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Modular Test Platform for Inductive Wireless Power Transfer

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***Abstract*—The promising technology of wireless power transfer is receiving increased attention from the industry. Despite the potential of this technology, many companies are faced today with barriers to implement wireless power transfer technologies into their products. This work obviates those barriers by proposing a modular inductive wireless charging test platform. The test platform is modularized to allow fast and accessible in-depth evaluations, from topological level of amplifier design to component level of integrated circuits. This allows the modular platform to bridge the gap between the theoretical literature and the practical applications in industry.**

***Index Terms*—inductive wireless power transfer, test platform, modularity**

I. Introduction

Wireless power transfer (WPT) through inductive coupling allows the battery of an electrical device to be charged without the need to plug in a physical cable. The incorporation of WPT offers a multitude of advantages [1]–[4], including enhanced robustness, miniaturization, automation, and user-friendliness of the device.

Because of these advantages, the wireless charging market is experiencing significant growth. Annual growth rates of 20 to 30% are recorded in units (transmitters and receivers) sold [5], [6]. For example, the number of wireless charging units sold worldwide increased from 541 million in 2018 to 661 million in 2019, and as many as 2.2 billion in sales are expected by 2024 [5].

Large multinationals already introduced wireless technology in many products. In contrast, many enterprises, especially small and mid-size enterprises, SMEs, lack the resources to acquire the necessary knowledge to implement wireless power transmission. This limits the SMEs to todays standards or other non-product-specific solutions availible on the market. Considering the scope of this work, the standards of today are represented by the Qi and Airfuel Alliance standard. Both standards are limited to a maximum power transfer of 15 W, which is insufficient for many products.

To reduce the challenges faced by these enterprises, this work proposes and elaborates the construction of a modular test platform of an inductive wireless power transmitter. The test platform is designed with a high degree of freedom to provide a wide variety of evaluations targeting both current and prospective solutions. The platform allows the examination of an inductive WPT transmitter at different design levels. These include topological design level evaluation, such as amplifier or resonant circuit design, and examination at the lower electronic component level of integrated circuits or used mosfet/eGaN-FETs. To this end, the modular testing platform bridges the gap between the application industry and the theoretical research field. It enables the industry to quickly and easily evaluate the theoretical proposed findings and additionally to define a range of application-oriented usable solutions which can lead to a more straightforward and faster implementation of inductive WPT technology into their products.

In the first phase of the test platform, only the transmitter is considered. The receiver is not yet modularized but care is taken to ensure that the transmitter is compatible with simplified standard receivers in order to formulate meaningful comparative tests and evaluations.

II. Methodology

The development of the proposed modular platform started from a conventional wireless energy transmitter depicted in Figure 1, which is derived from the Qi- and Airfuel Alliance standard [7], [8], literature [9]–[12] and various kits for inductive wireless energy transfer available on the market [13], [14].

The platform must have a high degree of freedom to evaluate a wide variety of (resonant) inductive wireless energy transfer technologies, including those covered by the Qi- and Airfuel Alliance standard and the ones utilizing a different amplifier- or resonant circuit topology, or even a smaller variation at the integrated circuit level. To achieve these objectives, the conventional wireless energy transfer transmitter of Figure 1 needs to be divided into several modular segments as shown in Figure 2.

A first division is the separation of the peripherals, amplifier and matching network. This segmentation enables the evaluation of different matching networks as a function of a constant amplifier and peripherals. The same can be stated concerning the evaluation of different amplifiers and peripherals.

