Karlsruher Institut für Technologie

Operation Mode of Fluorescent Lamps and Compact Fluorescent Lamps

KSOP lab

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supervisor: Dipl.-Ing. Michael Meißer

Tel. 0721 608 42536

michael.meisser@kit.edu

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Basics

Due to their negative current-voltage characteristic, fluorescent lamps (FL) require an ballast which limits the current absorbed by the lamp. The ballast also manages the first and the following ignitions of the FL, which is a low-pressure type of lamp.

Especially advantageous is the utilisation of an inductor which is connected in series to the lamp. In connection with a so called starter it forms a so called conventional control gear (CCG), and provides the high ignition voltage. Before, the ignition, the starter is closed and the filaments of the lamp are heated to increase the charge carrier density. The current though the inductor has to be steady, therefore it forces the voltage to advance. With this, continuous conduction mode (CCM) is provided and the pek ignition voltage of the lamp in steady state are much lower than the initial ignition voltage. Compared to an ohmic ballast, the inductively coupled ballast has also an enhanced electrical efficiency. With the use of the inductively coupled ballast and 50 Hz operation frequency, the voltage across the lamp is close to a square wave. The sine waveform of the current is superposed by a third harmonic.

In contrast to the 50 Hz CCG, an electronic control gear (ECG) drives the lamp with an high frequency (HF) alternating voltage. Fig. 1 shows a typical schematic of an ECG for fluorescent lamps.

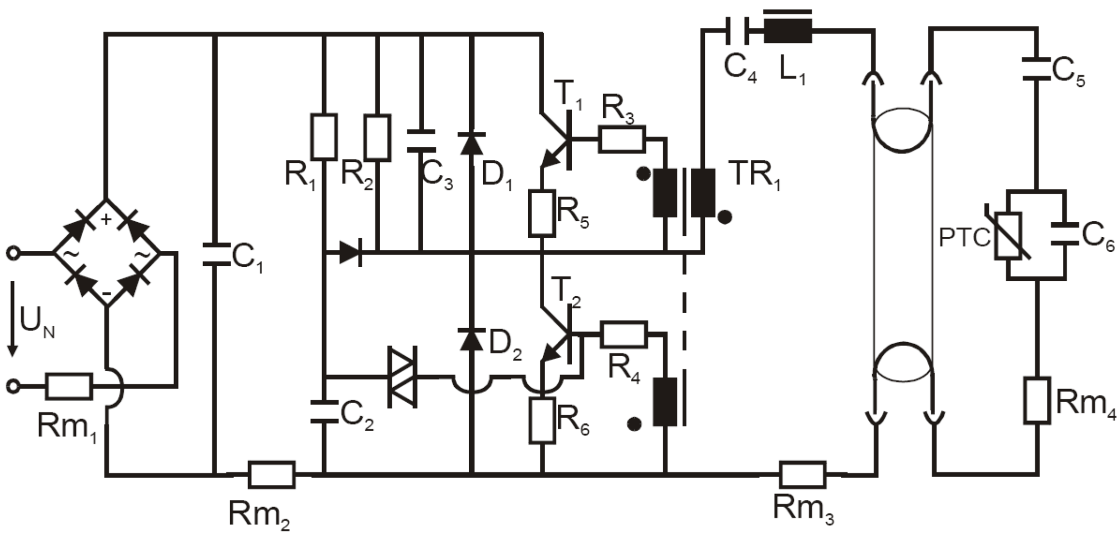

Fig. 1: Circuit diagram of an electronic control gear with discrete electrical and electronic components. Rm are 1Ω-shunts that allow to easily measure the currents in the respective paths.

DC voltage is attained by full-wave rectification and subsequent smoothing by the large value capacitor C_1. The following chopper, consitsting of an transistor half-bridge and a saturation transformer to control the bridge, generates an alternating square-wave voltage. This with respect to ground asymmetrical voltage shape is then symmetrized by DC-blocking capacitor C4. Basically, C4 is charged to half the amplitude of the square-wave voltage and then acts as a level shifter.

