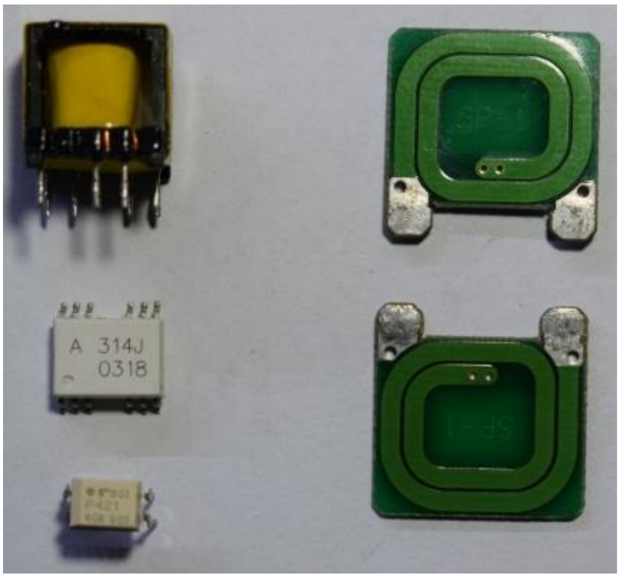


Fig. 4.3 Replacing the optocoupler and pulse transformer with WPT coils

In Fig.4.3 you can see the commonly used transmission elements, in this case the pulse transformer, the digital optocoupler and the analog optocoupler. Frequency response is much better with WPT coil couplers.

4.4. Modification 4 - Capacitive couplings used in the feedback loop

In order to improve the feedback loop response and reduce production costs in galvanically isolated and closed-loop switching power supplies, I propose replacing the inductive coupling consisting of a ferrite-core pulse transformer and the optical coupling made by an optocoupler, with a capacitive coupling made of two capacitors formed on the PCB printed circuit path.

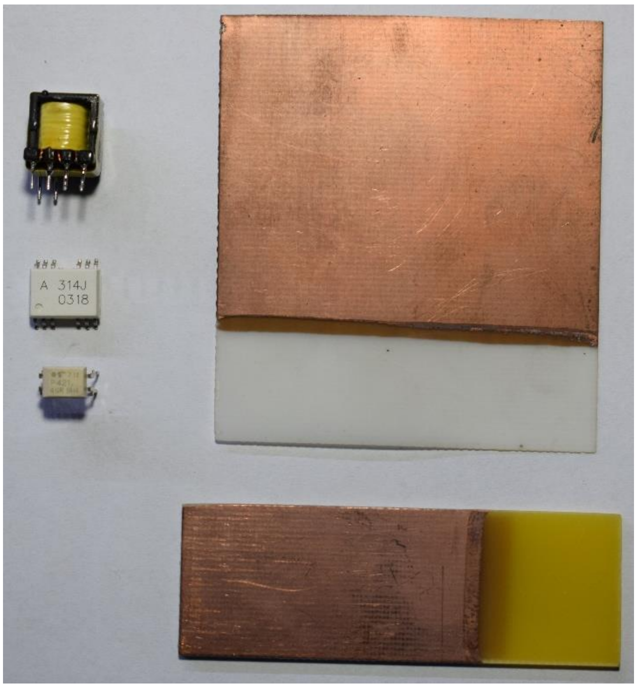


Fig. 4.4 Replacing the pulse transformer and the optocoupler with a capacitive coupling

In Fig.4.4 you can see the optical couplings through the two optocouplers, the inductive coupling through the pulse transformer and the capacitive coupling formed by the two copper layers arranged on the printed circuit PCB path. One can distinguish the dielectric of the capacitive coupling, made of pertinax.

4.5. ConCluSIonS

Following the laboratory experiments carried out, I can say that these couplings represent a viable solution in the construction of switching power supplies with galvanic separation.

To demonstrate the functionality of the above, the design, mathematical calculation, simulation and physical realization of four switching power supplies are carried out, using the design changes presented.

5. CONSTRUCTION OF A SWITCHING POWER SUPPLY, HALF-BRIDGE TOPOLOGY USING INDUCTIVE COUPLING, WITH OPEN FEEDBACK

5.1. Introduction

The designed electronic module aims to demonstrate the functionality of a switching power supply using the Half-Bridge topology, having the power transformer with a ferrite core, replaced by an inductive coupling made of coils arranged on the copper tracks of the PCB circuit.

The circuit provides galvanic isolation between the primary power supply module and the secondary output module.

5.2. Block diagram

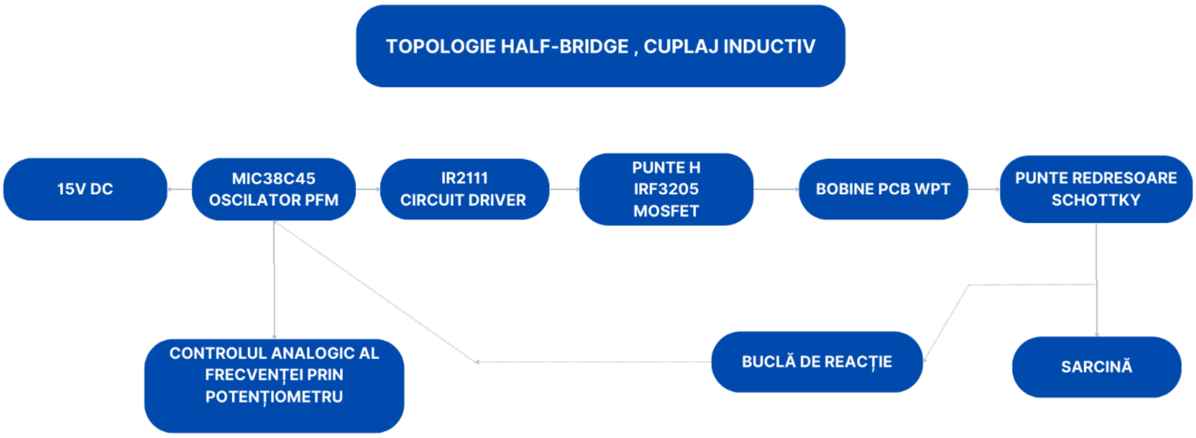


Fig. 5.1 Block diagram of the Half-Bridge topology switching power supply through inductive coupling

The module is supplied with a continuous voltage of 15V, this voltage supplies the oscillator circuit, the driver circuit and the H-bridge. The oscillator circuit is MIC38C45, it normally generates a rectangular signal, with fixed frequency and variable fill factor, the pulses transmitted to the output being current controlled. In the present case, the power supply is controlled by varying the frequency, PFM, and for this I had to make changes in the basic schematic to make the circuit work with 50% duty factor and variable frequency. Shown in the block diagram is the dotted line and the feedback loop, which would have replaced the analog potentiometer frequency control.

