Device for timing and power level setting for microwave applications

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Abstract. Nowadays, the microwaves are widely used for various technological processes. The microwaves are emitted by magnetrons, which have strict requirements concerning power supplies for anode and filament cathodes, intensity of magnetic field, cooling and electromagnetic shielding. The magnetrons do not tolerate any alteration of their required voltages, currents and magnetic fields, which means that their output microwave power is fixed, so the only way to alter the power level is to use time-division, by turning the magnetron on and off by repetitive time patterns. In order to attain accurate and reproducible results, as well as correct and safe operation of the microwave device, all these requirements must be fulfilled. Safe, correct and reproducible operation of the microwave appliance can be achieved by means of a specially built electronic device, which ensures accurate and reproducible exposure times, interlocking of the commands and automatic switch off when abnormal operating conditions occur. This driving device, designed and realized during the completion of Mr.Ursu’s doctoral thesis, consists of a quartz time-base, several programmable frequency and duration dividers, LED displays, sensors and interlocking gates. The active and passive electronic components are placed on custom-made PCB’s, designed and made by means of computer-aided applications and machines. The driving commands of the electronic device are delivered to the magnetron power supplies by means of optic zero-passing relays. The inputs of the electronic driving device can sense the status of the microwave appliance. The user is able to enter the total exposure time, the division factor that sets the output power level and, as a novelty, the clock frequency of the time divider.

1. Introduction
The microwaves can be used for either large-scale or small-scale operations, such as seed treatments, meat thawing, wood drying, pre-polymerisation of bakelite, sterilisation of pharmaceutical and medical tools, decontamination of patrimony objects, liquid food pasteurization etc. All these processes consist of exposing the treated materials or objects to microwaves, according to the special required conditions of each individual process, such as power level, exposure time, heating rate, safety regulations etc. [1-6]

The microwaves are emitted by magnetrons, which are special electronic devices with exact requirements concerning their anode and filament power supplies, magnetic field, cooling, shielding,
matching with the waveguide and treated object etc. If any of these requirements are not met, the magnetron will not work properly or, worse than that, damages can occur to the treated object and/or to the microwave appliance itself [1, 2, 5]. Because of these requirements, the output microwave power of a given magnetron is fixed and cannot be modified, unless the appliance is able to periodically turn the magnetron completely on and off periodically, according to a certain time pattern, so that the mean output power level will be the one required by the individual process [1, 2].

Another important parameter of the microwave processing is the exposure time, which can vary between very large limits according to the process itself. In order to attain reproducible results and, in the case of sensible processes, to not to damage the treated object by over-exposure, the timing must be very accurate and precise, and the user must be able to set it properly.

Last but not least, the appropriate shielding and security of the entire microwave device is of utmost importance, since the microwaves are dangerous to the human operators. The driving electronic command device must observe the proper operating conditions and shut down the appliance the very moment abnormal operation is sensed. Also, for safety reasons, the high voltages and currents of the magnetron must be kept away from the driving device and from the human operators [1, 2].

2. Design and realization of the timing and power level setting device
The block diagram of the electronic driving device is shown in figure 1.

![Figure 1. The block diagram of the electronic driving device.](image-url)

The counter block contains a high-accuracy quartz time-base, which yields the signals for the other blocks, such as 1Hz for the timer, synchronised with the “Start” button, and 1 – 2 – 4 – 8 – 16Hz for the power divider block. The four-digit timer can be programmed by means of “Seconds” and “Minutes” buttons, from 1s to 99 minutes and 59 seconds. The safety input combines the information about the door and the temperature of the microwave applicator and prevents the start of the process if the applicator is over-heated or its door is open, even if the “Start” button is pressed. The processing time is shown by a four-digit LED display. [1, 2]

The magnetron filament power supply gets enabled continuously during the microwave treatment process, but the magnetron anode power supply is intermittently turned on and off according to the power level setting, so that the mean power level meets the requirements of the process. The output power level can be programmed by the appropriate button and is shown by ten coloured LED’s.

The driving commands for the magnetron power supplies are sent to two optic zero-crossing relays, which ensure the complete electrical insulation and the safety for the human operators. The zero-crossing feature of the optic relays prevents the occurrence of electrical parasites during the commutation of the magnetron power supplies.

