FLUORESCENT LAMPS WITH MHz ELECTRONIC BALLAST

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***Abstract* – The CoolMOS transistor in combination with the silicone carbide diode from Infineon allows switching frequencies above 1 MHz. To demonstrate the capability's of these devices an electronic ballast is developed. Three main functions must be integrated into the electronic ballast, these are preheating and ingniting the tube and driving the lamp in steady state. For the research the ignition and the steady state power supply are selected.**
A faster and softer ignition can be achieved by an RF voltage burst (RF:Radio Frequency; here: >1 MHz), in contrast to DC-pulses or audio-frequency (20 kHz) voltage bursts mostly used today. In accordance with the RF-voltage and the status of cathode preheating the measured ignition time varies typically between 40µs to 160µs. To realize the electronic ballast a SEPIC is improved to a resonant SEPIC (rSEPIC).

KEYWORDS

electronic ballast, rSEPIC, CoolMOS, high frequency inverters

I. INTRODUCTION

It is not possible to operate fluorescent lamps from main supply voltage. A ballast is needed to adapt the voltage level and limit the lamp-current. Ballast circuits have also to fulfill a number of standards. In Europe the EN61000-3-2 applies to these kind of circuits. The standard defines the maximum harmonic current distortion at the common point of coupling and provides the application of a proper power factor correction (PFC).

A rough PFC can be achieved by using passive filtering, but active filtering by electronic ballasts is state of art. In [1] some topologies for electronic ballasts are classified. Compared to the passive methods the electronic ballasts take on a lot of additional functionality, so to say safety and supervising issues or prolonging lamp lifetime by appropriate filament preheating and fast ignition of the fluorescent lamp without any flicker.

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II. RF-IGNITION

It is known that the tube's plasma can't be ignited by an acceptable DC voltage, today AC voltages in the range of 1 kV are common.

Modern electronic ballasts work on 20 up to 100 kHz. The alternating voltage for driving the lamp is provided by a converter, in most cases half bridge converters and for some special applications full bridge converters. To limit the current through the fluorescent lamp an inductance is placed in series to the load. The circuit will be completed by a capacitor parallel to the lamp. This circuit has two main functions, these are preheating of the filament and the ignition of the tube's plasma.

This functionality is provided by driving the circuit with variable frequencies. Beside the main resonance the preheating of the filament takes place, after this phase the above meant exciting of the circuit brought in resonance. The high AC voltage ignites the lamp.

For EMI reasons this effective scheme should be left, because of the increasing switching frequencies, the electromagnetic interferences become a rising problem. As a solution the operation of a fluorescent lamp with a low frequency. For simplicity a converted DC voltage is preferred, the time characteristic of the used voltage is nearly rectangular. And the light efficiency is as the same as driving the lamp with more than 20 kHz. Unfortunately the new

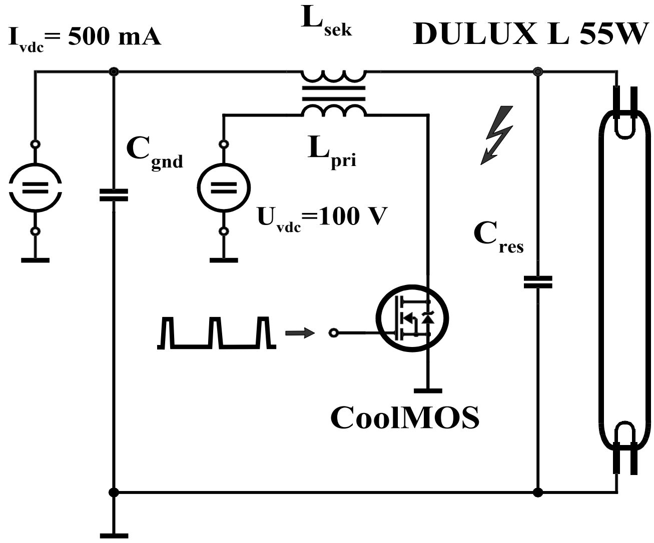

Figure 1. Schematic ignition circuit

topology needs a separate ignition circuit. It is well known that the ignition capability of the plasma increases with rising frequency, in the presented work 2.7 MHz is chosen.

In Figure 1 the principle schematic is depicted. Similar to todays solutions the lamp is connected to a resonant circuit.

For reasons of efficiency and dissipation heat it is necessary that the secondary winding of the transformer has a low DC-resistance. The used high ignition frequency allows to build up an RF-high-voltage transformer witch can perform these requests.