In order to have a control of the experiments both during the simulations and in the case of the practical experiments, the closed control through the reaction loop was abandoned, and an analog potentiometer was connected, the source operating in the open loop regime.

The signal generated by the oscillator circuit is transmitted to the IR2111 driver circuit. It is composed of one input and two outputs. The input is connected to the signal generator, and the two outputs to the MOSFET power transistors. The driver circuit has the role of maintaining the control voltage and ensuring a sufficiently high current in the transistor grid, especially in the case of inductive loads, such as the planar coil. Providing a large drive current results in a much shorter signal rise and fall time. It also acts as an inverting logic gate, while also introducing a dead time between the output signals.

The H-bridge is composed of two branches, the first branch is a capacitive divider that divides the supply voltage into two, the other branch is composed of two IRF3205 MOSFET semiconductor elements.

Transmission of electrical power and galvanic separation between primary and secondary is achieved through an inductive coupling. In the research carried out both in calculations and simulations and in the physical realization of the module, four coils were used, two for the primary and two for the secondary.

6. CONSTRUCTION OF A SWITCHING POWER SUPPLY, HALF-BRIDGE TOPOLOGY USING CAPACITIVE COUPLING, WITH OPEN REACTION LOOP

6.1. Introduction

The switching power supply aims to replace inductive coupling using pulse transformers by capacitive coupling using capacitances made with the help of the circuit PCB trace.

Due to the reduced capacities obtained through the PCB route, the power supply is suitable experimentally, for maximum powers of 10W. The research aims to find a capacitive coupling, of small dimensions, with low costs, and made of the same material as, which is made of the electronic module, so that it can be adapted and integrated much more easily.

6.2. Block diagram

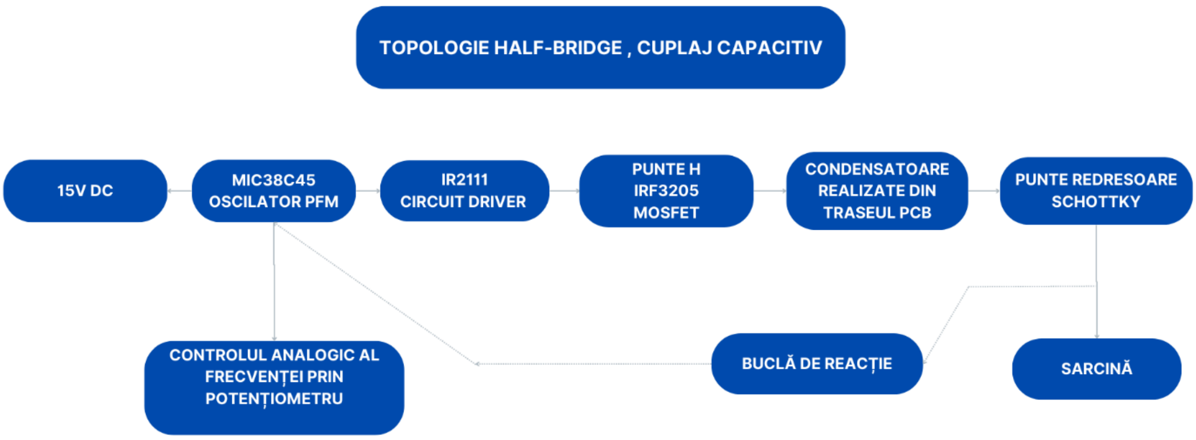


Fig. 6.1 Block diagram of switching power supply using capacitive coupling

The power supply is made with the voltage of 15V DC, it is composed of an oscillator circuit, a driver circuit and a semi-controlled bridge H. These control modules were presented in detail in (subchapters 5.3; 5.4; 5.5).

Experimentally, at the output of the H-bridge, two series CPT circuits are connected in turn, formed by capacitances made from two different PCB circuits.

Also (chapter 5), in order to have a control of the output load, the reaction loop was separated, the source operating in open loop mode. To ensure maximum power transfer, the oscillator frequency was set to the resonant frequency for each experimental circuit connected to the H-bridge.

7. CONSTRUCTION OF A SWITCHING POWER SUPPLY, FLYBACK TOPOLOGY, WITH CLOSED FEEDBACK LOOP, CLOSING THE FEEDBACK LOOP BY INDUCTIVE COUPLING

7.1. Introduction

In order to demonstrate the functionality of a feedback loop through inductive coupling, using coils made from the PCB route of the printed circuit, I propose the realization, for research purposes, of a switching power supply using Flyback topology (subchapter 2.4.1) with galvanic isolation between the primary module and the secondary module. The research includes the design of the electronic scheme of the source, the simulation on modules of the scheme, the physical realization of the power source, and the retrieval of the results obtained in the laboratory, during the various tests.

The aim of the research is to:

- increases the reliability of switching power supplies, by eliminating the optical coupling used in most power supplies, we no longer need to keep the LED on inside the optocoupler, the inductive coupling consuming less electricity, if it is sized correctly.
- reduce production cost by making the feedback loop coupling coils on the PCB path, replacing the optocoupler
- reduces the variation of the output voltage with temperature, the optocoupler being an element sensitive to temperature variations and controlled in current, it can show large variations in the parameters of the reaction loop
- reduces the power consumed in idle mode, by using the sleep function of the Driver circuit

7.2. Block diagram

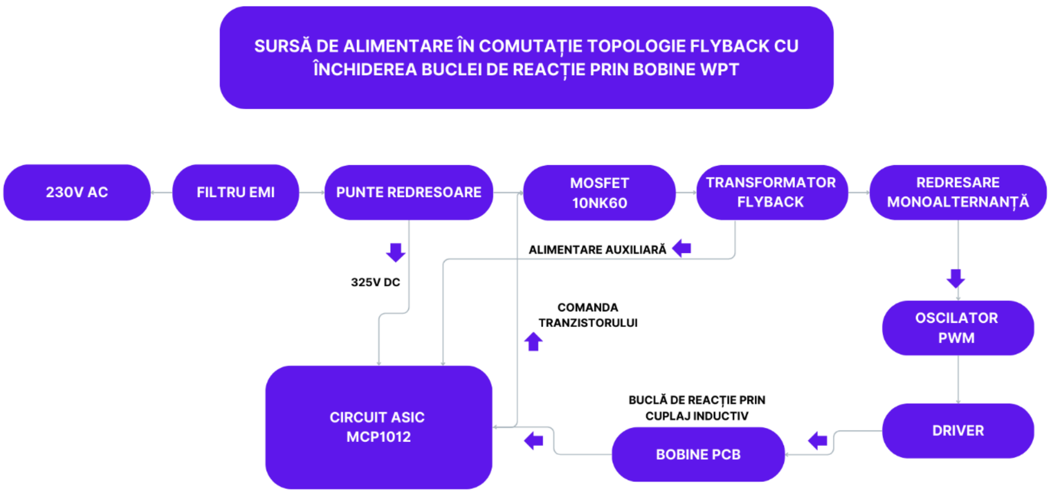


Fig. 7.1 Block diagram of Flyback switching power supply, with feedback loop closure by inductive coupling

The source is fed from the national grid, with a voltage of 230V AC, the voltage initially enters a common mode filter, for cutting high frequencies. From the filter the voltage reaches the rectifier bridge, which converts the alternating voltage into direct voltage of approximately 325V DC. The specialized circuit is fed directly with this high voltage, being necessary in sleep mode.

