Design of Single Phase High Frequency Inverter for Wireless Charging Application

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Abstract - Class-E power amplifier is the most common inverter topology at the source side for wireless electric vehicles (EVs) charging systems. This paper presents the design of a single phase high frequency inverter using SG3525A pulse width modulation (PWM) control circuit IC which eliminates the use of complex circuitry to generate pulses for transistor switches. This design also features built–in soft–start circuitry, requiring only an external timing capacitor and input under voltage lockout with help of SG3525A IC. The proposed design is capable of producing a single phase high frequency AC voltage of 12V(for experimental purpose) with 85KHz frequency(as per SAE TIR J295)

Key words: Power Amplifer, PWM, Inverter, Wireless charging

I. INTRODUCTION

Plug-in station are the most common charging method for electric vehicle which means that consumer must insert the receptacles on the car which has danger of connecting cars with cables to power grid. Swappable batteries (replace used-out batteries at charging station) is another method of charging electric vehicle which is costly and requires special infrastructure. Convenience, integration, multiple vehicle charging and low risk are some advantages of wireless charging systems.

Pulse width modulated(PWM) inverters are the most used power-electronic circuits in practical applications. They are capable of producing ac voltages of variable magnitude as well as variable frequency. The quality of the output voltage will be greater then a square wave inverters. PWM inverter can be single phase as well as three phase types. There are several other PWM techniques, SINE-PWM technique, Space Vector based PWM technique, Hysteresis current controller based PWM technique are some of the important ones.

The single Phase PWM inverter can be built from two half bridge connected to form as a full bridge or H-bridge. It comprise of DC voltage source, four Power switches and the load.

In Fig. 1,if all the time one of the two diagonal pair of switches (Sw1 and Sw4) or (Sw2 and Sw3) conduct, the load voltage will have two levels; +E or –E. By suitably switching between one diagonal pair to another diagonal pair one can obtain a PWM waveform. Now if the allowed switching combination includes conduction of Sw1 along with Sw3 (or Sw2 along with Sw4) the load voltage may have three-levels, i.e., +E, zero and –E.

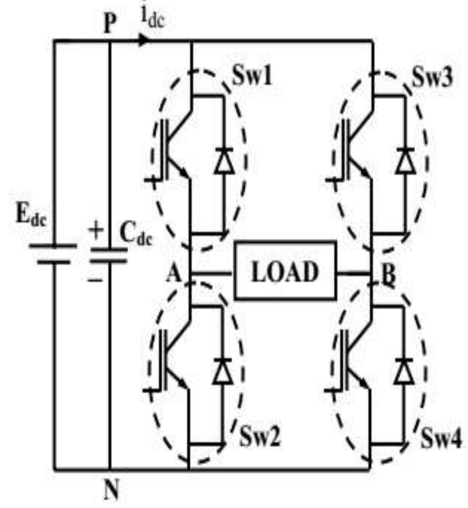

Fig.1. Single phase full bridge PWM inverter

II. LITERATURE SURVEY

In[1],authors present a class E power amplifier based inverter architecture for electric vehicle charging and also presents strategy to improve the inverter efficiency

In[2],authors introduces a 50W 6.78MHz single stage power amplifier based on phase-modulated full-bridge topology and presents its merits over multi stage power conversion.

In[3],authors proposes design and implementation of a 13.56 MHz GaN Class-E power amplifier which simplifies circuit structure using the parasitic capacitance of the transistor to replace the charging capacitance.

In[4],authors proposes design and construction of pure sine wave inverter based on SG3525.

III. SG3525 PWM IC CONFIGURATION AND MOSFET CONFIGURATION

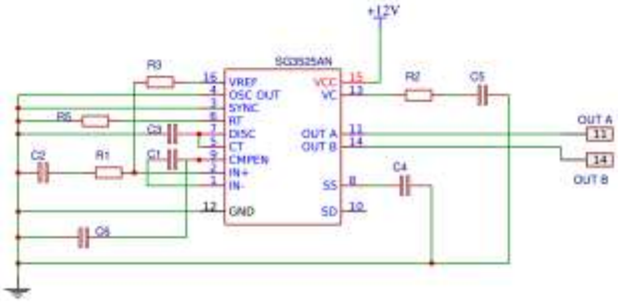

Fig. 2. Pin Configuration

The SG3525 PWM IC is a 16-pin device which has operating voltage range from 8.0VDC to 35VDC and 100 Hz to 400KHz has oscillator range. They include reference voltage regulator, an error amplifier, a comparator, an oscillator under-voltage lockout, soft start circuit and output drivers.