The second modular separation addresses the peripherals. In literature several papers on the power control of a WPT system can be found [15], discussing e.g. the effect of frequency,

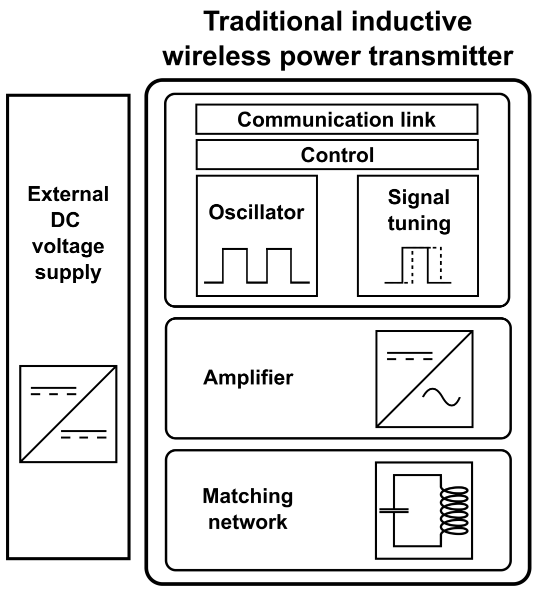

Fig. 1. Block diagram of a traditional inductive wireless power transfer transmitter.

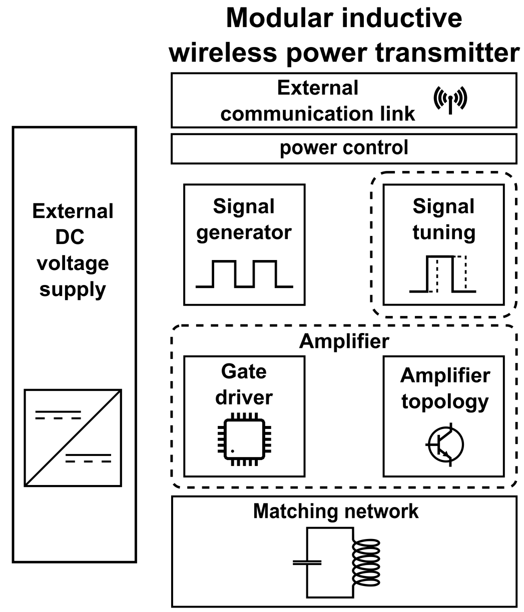

Fig. 2. Block diagram of the modular inductive WPT test platform.

voltage, and duty cycle control. Nevertheless, the modular test platform should still cover both the Qi and Airfuel Alliance standards. This means that multiple resonant frequencies and wireless communication techniques must be feasible. Hence, the peripherals module is divided into three separate modules being an oscillator, communication and power control module. An optional signal tuning module can be installed between the signal generator and the amplifier module. The frequency signal, for example a 200 kHz square wave, can accordingly be adjusted, propagated and inverted depending on the requirements of the amplifier. Introducing these separations into the traditional inductive wireless power transmitter schematic of Figure 1, the proposed modular inductive WPT transmitter test platform of Figure 2 can be derived.

III. Set-up

To illustrate the implementation of modularity into an existing inductive WPT transmitter, a modular showcase is built. For the simplicity of the showcase, the control, communication and oscillator module are left out of consideration or replaced by external devices.

The construction of the modular amplifier implemented in the showcase is inspired on the EPC9065 development board [14] featuring GaN-FETs in a class D amplifier configuration. To allow the evaluation of several gate driver circuits as a function of a given H-bridge construction, and vice versa, the amplifier module is divided into a separate gate driver module and H-bridge module. Similar to the EPC9065 development kit, the dimensioned gate driver circuit features the LM5113 gate driver IC and the EPC2007C GaN-FETs for the H-bridge. The utilized bridge converter is additionally supplemented with an optional zero voltage switching (ZVS) circuits to allow the evaluation of the class D inverters performance both with and without soft switching. An illustrative schematic of the modular full bridge amplifier is presented in Figure 3.