The circuit in the primary controls the pulses sent to the MOSFET transistor, the transistor controlling the current in the primary winding of the ferrite core transformer. From the transformer through the secondary winding, monoalternating rectification is achieved with a fast diode, the output voltage being filtered through a low-pass filter, then transmitted to the PWM oscillator circuit in the secondary.

In the secondary module there is a PWM generator, it is the same circuit as in Fig.5.3, but the electronic scheme is different. A simple class AB amplifier with bipolar transistors is connected to the output of the circuit, which has the role of feeding the feedback loop circuit through inductive coupling.

The feedback loop works in digital mode, the control pulses being transmitted by the secondary circuit. For this reason, it is necessary for the circuit in the primary to charge the capacitors in the secondary at start-up in order for the circuit in the secondary to turn on and close the feedback loop. If this does not happen, the source will operate in open loop mode.

When the power supply is switched on, the source operates in open loop mode, the circuit in the primary having a built-in low-frequency LFO signal generator, with the role of charging the capacitors in the secondary and thus waking up the circuit in the secondary. After the wake-up time of the secondary circuit, the primary circuit receives the control pulses and automatically enters the inverting driver mode, the power supply operating at this moment in closed-loop mode.

8. CONSTRUCTION OF A SWITCHING POWER SUPPLY, FLYBACK TOPOLOGY, WITH CLOSED FEEDBACK LOOP, CLOSING THE FEEDBACK LOOP BY CAPACITIVE COUPLING

8.1. Introduction

Power sources use optical couplings through optocouplers or inductive couplings, using pulse transformers, to close the feedback loop. In order to increase the performance of switching power supplies, together with the reduction of the production cost, I propose to replace the inductive and optical couplings used to close the feedback loop, with a capacitive coupling made from the PCB wiring of the power supply and the copper layers that it incorporate.

Following the research carried out, I consider this coupling viable, and I propose the realization of a switching power source with galvanic separation and Flyback topology Fig.2.18, using a capacitive coupling to close the reaction loop.

8.2. Block diagram of power supply using capacitive coupling feedback loop closure

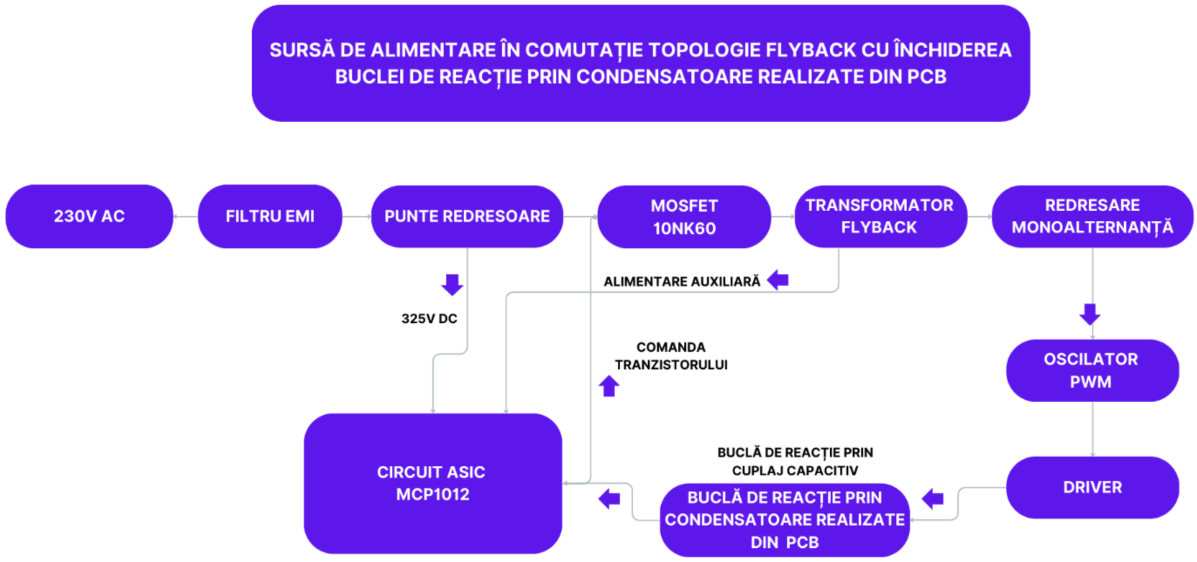


Fig. 8.1 Block diagram of switching power supply, Flyback topology, with feedback loop closure by capacitive coupling

The operation of the power supply is similar to the switching power supply shown in (chapter 7), except the internal block contains the feedback loop closure by capacitive coupling.

Capacitive coupling, like inductive coupling, works only with alternating component. The control of the reaction loop is realized from the secondary module with the help of the PWM generator.

8.3. Electronic schematic of capacitive coupling

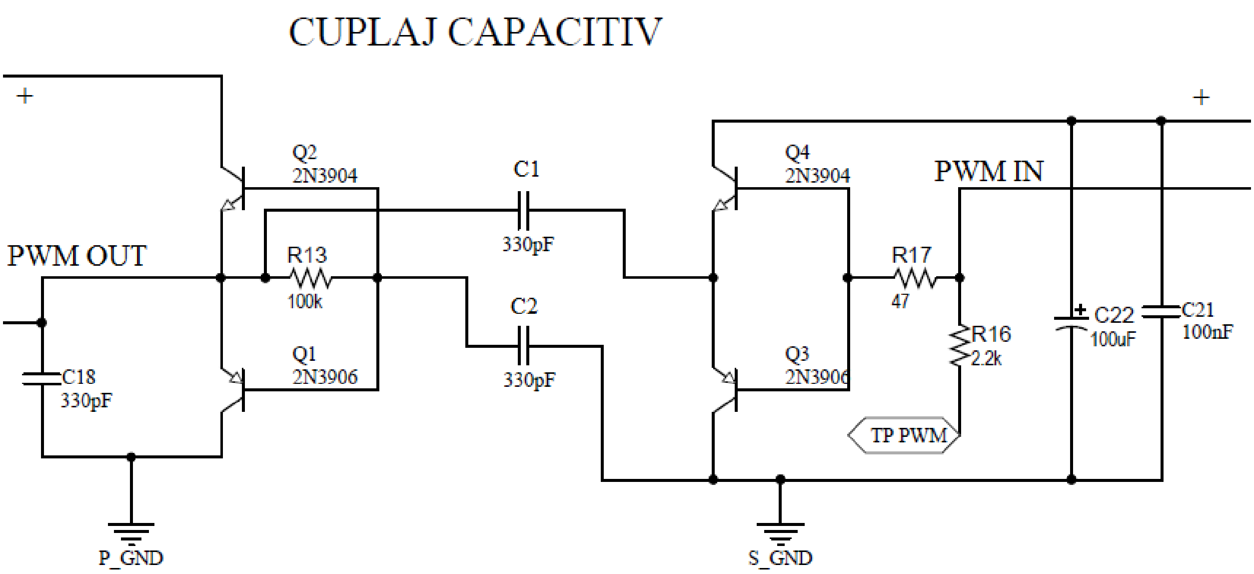


Fig. 8. 2 Electronic schematic of the capacitive coupling used to transmit the signal to the feedback loop