The resonant LRC lamp circuit, which is connected between C4 and ground is excited by this symmetric voltage and forms an sine wave across the lamp. The amplitude of this sine wave depends on the quality factor Q of the resonant circuit formed by L1 and the series connected C5 and C6. The positive temperature coefficient (PTC) resisitor and the shunt resistors Rm damp the resonant circuit while the lamp is not ignited.

In the moment of switching on the ECG, resonance occurs and at first leads to an current flowing through the PTC. The lamps filaments are heated by that current and provide charge carriers by glow emission. The PTC also gets hotter and thereby its resistance increases. As a result, the effective circuit capacitance is getting lower and the quality factor of the circuit rises. The voltage across the lamp is a function of the quality factor and therefore rises as well.

This continues until the breakdown voltage of the CFL is reached. The gas inside the lamp is then ionized and plasma is established.

The ignited lamp is characterized by a rather small resistance which heavily damps the resonant circuit. Therefore, the voltage across the lamp returns to the steady burning voltage.

Equipment of the lab

- 36 W fluorescent lamp
- 13 W compact fluorescent lamp
- inductor and starter forming the CCG
- electronic ballast with socket and test ports
- isolating transformer
- digital storage oszilloscope Agilent 54831b including HV probe
- precision wattmeter Zimmer LMG 95
- current transformer Pearson 110 A
- luxmeter
- various electrical connectors and small parts

General instructions on doing measures

Be sure to place the isolating transformer appropriately within the circuit. Consider the interrelationship of the earth terminal of the oscilloscope probe head and the protected earth (PE) cable of all plug cables. The oscilloscope entries are **not** galvanically isolated and limited to a maximum input voltage of 150 V! Always make sure that you choose the right probe and the right measurement range. Pay attention to the correct positioning of the current measuring coil and its ratio. The test ports of the electronic ballast are led out corresponding to their position in the circuit. Relative light fluxes should only be recorded after sufficient burn-in time. Take into account the temperature dependency of the characteristics of the lamp. **Only use measuring circuits after inspection by the supervisor! Always be aware that you could come into contact with hazardous high voltages!**

Exercises

1. A linear 36 W fluorescent lamp of 26 mm tube diameter has to be operated in series with an inductive ballast, also called conventional control gear, at 230 V mains voltage.

   Record current and voltage of the lamp against time and determine the effective power input of the lamp.

   Determine the effective values of input supply voltage and input supply current as well as effective power by means of the precision wattmeter.

   Calculate the electrical efficiency of the circuit out of the measured characteristic values.

2. A 13 W compact fluorescent lamp has to be operated using an electronic control gear at U_S = 230 V mains voltage. Record the relative light flux of the compact fluorescent lamp as a function of

   a: the system power input

   b: the effective value of the lamp current

The supply voltage is the setting parameter with three steps at 180 V, 230 V and 250 V. Determine the electrical efficiency of the circuit under nominal conditions (U_S = 230 V)!

3. Record the starting of the lamp by means of an scilloscope plotting of the HF envelope of the current trough lamp circuit and of the voltage across the lamp. Explain the shape of your records and track the change of operating frequency with at least 10 points of measure. Describe the different operating periods of the electronic ballast!

Homework:

4. Compare the uncertainty of measurement of the precision wattmeter to the one of the oscilloscope.

Questions concerning the lab

In advance of the practical work, some questions will be addressed to you by the supervisor to check your status of preparation. Please inform yourself on the basis of the provided questions and the given bibliography. Try to give a ***short*** answer and clarify the physical context. **You are not requested to elaborate and to show written answers!**

General questions on gas discharge lamps:

1. What are the significant differences between incandescent lamps and discharge lamps, especially low-pressure fluorescent lamps (physical processes of radiation generation, luminous efficacy, temperature, size, …)?

2. What is a plasma (definition), what is the temperature in the lamp?

3. What is the reason for the conductivity of the plasma?

4. What is the electric field intensity in the low-pressure discharge and on what does it depend on?

5. How does the fluorescent material (phosphor) actually act? What determines the spectrum (light colour) of the fluorescent lamp?