The resonant circuit and power transfer coil are, in contrast to the amplifier, inspired by Würth Elektronik's 200 W development kit [13]. The resonant frequency is determined based on the quality factor specified in the technical datasheet. For the utilized coil a high quality factor is obtained at a frequency of 200 kHz. Tuned to this resonant frequency, a series resonant circuit module is developed as a matching network. An external waveform generator is used to generate the desired 200 kHz control signal. In conjunction with the waveform generator, an adjustable signal tuning network is constructed. The purpose of the tuning network is to match the signal from the waveform generator to the desired input of the used class D amplifier. This is done by duplicating the incoming signal four times and inverting it two times. Four adjustable delay circuits are implemented to delay the output signals independently. This allows ZVS and power control. To connect the various components of the modularized transmitter represented in Figure 2, SMA connectors are utilized to minimize signal interference.

As a result, a modular inductive wireless power transmitter is constructed using four distinct, customizable PCBs, Figure 4. By the creation of a modular system, researchers can perform a comprehensive analysis of various topologies and components, without the need to redesign the entire system. This approach simplifies the overall design process of wireless power systems.

IV. Measurement

For evaluation, several external devices must be connected to the modular transmitter, including an external signal oscillator and an external DC power supply. For convenience

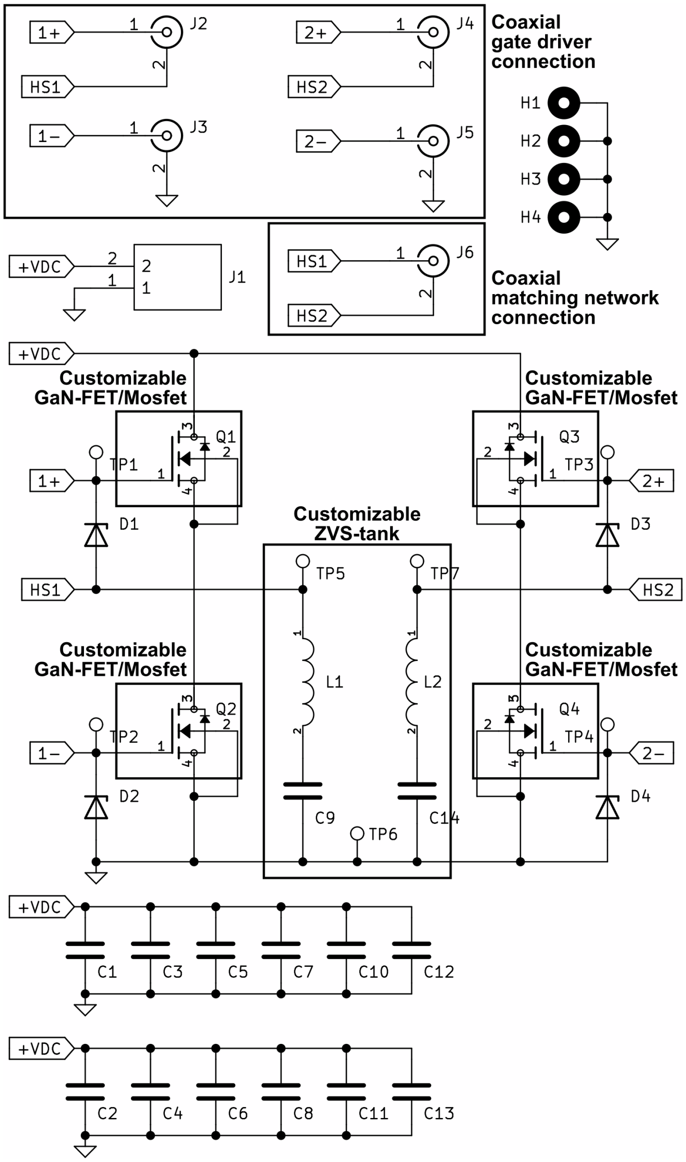

Fig. 3. Schematic of the H-bridge module of the modular inductive WPT transmitter.