In the electronic scheme shown in Fig.8.2, the signal input to the block is made from the right, through the PWM IN connection, and the signal output to the driver circuit in the primary is made through PWM OUT. The signal enters resistor R17, which has the role of limiting the bias current, and not exceeding the limits of the static operating point of the bipolar transistors.

In order to be able to measure the signal with the oscilloscope, a resistor is connected from the signal branch with the role of short circuit protection during measurements, the oscilloscope presenting high input impedance, of the order of MΩ, a resistor with the value of 2.2kΩ will not affect the read signal . The measuring probe is connected to the point (TP PWM).

The circuit is powered by the + terminal, and to ensure voltage stability, both at low frequencies and at high frequencies, two capacitors, C22 and C21, are connected on the power supply branch, close to the bipolar transistors, as capacitors of bypass.

The amplified output signal from the bipolar transistors is then transmitted through two capacitive couplings C1 and C2, to the circuit in the primary. The circuit takes the transmitted signal and amplifies it using two bipolar transistors forming a class AB amplifier. Parallel to the received signal, R13 is connected with the role of signal adaptation. On the physically realized, experimental module, this resistor is a trimmer.

The amplified signal is transmitted to the driver circuit through capacitor C18, it has the role of maintaining the voltage at the terminals throughout the $T_{ON\ period}$ of the MOSFET power transistor. The circuit presents in the input pin, the PULSE pin Fig.7.4, a high input impedance, which does not discharge the capacitor and maintains the positive voltage during the conduction period.

9. FINAL CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

9.1. GENERAL CONCLUSIONS

Power supplies are used in almost every electronic equipment, they are almost indispensable when it comes to equipment that connects to the national grid, for this reason, their development must represent a continuous process.

The main idea of the research in the doctoral thesis starts from the need to develop switching power supplies with the best possible performance, costs and characteristics. The experience gained from the design of power supplies, the passion for this field and the research carried out, are transposed in the work of research through the development of the four types of couplings that bring beneficial changes in the construction of various topologies of switching power supplies.

During the research stages, some problems were encountered, especially during the physical realizations of the modules powered by high voltages, because any error, or any experiment done wrong, will automatically lead to the irreparable destruction of the components, especially in the primary module. But to achieve satisfactory and notable results, research must go through failure and continue.

In the case of research on inductive couplings, which replace the transformer with a ferrite core, I believe that the results obtained represent an important step in the development of power sources. The possibility of eliminating the ferrite core offers the advantages of making power modules with much lower costs, much lower weights and better response time. Removing the ferrite core will also remove noise in the audio frequency range.

Following the research carried out, the replacement of the power transformer with capacities made of PCB modules, are suitable where there is sufficient space for the power supply module, and the nominal power required by the load does not exceed the value of 10W, such as an application with LEDs, a signaling module, or powering a switch.

The two ways of closing the feedback loop through inductive and capacitive couplings offer a wide range of advantages in the development of future power supplies with galvanic separation. Energy advantages, the feedback loop consumes a lower amount of energy than the classic optocoupler coupling. The operating frequency is much better, which translates into shorter conduction and blocking switching times. Safety in operation, in the case of the optocoupler, it can fail, especially in the case of working environments with high temperatures, capacitive or inductive couplings being much more resistant in these environments.

I believe that from the research carried out I can derive power supply projects with improved general characteristics.

9.2. ORIGINAL CONTRIBUTIONS

The contributions made in the field of switching power supplies can be summarized as follows:

- In the first chapter, a brief presentation of the problems with reference to switching power supplies was made. Their main topologies were briefly presented in chapter two, where both galvanically isolated and non-isolated power supplies were included. For these, the basic electronic diagram was made and the principle of operation was explained for each individual topology;
- In the second chapter, the most common switching power supply topologies with galvanic isolation and closed feedback loop were presented. All the presented topologies use one or more feedback loops, and the experiments presented in the thesis, regarding the closing of the feedback loop by inductive or capacitive coupling can replace the usual version by optocoupler or impulse transformer;
- In chapter 3, a simulation of the three types of couplings, optical, inductive, and capacitive, was carried out, and the statements made were demonstrated with the help of laboratory experimental results.
- In chapter 4, the solutions that come to the aid of the previously presented problems were presented.
- In chapters 5, 6, 7, and 8, I can say that for each new, verified research idea, an experimental module was made, these modules are arranged separately in the four chapters. Within each individual module of the four chapters, the electronic scheme was designed, calculations were made for the correct dimensioning of the

components, and computer-assisted simulation was used to validate the values and principles used. After the validation of the results, it was moved to the physical realization on different modules, to confirm the results obtained up to this point. After the realization of the modules, on the breadboard, circuits in the air, it was moved to the stage of designing the final module, by assembling the previously experimentally verified modules. After the physical realization, the experimental determinations were made, then the areas where the results can be better were identified. After completing the research, they were translated into the present thesis.

The original contribution made in the doctoral thesis consists in: the design, simulation, construction and testing (using various tasks) of switching power supplies using inductive and capacitive couplings both on the electric power transmission branch and on the signal transmission branch command.

The main original contributions made by the author in the thesis are:

- ✓ Ensuring galvanic separation from the feedback loop using inductive and capacitive couplings in the area of switching power supplies, by replacing the optical coupling or impulse transformer with WPT or CPT circuits.
- ✓ Improving response time within the feedback loop through capacitive and inductive couplings.
- ✓ Reduction of electricity consumption when the switching power supply is in stand-by mode.
- ✓ Implementation and simulation of the sleep regime in the case of the oscillator circuit in the primary.
- ✓ Reduction in voltage output ripple, reduction due to much better response time of the feedback loop, in the case of switching power supplies using flyback topology.
- ✓ Replacing the magnetic circuit made of ferrite with a WPT coupling, offering reduced dimensions compared to the pulse transformer.
- ✓ Replacing the magnetic circuit made of ferrite with a CPT coupling, this was done using the module's PCB trace.
- ✓ Simulation of capacitive couplings, their analysis and experimentation, for a frequency band included in the working range of switching sources.
- ✓ Simulation of inductive couplings, their analysis and experimentation, for a frequency band included in the working range of switching sources.
- ✓ Analysis of capacitive and inductive couplings (art. 7), analysis of response times of the reaction loop.
- ✓ Analysis of semiconductor elements (art. 8), the effect of C_{GS}, C_{GD} (Miller) capacity on the driver circuit, the behavior of ultrafast diodes in the rectification circuit in the secondary.
- ✓ The behavior of the driver circuit in the primary module, operating in PWM mode, respectively the analysis of the reaction loop when the source is in no-load mode, respectively Dc-0.3%
- ✓ The experimental behavior of the reaction loops using the test mode , the signal generation being carried out by a bench oscillator.