6. Why does a fluorescent lamp has two the electrodes, each having two connections at both ends of the lamp?

7. Why is the electrode a filament made of tungsten (resistance, temperature)? Why is the filament (electrode) coated with a paste?

Questions on the ballasts:

1. What kind of ballasts are in principle suitable for operating fluorescent lamps (advantages/ disadvantages)?

2. How can a fluorescent lamp be ignited by a choke?

3. How does the starter work and how is it connected?

4. What does the term "power factor (PF)" mean? Who is interested in a high power factor?

5. What are the advantages/ disadvantages of conventional control gears and of electronic control gears?

6. Why can the fluorescent lamp be ignited more quickly and mostly more carefully by an electronic ballast than by a conventional ballast?

7. Into which functional blocks can the electronic ballast be divided?

8. How can the power factor be improved and the harmonics of the mains supply be reduced ?

9. How can an ignition voltage of more than 1000 V be attained, although the supply voltage is only an effective voltage of 230 V?

10. What is a series resonant circuit? Give an equivalent circuit diagram of the damped resonant circuit before and after the lamp has been ignited.

11. What is a PTC resistor (characteristic, time dependency)?

12. What is the purpose of capacitor C_1? How can its capacitance value compared with the other capacitors?

Questions on the measurement setup and the procedure:

1. How do you measure the relative light flux, what does V(λ)-corrected sensor mean?

2. How can you determine the effective power for non-sinusoidal currents and voltages?

3. What are the fundamental measurement errors in measuring the current, the voltage and the power?

4. What is the purpose of probe head calibration?

5. How do lamp power and light flux behave during the first 10 minutes after the lamp has been turned on? After what time do measurements make sense?

Report preparation

- use clear and compressed sentences – you are not requested to write a novel
- sum up the scope of the experiments and shortly the physical / technical background
- focus on the set-up and the results of the experiments and **discuss** them
- consult literature on writing reports / student works – you find them in the KIT library

References

Spiros Kitsinelis	„Light Sources – Technologies and Applications“ (KIT)
W. Elenbaas:	“Light Sources” (KIT)
Roland Heinz	„Grundlagen der Lichterzeugung“ (KIT)
Heering / Kling:	notes on lecture “Plasmastrahlungsquellen”
Heering:	notes on lecture „Schaltungen der Optoelektronik“
C.H. Sturm:	„Vorschaltgeräte und Schaltungen für Niederspannungs-Entladungslampen“
H. Albrecht:	„Optische Strahlungsquellen“
P. Schulz:	„Elektronische Vorgänge in Gasen und Festkörpern“
W. Elenbaas:	„Leuchtstofflampen und ihre Anwendung“

Safety instruction:

- The oscilloscope is connected to protective earth, every BNC outer conductor and every outer conductor of the probe heads is connected to protective earth!
- The earth connection of the probe heads affects the circuit to be measured; using several probe heads therefore entails risk of short circuits!
- Use the isolating transformer.
- Pay attention to the maximum input voltages of the oscilloscope:
    - 1:1 probe head : U_{toe} = 50V
    - 10:1 probe head : U_{toe} = 500 V
    - 100:1 probe head : U_{toe} = 5000V

5. Circuit works must not be done before grid disconnection.
6. Check the isolation of the cables. In case of doubt, exchange the cables immediately.
7. The positions of the residual current circuit-breaker and of the emergency stop switch are known.
8. Probe tip elements have to be prevented from sliding (risk of short circuits).
9. Electricity safety measures:
    - switch off electricity
    - ensure that electricity cannot be switched on again
    - double check that no electrical current is flowing
    - ground the circuit
    - cover or otherwise isolate components that are still electrically active

With my signature, I confirm that I have been informed about possible dangers and about electricity safety concerns and that I have been pointed out the importance of accurate use of the laboratory equipment and electrical circuits.

Karlsruhe,

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Name Signature