On the primary side of the RF-HV-transformer operates a class-E final stage in a special mode. This final stage is the exciter for the ignition circuit and works with a RF-switching frequency.

To adapt the voltage level and prevent the switch from overload the duty cycle of the converter is smaller than 0.5. The turn on time in our setup was in the range of 70 ns at a period of 370 ns. The final stage transforms the DC input voltage into the RF ignition voltage, by transferring the energy to the secondary side of the transformer the resonant circuit is excited to a peak voltage of approximately 900 V. After the lamp's ignition, the exciting circuit has to provide a RF-current of 1.5 A to heat up the plasma in the tube and pass the lamp into steady state. Following the ignition the plasma resistance decreases and the ignition circuit gets in to a non-resonant operation mode. In consequence the voltage drops down, the current grows. The circuit leaves the optimized resonant switching mode but is still able to provide the required RF-current.

III. Resonant SEPIC (rSEPIC)

The aim of each new development are a unit power factor with less disturbances and power losses. To observe the above named limiting values a passive energy storage couldn't be used after the input rectifier. The rectifier doesn't provide a smoothed DC voltage. Thus only converter applicable, which combines buck and boost capabilities. In this paper the discussion is restricted to the single ended primary inductance converter (SEPIC). A significant part of the losses in the SEPIC takes place in the ohmic losses of the core windings. A reduction of these power could be achieved by minimizing the core inductance with its coupled winding resistance.

To keep the transmitted power constant at the same period of time with the reduced inductances, the switching frequency must be increased. In conclusion with the above named European standards a frequency above 1MHz is selected.

Two problems are growing up with these increased frequency. First, smaller inductance yields a higher di/dt, and switching off results in a higher voltage stress for the rectifier diodes and the MOSFET. Second, increased disturbances at the point of coupling results from higher switching sides. To reduce these stress and to reach a switch on relief the SEPIC in Figure 2

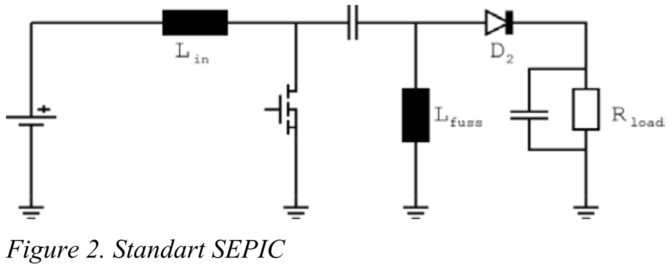

Figure 2. Standart SEPIC

is improved to the resonant SEPIC (rSEPIC), shown in Figure 3.

Two additional devices expand the SEPIC and provide these features. D_{in} and C_{in} prevent the switching voltage peak from the rectifier diodes. They also tune the frequency of the resonant circuits in this way, that the CoolMOS switch on in a minimum of the drain voltage. But there are two main

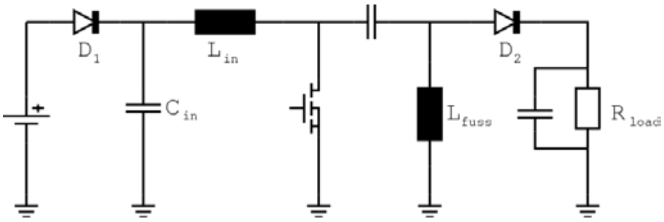

Figure 3. Resonant SEPIC

problems in this application. The circuit works in a resonant way and this results in high amplitudes of the drain voltage. And the drain voltage should be observed to detect the minimum an switch on in this minimum. The control circuit couldn't be designed to that point of time. To drive the lamp a full bride rectifier is used with a very low switching frequency. So the lamp see's a alternating dc current.

IV. MEASUREMENT RESULTS

In the reported ignition application two different configurations are discussed, a compact U-type (DULUX L 55W) with short cables and a rod type (LUMILUX FQ 54W) with much longer cables. This separation is necessary because of two possible kinds of installation. The first one is the mounting of the ballast close to the lamp like in a desktop light and the second one is the use in ceiling fittings. In this application the cable could be as long as 2 x 1.5