- ✓ Analysis of output voltage variation with temperature using the two couplings, inductive and capacitive.
- ✓ Experimental realization of a switching power supply using flyback topology, using PWM, with galvanic isolation using capacitive coupling CPT to close the feedback loop.
- ✓ Experimental realization of a switching power supply using flyback topology, by PWM control, with galvanic isolation using WPT inductive coupling to close the feedback loop.
- ✓ Experimental realization of a switching power supply using half-bridge topology, using PFM, with galvanic separation using capacitive coupling for the transmission of electrical power.
- ✓ The response of the power supply using half-bridge via capacitive coupling CPT in the case of operation in the resonant regime.
- ✓ Experimental realization of a switching power supply using half-bridge topology, using PFM, with galvanic separation using inductive coupling for the transmission of electrical power.
- ✓ Analysis of the response to variable resistive loads of flyback and half-bridge sources.
- ✓ The variation of Dc, and the behavior of the command signal, was analyzed using a supply voltage range of 80-250V AC, the variation being made with the help of an autotransformer, for the flyback topology.

9.3. PROSPECTS FOR FUTURE DEVELOPMENT

From the research done, many other switching power supply configurations can be derived. Power supplies can be created using inductive or capacitive couplings, both for transmitting power and for transmitting feedback signals. Due to the couplings made, communication signals (such as sleep input signals of the primary module) can be transmitted through the power cable with coaxial, using only the power wire and the GND plane, a signal can be transmitted with, alternative component .

Due to the elimination of the ferrite magnetic core, mechanically flexible power supplies can be made, where the components are part of the SMD technology, together with the inductive or capacitive couplings to be glued and made of flexible foil.

The implementation of much faster protections in the module from the secondary, given the fact that in the research carried out, the pulse command is carried out from the secondary module, from here we can deduce that the overcurrent or overvoltage protection is much faster, as well as the actuation time.

The design of a power supply has begun by integrating the two sources presented in chapters 5 and 7, thus we can create an inductive coupling made from the PCB route, both for signal transmission and for electrical power transmission.

10. BIBLIOGRAPHY

[1] https://www.onsemi.com/ Switch mode power supply reference manual, SMPSRM/D Rev. 3, Jul-2002
[2] Linear Technology, LTC1871 Wide Input Range, No Rsense Current Mode Boost, Flyback and SEPIC Controller, 2001
[3] *YILMAZ, Mehmet & CORAPSİZ, Muhammedfatih & Çorapsız, M. Resit. (2020).* Voltage Control of Cuk Converter with PI and Fuzzy Logic Controller in Continuous Current Mode. Balkan Journal of Electrical and Computer Engineering. 127-134. 10.17694/bajece.660025.
[4] *Li, Xiaodong & Bhat, Ashoka.* (2014). A Fixed-frequency Series-parallel Resonant Converter with Capacitive Output Filter: Analysis, Design, Simulation, and Experimental Results. Electric Power Components and Systems. 42. 10.1080/15325008.2014.890975.
[5] *Han, J.-H.; Lim , Y.-C.* Design of an LLC Resonant Converter for Driving Multiple LED Lights Using Current Balancing of Capacitor and Transformer. Energies 2015, 8, 2125-2144. https://doi.org/10.3390/en8032125
[6] https://docs.broadcom.com/doc/Very-High-CMR-Wide-VCC-Logic-Gate-Optocouplers-DS
[7] *I. Lope, C. Carretero, J. Acero, JM Burdio and R. Alonso* , "Printed circuit board implementation of small inductors for domestic induction heating applications using a planar litz wire structure," 2013 Twenty-Eighth Annual IEEE Applied Power Electronics Conference and Exposition (APEC), Long Beach, CA, USA, 2013, pp. 2402-2407, doi: 10.1109/APEC.2013.6520632.
[8] https://www.protoexpress.com/blog/build-multilayer-pcb-stack-up/
[9] https://webench.ti.com/wb5/LDC/#/spirals
[10] https://ww1.microchip.com/downloads/aemDocuments/documents/APID/ProductDocuments/DataSheets/MIC38C42-43-44-45-BiCMOS-Current-Mode-PWM-Controllers-DS20006436B.pdf
[11] https://www.infineon.com/dgdl/Infineon-IR2111-DS-v01_00-EN.pdf?fileId=5546d462533600a4015355c810e51682
[12] *David Maier and Normen Lucht and Alexander Enssle and Anna Lusiewicz and Julian Marius Fischer and UrsPecha* Numerical Simulation of PCB-Coil-Layouts for Inductive Energy Transfer Systems https://api.semanticscholar.org/CorpusID:173169074
[13] https://www.we-online.com/components/products/datasheet/760308111.pdf
[14] https://ww1.microchip.com/downloads/aemDocuments/documents/APID/ProductDocuments/DataSheets/MCP1012PrimarySideStart-UpICforIsolatedConverters20006277B.pdf
[15] https://www.microchip.com/en-us/tools-resources/develop/analog-development-tool-ecosystem/mplab-mindi-analog-simulator
[16] *Marius Voinea* , Research on the testing and simulation of emissions produced by narrowband electrical signals, PhD Thesis, Politehnica University of Bucharest, 2018.
[17] *Teodor-Cătălin Bibirică* , Contributions regarding the realization of an intelligent battery management system for electric vehicles, Doctoral Thesis, Politehnica University of Bucharest, 2019.
[18] *Marius Florin Stăniloiu* , Contributions regarding the simulation of complex nonlinear circuits, Politehnica University of Bucharest, 2023.
[19] *Lucian – Vasile Ene* , Contributions regarding the wireless transfer of electromagnetic energy to electric cars , Doctoral Thesis, Politehnica University of Bucharest, 2021.
[20] *Clayton R. Paul* , "Introduction to Electromagnetic Compatibility" (2006) Second Edition.
[21] *Khambhadiya, Hardik & Kapil, Pattath* . (2015). Design and implementation of the SMPS for IGBT Driver.
[22] *Muhammad H. Rashid, Dariusz Czarkwosky (* 2001) - Power Electronics Handbook,.
[23] *Robert W. Erickson* , *Dragan Maksimovic* (2001)- Fundamentals of Power Electronics, Second edition.