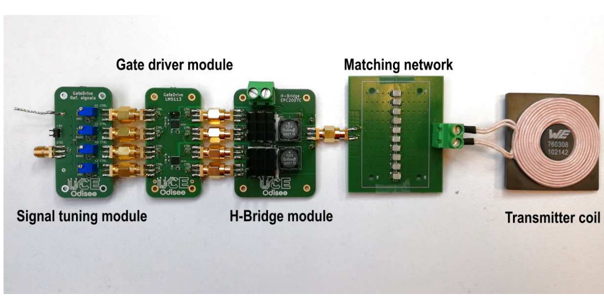

Fig. 4. Developed modular inductive WPT transmitter.

the transmitter is tested in conjunction with a simplified receiver. The utilized receiver consist of a matching network and calibrated resistor. The measurement setup is presented in Figure 5, the modular transmitter is connected to an external signal generator and two external DC voltage supplies.

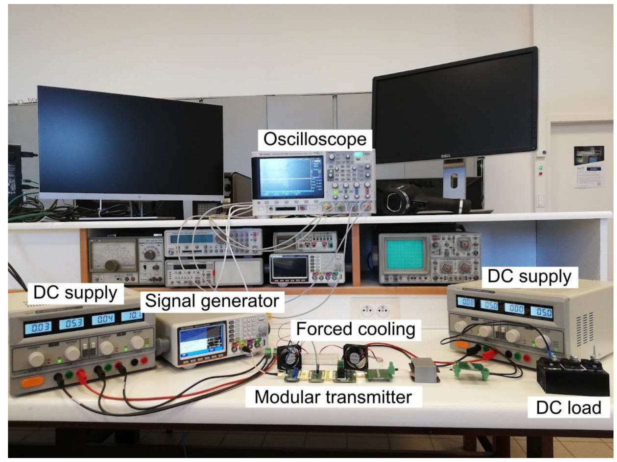

Fig. 5. Measurement setup of the modular inductive transmitter.

The integration of two power supplies enables separation of the IC component's power supply and H-bridge's power supply, thereby providing manual control over the transferred power. To assess the performance of the different boards, the on-board test points are utilized in combination with an external oscilloscope. Additionally, to ensure best practices, forced cooling is employed to cool the GaN-FETs.

Different reference signals can be mapped and examined depending on the optimisation or analysis to be performed. For illustration purposes, Figure 6 shows the obtained measurements including the reference voltage signal of the oscillator (1), the square wave generated by the used class-D inverter (2, 3), and the voltage signal over the secondary load (4). During this measurement the external voltage supply of the H-bridge is set to 5 V DC and the external oscillator is configured to generate a square wave of 204 kHz, corresponding to the resonance frequency of the primary and secondary matching network in the system.

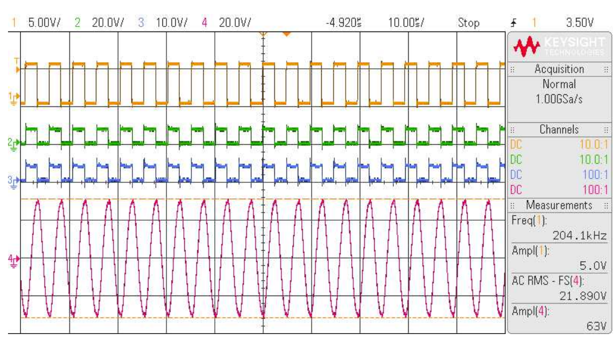

Fig. 6. Scope image obtained during the measurements of the modular inductive WPT transmitter.

V. Conclusion

SMEs do not have the same resources as multinationals to implement innovative technologies such as WPT into their products. To lower the threshold of implementing (non-) standardized inductive WPT, a modular test platform of an inductive WPT transmitter is proposed in this work. The test platform provides simple yet efficient testing of a wide variety of WPT configurations at the request of companies. With the results of these tests, a knowledge base is compiled providing companies with a range of solutions to implement the WPT technology into their products. In the next phase of the project, the receiver will also be modularized to evaluate a wide variety of inductive WPT technologies.

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