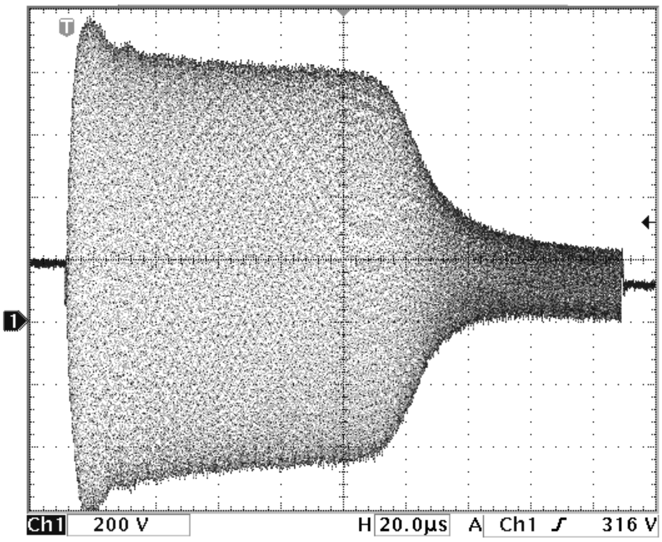

Figure 4. Voltage for the long line ignition

meters. In each measurement the preheating time of the lamp filaments were chosen to 1 second.

In Figure 4 the RF-voltage across the output stage during the ignition of the long cable configuration is shown. In front of the diagram, the higher DC-open-circuit voltage (190 V) is visible, the plasma is non conducting and the resonant circuit is formed by the capacitor C_{res} and the secondary winding of the transformer L_{sek}. C_{gnd} is large enough to be neglected. The ignition starts at 7 µs. The oscillation grows up and prepares the tube's plasma for ignition.

The RF-burst time last here 95 µs, then the gas inside the tube is ionized and plasma resistance is dropping. The lamp voltage diminishes significantly to 220 V_{peak}. The capacitor parallel to the lamp is now nearly shorted by the conducting

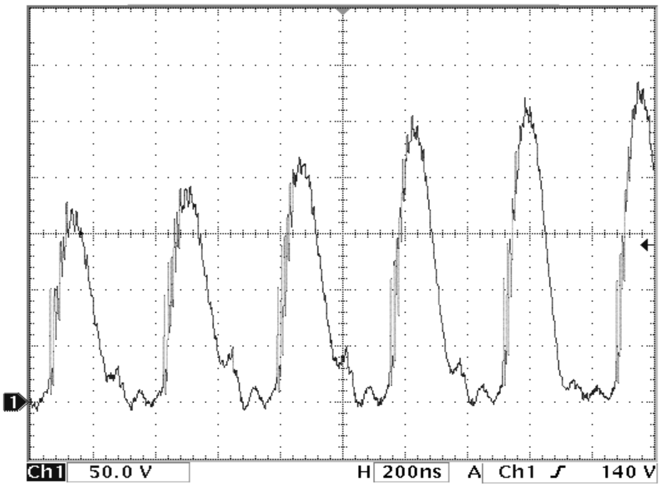

Figure 5. Drain voltage

tube.

Figure 6 shows the corresponding current trough the lamp. In the first part of the curve only a small capacitive RF-

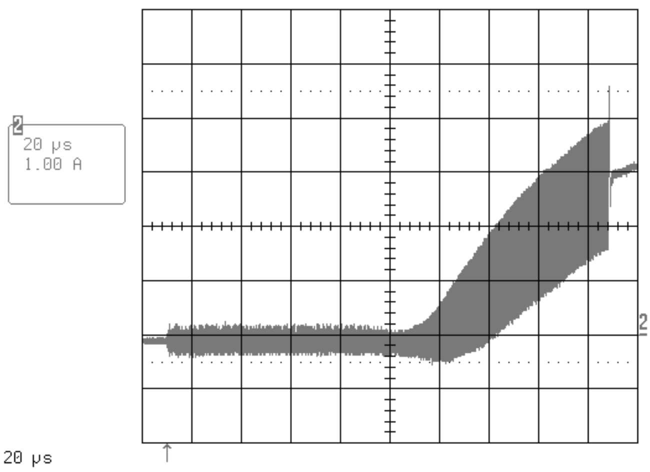

Figure 6. Lamp current - short line

current is to be seen. After ignition as well the RF- as the DC current is evidently rising.

A part of the time scale of the drain voltage from the CoolMOS-transistor(7 A / 600 V) in the ascending phase of the oscillation is shown Figure 5. The voltage stress is very moderate, because the voltage doesn't rise up over 350 V during the hole ignition time.