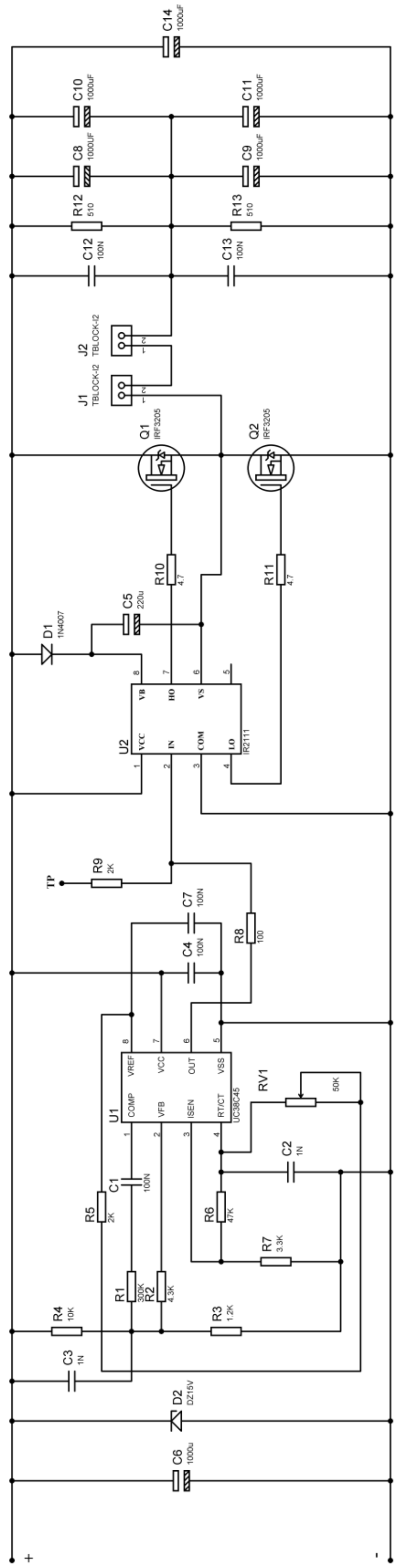
[24] *Ned Mohan, Tore M. Undeland , William P.Robbins* – Power Electronics: Converters, Applications, and Design – Wiley.
[25] *Mohan, N., TM Undeland, and WP Robbins* , Power Electronics, Converters, Applications, and Design, 2nd Edition, John Wiley & Sons, Inc., New York, 1995;
[26] *Chiola, Davide & Griebl, Erich & Husken, Holger* . (2013). Fast IGBT and diode technologies achieve platinum efficiency standard in commercial SMPS applications.
[27] *Brown, Marty* , Practical Switching Power Supply Design, IWO. San Diego. California 92101-4495. USA, ISBN 0-12-137030-5.
[28] *Nicolae, PM, Griva, GB, Voinea, M.,* Low Power Generating System, Simulation and Analysis, Annals of the University of Craiova, Electrical engineering series, No. 34, 2010; pp. 97-102; ISSN: 1842-4805 (Index Copernicus database – Master Journal List).
[29] *Marius VOINEA, Mihai IORDACHE* , "Transmition Lines and Square Wave Signal Integrity Analysis", Proceedings of the The 9th International Conference Electronics, Computers and Artificial Intelligence, 29 June-1 July 2017, Târgoviste, ROMANIA, IEEE Xplore: 07 December 2017, DOI: 10.1109/ECAI.2017.8166399 , Publisher: IEEE. pp. 1-5.
[30] *Ioana – Gabriela Sîrbu, M. Voinea, M. Iordache* , "The Circuit Analysis of a Step-Down DC-DC Converter under Ideal and Real Passive Components Assumption", IEEE Xplore, Print ISBN: 978-1-4673- 1809-9, INSPEC Accession Number: 14432811, Digital Object Identifier (DOI): 10.1109/ICATE.2014.6972595 , Page(s): 11 – 16.
[31] *Christophe P Basso* , Switch-Mode Power Supplies - SPICE Simulations and Practical Designs, 1st ed. New York, US: The McGraw-Hill Companies, Inc., 2008.
[32] *Nicolae, PM, Voinea, M.,* Modeling and Simulation of Electromagnetic Conducted Emissions from Buck Converter with Resistive Load – 25-27 Oct. 2012 International Conference on Applied and Theoretical Electricity (ICATE).
[33] *Petre-Marian NICOLAE* , Marius VOINEA, Simulation And Analysis Of Emissions From A Switched Mode Power Supply And Methods Of Reducing Their, The 8th International Workshop Of Electromagnetic Compatibility Sibiu, ROMANIA, September, 27 – 29, 2012.
[34] *Mihaela Grib, Ionela Vlad, **OD Lăudatu** , AR Grib, M. Iordache* , Hybrid Equivalent Circuit Generation, Carpathian Journal of Electrical Engineering, vol. 15, no. 1, pp. 81-93, 2021.
[35] *M. Grib, M. Iordache, AR Grib, H. Popescu, **O. Laudatu** and M. Staniloiu* , "The Use of Thévenin, Norton and Hybrid Equivalent Circuits in The Analysis and Polarization of Nonlinear Analog Circuits," 2022 International Conference and Exposition on Electrical And Power Engineering (EPE), Iasi, Romania, 2022, pp. 198-207, doi: 10.1109/EPE56121.2022.9959871.
[36] ***O. Laudatu** , M. Iordache, M. Stanculescu, L. Bobaru, D. Niculae and O. Drosu* , "Wireless Power Transmission System Design. A Practical Approach." 2023 13th International Symposium on Advanced Topics in Electrical Engineering (ATEE), Bucharest, Romania, 2023, pp. 1-4, doi: 10.1109/ATEE58038.2023.10108155.
[37] *D. Niculae, M. Iordache, L. Bobaru, M. Stănculescu, M. Grib and **O. Laudatu*** , "Adapting the Impedance of The Signal Transmission Lines," 2023 10th International Conference on Modern Power Systems (MPS), Cluj-Napoca, Romania, 2023, pp. 01-05, doi: 10.1109/MPS58874.2023.10187513.
[38] ***O. Lăudatu** , M. Iordache, M. Stănculescu, L. Bobaru, D. Niculae and E. Cazacu,* "Loop Closing of Flyback Switching Power Supply Using Capacitive Coupling," 2023 International Conference on Electromechanical and Energy Systems (SIELMEN), Craiova, Romania, 2023, pp. 1-6, doi: 10.1109/SIELMEN59038.2023.10290757
[39] ***Ovidiu Lăudatu,** Mihai Iordache* , " Comparison of Inductive and Capacitive Couplings Used to Close the Feedback Loop Used in Switch Mode Power Supplies ", Rev. Roum. Sci. Techn.– Électrotechn. et Énerg., Vol. **68** , 4, DOI: https://doi.org/10.59277/RRST-EE.2023.4 , **WOS:001126934500008,** Bucarest, 2023, Published: 14.12.2023. pp. 363–368.