Negative feedback is used to force the voltage at the inverting input (pin 1) of the error amp to be equal to the voltage at the non-inverting input (pin 2) of the error amp. The internal oscillator drives a flip flop. Each half-cycle of the flop puts on the NOR gate for a full PWM cycle. It has an internal pair of complementary BJT gate drivers which can deliver high and low output voltages necessary to adequately drive power switches.
The soft start circuit is necessary for limiting the pulse width produced when the IC initially starts operating.

The switching frequency used in this design is 85KHz(as per SAE TIR J295). The frequency of PWM is dependent on the timing capacitance and the timing resistance. The timing capacitor (CT) is connected between pin 5 and ground. Between pin 6 and ground, timing resistor (RT) is connected. The resistance between pins 5 and 7 (RD) determines the deadtime

R_T, C_T and R_D decides the frequency.

$$f = \frac{1}{C_T(0.7R_T + 3R_D)}$$

With R_T and R_D are in Ω and C_T in F, f is in Hz.

Typical values of R_D should be in the range of 10Ω to 47Ω. The range of values usable (as specified by the manufacturers of SG3525) is 0Ω to 500Ω.

R_T should be within the range 2kΩ to 150kΩ. C_T must be within the range 1nF (code 102) to 0.2µF (code 224). The oscillator frequency must be within the range 100Hz to 400kHz.

$f=1/0.02*10^{-6}(0.7*845+3*0)$
= 84,530.85 Hz
≈ 85KHz

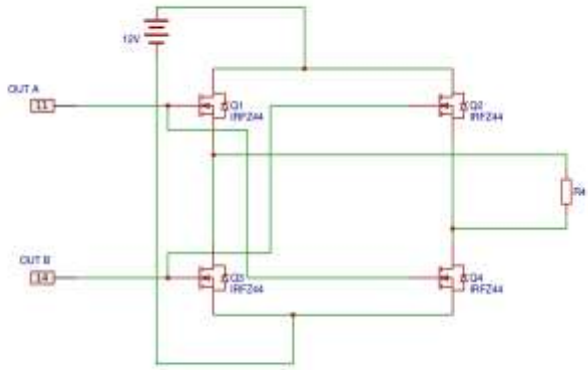

Fig. 3. MOSFET switch arrangement

IRFZ44 power MOSFET is used for switching purpose. They have best combination of low on-resistance, fast-switching, ruggedized device design and cost-effectiveness.
IRFZ44 power MOSFET has maximum V_{DS} of 60V, I_D of 50A and operating temperature ranging from -55 to +175.

Fig. 3 illustrates MOSFET switch arrangement and approach in which the controller outputs are connected with the MOSFET switches. The turn ON and OFF for Q1 and Q4 are controlled by OUT A generated at pin 11.While the turn ON and OFF for Q2 and Q3 are controlled by OUT B generated at pin 14.

Both OUT A and OUT B uses the same control signal generated by SG3525A IC. With OUT A signal leading OUT B by half cycle or 180 degree of switching signal.

For experimental purpose, resistive load is connected at the output of the inverter. In real world, resistive load will be replaced by wireless transmitter coil, which transmits power to receiver coil which will be rectified and provided to the Battery in the electric vehicle.

TABLE 1 COMPONENT REVIEW

S.No	Component	Value
1.	R1	56KΩ
2.	R2	100Ω
3.	R3	33KΩ
4.	R4	100KΩ
5.	R5	845Ω
6.	C1	100nF
7.	C2	10µF
8.	C3	0.02µF
9.	C4	10µF

10.	C5	10μF
11.	C6	100nF
11.	Power MOSFET	IRFZ44

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