Finally Figure 7 show the results of the short line

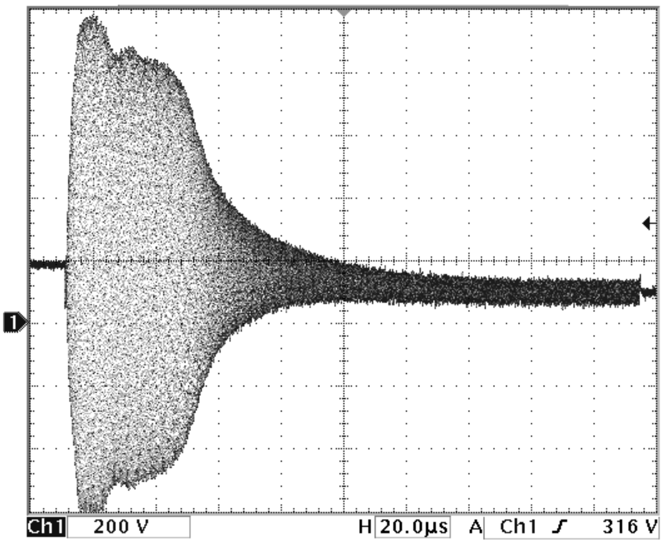

Figure 7. Short line ignition voltage

configuration, similar to Figure 4, a significant shortening of the ignition time takes place. The peak values of voltage and current are very similar however.

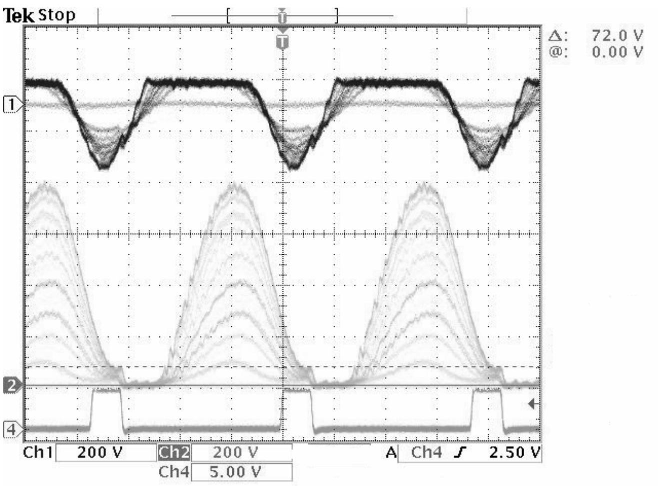

Figure 8. Drain voltage and control signal

At the current time the researched rSEPIC application works with a ohmic load at 230V AC power line. In Figure 8 the graphs represent some overlayed measurements over one main period (50Hz). Channel one shows the voltage across the diode D_{rec}. The captured max. voltage peak demonstrate, one silicone carbide Schottky diode can withstand the applied voltage stress. More interesting are the results of channel two. The print out describes one of the main problems in resonant switching. The switch on voltage reach a minimum, but the maximum voltage grows up to the nominal voltage of the used CoolMOS transistor.

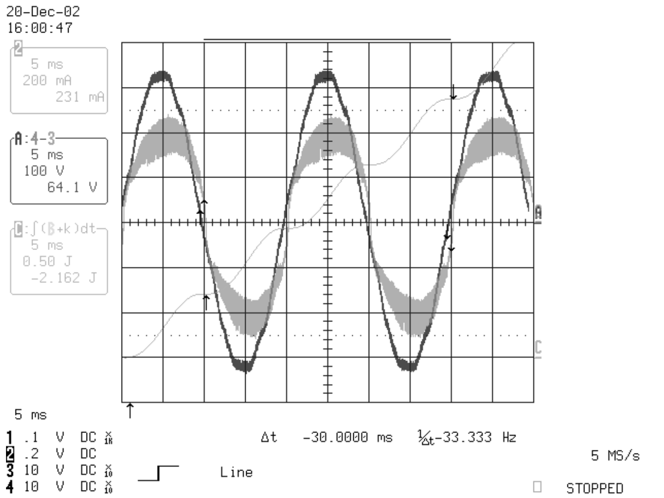

Figure 9. Main current and main voltage

With tuning up the circuit frequency the switch on voltage is reduced to 40V, independently of the input voltage. In opposition the maximum voltage grows up relative to the input voltage.

At the end Figure 9 depict the input surrent and the input voltage from the researched topology. As you can see, the circuit provide a low phase shifting but a visible distorsion in the current wave.

V. CONCLUSION

CoolMOS power transistors in combination with silicone carbide diodes may open the way to power electronics above 1 Mhz. New circuit topologies are needed, not completly new but evolutionary improved circuits. The research shows that switching losses play a major rule in this frequency range and could not be neglected.

The introduced ignition circuit provide a softer ignition and may improve the tube lifetime. This invetigation is still pending. Additionell the device stress could be reduced, smaller devices are integrated and furthermore the costs decreasing.

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