[40] ***Ovidiu Lăudatu*** , *Drago ş Niculae, Mihai Iordache, Maria – Lavinia Bobaru, Marilena Stănculescu* , " Experimental Analysis of Power Semiconductor Elements Used in Flyback Converters ", Rev. Roum. Sci. Techn.– Électrotechn. et Énerg., Vol. 69 No .1 (2024): RRST-EE , 1, https://doi.org/10.59277/RRST-EE.2024.1.12 , **WOS:001198252400013,** Bucarest, 2024, Published: 04.04.2024. pp. 67–72.
[41] ***O. Lăudatu*** *, M. Iordache, M. Stănculescu, D. Niculae, L. Bobaru and O. Drosu* , "Loop Closing of Flyback Switching Power Supply Using Inductive Coupling. Practical Study," 2023 10th International Conference on Modern Power Systems (MPS), Cluj-Napoca, Romania, 2023, pp. 01-04, doi: 10.1109/MPS58874.2023.10187546.
[42] *Niculae, Dragos & Iordache, Mihai & Bobaru, Lavinia & Stanculescu, Marilena & Drosu, Oana & Moscu, Anton.* (2023). Dedicated Analog Circuit Simulation Programs. 1-6. 10.1109/SIELMEN59038.2023.10290763.
[43] *Bobaru, Lavinia & Niculae, Dragos & Georgiana, Rezmerita & Stanculescu, Marilena & Iordache, Mihai & Drosu, Oana & Deleanu, Sorin.* (2023). Factors Influencing the Optimization of Magnetically Coupled Coil Structures-Analysis and Discussions.
[44] *Staniloiu, Marius & Popescu, Horatiu-Samir & Iordache, Mihai* . (2023). SPICE model of an "n" channel MOSFET transistor.
[45] *Iordache Mihai, Stanculescu Marilena, Andrei Paul, Bobaru Lavinia, Andrei Horia, Diaconu Emil, Cobianu Cosmin, Caciula Ion, Niculae Dragos* . (2023). Equivalent Models of Nonlinear Circuit Elements in Nonsinusoidal Regime.
[46] *Popescu, Horatiu-Samir & Staniloiu, Marius & Iordache, Mihai.* (2023). A method for extracting the main parameters of a NPN bipolar transistor from datasheet for use in the SPICE model.
[47] *Iordache, Mihai & Stanculescu, Marilena & Asanache, Razvan & Bobaru, Lavinia & Deleanu, Sorin & Niculae, Dragos & Georgiana, Rezmerita.* (2023). Analog circuit analysis using S-parameters and Smith chart.
[48] *Iordache, Mihai & Stanculescu, Marilena & Niculae, Dragos & Bobaru, Lavinia & Deleanu, Sorin & Drosu, Oana.* (2022). Wireless Power Transfer Systems Optimization. 10.1109/EPE56121.2022.9959759.
[49] *Iordache, Mihai & Dumitriu, Lucia & Niculae, Dragos & Zainea, Georgiana.* (2022). Power Transfer by Magnetic Induction Studied by Coupled Mode Theory. 10.1201/9781003340065-1.
[50] *Iordache, Mihai & Dumitriu, Lucia & Niculae, Dragos* . (2022). Power Transfer by Magnetic Induction Using Coupled-Mode Theory. 10.1201/9781003340072-1.
[51] *Niculae, Dragoș & Stanculescu, Marilena & Deleanu, Sorin & Iordache, Mihai & Bobaru, Lavinia* . (2021). Wireless Power Transfer Systems Optimization Using Multiple Magnetic Couplings. Electronics. 2021. 1-16. 10.3390/electronics10202463.
[52] *Bucata, Victor & Iordache, Mihai & Ionela, Vlad & Orosanu, Alina & Popescu, Horatiu-Samir & Staniloiu, Marius.* (2021). Wireless Power Transfer Systems: Thévenin Equivalent Circuits for Parallel-Series and Parallel-Parallel Magnetic Resonator Configurations. 1-6. 10.1109/ICATE49685.2021.9464974.
[53] *Andrei, Horia & Iordache, Mihai & Andrei, Paul & Stanculescu, Marilena & Deleanu, Sorin & Bobaru, Lavinia.* (2021). Power and Energy Flow in Quasi-Stationary Electric and Magnetic Circuits. 10.1007/978-3-030-62191-9_24.
[54] *Constantin Sora* (1982) Basics of electrotechnics. Didactic and Pedagogical Publishing House.
[55] *Mihai Iordache,* Electrotechnical Basics, Matrix Rom Bucharest.
[56] *Mihai Iordache, Marilena Stanculescu, Lavinia Bobaru, Dragos Niculae, Sorin Deleanu, Victor Bucata* , Wireless transfer systems of electromagnetic energy, Matrix Rom Bucharest.
[57] *Lucia Dumitriu, Mihai Iordache,* Theory of electric circuits, Matrix Rom Bucharest.

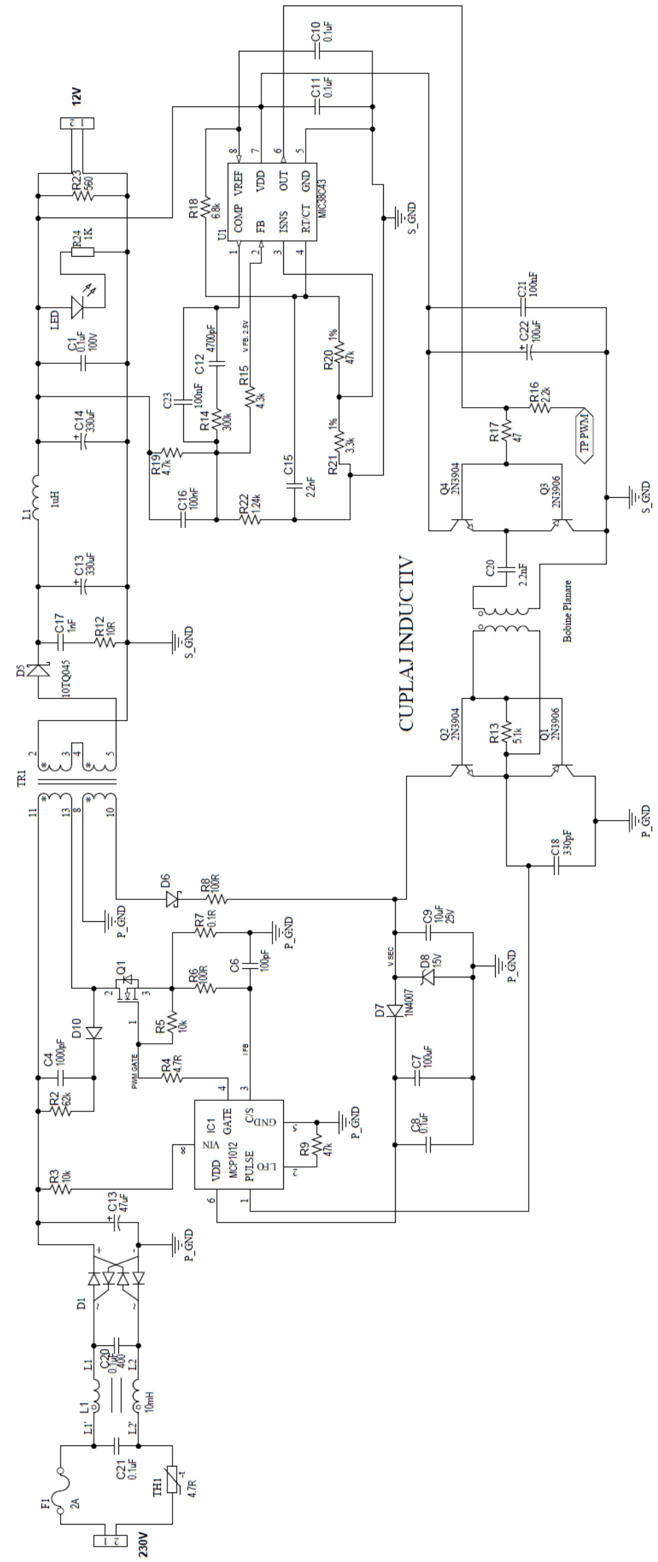
[58] *Mihai Iordache* , Special issues of electrical engineering, Matrix Rom Bucharest.
[59] *Mihai Iordache* , Dragos Niculae, Marilena Stanculescu, Lavinia Bobaru, Georgiana Rezmerita, The use of pathological parameters in the analysis of analog circuits, Matrix Rom Bucharest.
[60] *Wu, Zhaohui & Chen, Kangping & Li, Bin* . (2023). A High Crosstalk Suppression SiC MOSFET Gate Driver. Journal of Physics: Conference Series. 2584. 012071. 10.1088/1742-6596/2584/1/012071.
[61] *Dou, Sheng & Huang, Liansheng & Fu, P. & Chen, Xiaojiao & Zhang, Xiuqing & He, Shiying & Wang, Zejing & Yang, Jian* . (2024). Series Capacitance Gate Driver to Suppress Voltage Oscillation of SiC MOSFET. IEEE Journal of the Electron Devices Society. PP. 1-1. 10.1109/JEDS.2024.3349684.
[62] *Ma, Jiuxin & Liang, Yu & Ren, Lvheng & Xu, Wenbo & Ma, Jianhao & Dong, Shoulong & Yao, Chenguo.* (2023). Ultrafast Gate Driver With GaN HEMTs for ns-Pulse Generator Using SiC MOSFET. IEEE Transactions on Plasma Science. PP. 1-10. 10.1109/TPS.2023.3289868.
[63] *Choi, Hojong & Shung, K* . (2014). Crossed SMPS MOSFET-based protection circuit for high frequency ultrasound transceivers and transducers. Biomedical engineering online. 13. 76. 10.1186/1475-925X-13-76.
[64] *Lee, Dong-Hee* . (2017). Simple MOSFET gating delay scheme for SMPS start-up in the standby power reduction circuit. IET Power Electronics. 11. 10.1049/iet-pel.2016.0602.
[65] *Hastings, A..* (1995). Integrated MOSFET interface for a synchronously-rectified SMPS. Journal of Clinical Neuroscience - J CLIN NEUROSCI. 58 - 61. 10.1109/BIPOL.1995.493866.
[66] *Fauzi, Fijay & Zaidi, M & Udom, U & Abdul-Manaf, N. Azlian* . (2022). Switch Mode Power Supply (SMPS) Utilizing Flyback Converter Topology: Simulation and Experiment. Journal of Physics: Conference Series. 2312. 012050. 10.1088/1742-6596/2312/1/012050.
[67] *Jung, Jeesung & Huang, Alex.* (2009). Improved Breakdown-Voltage Complementary MOSFET in a 0.18 mu m Standard CMOS process for Switch Mode Power Supply (SMPS) applications. Proceedings of the International Symposium on Power Semiconductor Devices and ICs. 239 - 242. 10.1109/ISPSD.2009.5158046.
[68] *Banerjee, S. & Parthasarathy, Vijay & Manley, Martin* . (2010). Design of stable 700V lateral MOSFET for new generation, low-cost off-line SMPS. Proceedings of the International Symposium on Power Semiconductor Devices and ICs. 269 - 272.
[69] *Yadav, Prasad & Chavan, Akshay & Apte, A & Ponkshe, & Ospanova, A..* (2022). Design of Robust & Efficient SMPS for Charging of Lithium Ion Battery used in Electric Vehicle. International Journal of Innovative Research in Science Engineering and Technology. 11. 3815-3819. 10.15680/IJIRSET.2022.1104061.
[70] *Ye, Xuerong & Chen, Cen & Wang, Yixing & Zhai, Guofu & Vachtsevanos, George.* (2016). Online Condition Monitoring of Power MOSFET Gate Oxide Degradation based on Miller Platform Voltage. IEEE Transactions on Power Electronics. 32. 1-1. 10.1109/TPEL.2016.2602323.
[71] *Escudero, Manuel & Morales, Diego & Rodriguez, Noel.* (2021). Optimum Design And Novel Control Techniques For Isolated, Resonant And Quasi-Resonant, Dcdc Converters.
[72] *Huang, C & Liang, J & Hsu, W & Yang, C.* (2021). A design of flyback switched-mode power supply with soft switching using the UC3842 controller. Journal of Physics: Conference Series. 2020. 012031. 10.1088/1742-6596/2020/1/012031.
[73] *Manjunath, Ashritha & ML, Sudheer.* (2021). Mitigation of CM conducted EMI in flyback converter using balancing capacitors. IET Power Electronics. 13. 10.1049/iet-pel.2020.0847.
[74] *Fukunaga, Shuhei & Takayama, Hajime & Hikihara, Takashi.* (2022). Slew rate control of switching transient for SiC MOSFET in boost converter using digital active gate driver. IET Power Electronics. 16. n/a/y. 10.1049/pel2.12398.

11. ANNEXES

11.1. A1 DIAGRAM OF THE BASIC MODULE OF HALF-BRIDGE TOPOLOGIES



11.2. A2 SCHEMATIC OF FLYBACK POWER SUPPLY USING CLOSING OF THE FEEDBACK THROUGH INDUCTIVE COUPLING



11.3. A3 SCHEMATIC OF FLYBACK POWER SUPPLY USING CAPACITIVE COUPLING CLOSING THE FEEDBACK LOOP