The electronic driving device is shown in figure 2.
According to Mr. Ursu’s ideas, using general-purpose digital IC’s, the electronic schematics were drawn and the printed circuit boards (PCB’s) were designed by means of computer-aided design applications, such as OrCAD3.2. Then, the project files were processed and loaded to the CNC milling machine LPKF ProtoMat S62 (figures 3-7) and the PCB’s were milled and drilled automatically.
Figure 7. LPKF ProtoMat S62 milling machine.

3. Use of the timing and power level setting device
This electronic driving device was used for research during the completion of Mr. Ursu's PhD thesis, in connection to different microwave appliances at the INCDTIM Institute of Cluj-Napoca (figure 8) and at the University of Oradea (figure 9). The experiments went on without any trouble or malfunctions, due to the careful design of the electronic driving device, interlocking of the commands and sensing of the potential problem sources. The parameters of the microwave treatment – exposure time and power level – were perfectly reproducible from one experiment to another, irrespective of the driven microwave devices. [1, 2]

Figure 8. Experimental device for dynamic processing of substance in microwave power field (Laboratory of Molecular and Biomolecular Physics, INCDTIM Cluj-Napoca), connected to the electronic driving device; 1 – microwave processing device, 2 – electronic driving device, 3 – autotransformer and measuring devices for anode power supply, 4 – autotransformer and measuring devices for filament power supply.
Figure 9. Adapted microwave oven (Microwave Laboratory, University of Oradea), connected to the electronic driving device; 1 – microwave oven, 2 – electronic driving device, 3 – autotransformer and measuring devices for anode power supply, 4 – autotransformer and measuring devices for filament power supply.

The electronic driving device was able to be used for many other experiments which implied microwave treatments, such as patrimony objects decontamination and reconditioning [4, 6], proving itself to be reliable, versatile, flexible and easy to use.

4. Conclusions
Microwaves are more and more often used for various processing operations, due to their thermal effect, that has been described in the literature [1-6]. The use of microwaves ensures fast processes, reliability and reproducibility, and the treated materials are uniformly heated because microwaves are able to penetrate them and exert their thermal effect throughout the entire batch or object.

However, microwaves are to be used with great care because they can be dangerous for the human operators in case of leaks or other malfunctions of the microwave equipment. Therefore, special safety measures and regulations were designed and must be observed when operating each and every microwave device.

According to the scale of the process, the microwave appliance is designed and built, starting from the magnetron, its characteristics and supply requirements, continuing with the waveguide(s), applicator(s), electronic devices for setting and driving, safety controls, shielding etc. Several principles must be observed, such as the matching between the magnetron, waveguide(s), applicator(s) and the treated material or object, the correct power supply for the magnetron and its surrounding devices, the adequate shielding against microwave leaks etc.

The microwaves can be used either for large-scale processes, such as seeds treatment (decontamination or sterilisation) [6, 8], meat thawing, wood drying etc, or for small-scale processes, such as pharmaceutical applications, medical diathermy, decontamination and reconditioning of patrimony objects [4], liquid food pasteurization [3] etc. This means that different power levels and different processing periods are required, and all these must be supplied by the microwave appliance and its command and control devices.

Greater power levels can be attained by grouping several units of magnetrons and power supplies on the same waveguide or applicator. Of course, the magnetrons themselves cannot be directly
connected in series or in parallel, but the inputs of their power supplies can be interconnected and driven adequately by the electronic command and control device. Furthermore, in the case of special exposure patterns for large-scale applicators with internal conveyors, the magnetrons can be individually switched on and off according to the process to be carried out.

Smaller power levels can be attained by time-division of the magnetron microwave emission, by periodically switching on and off its anode power supply. Also, small-scale processes involve short exposure periods, of minutes or even seconds, so the setting of the time-division clock becomes important in order to protect the small treated object from overheating, which can occur if the on/off switching is not fast enough in comparison with the total exposure time.

The electronic driving device, presented in this paper, is able to be fitted into a wide range of microwave appliances, either large-scale or small-scale, providing accuracy, reliability and reproducibility of the microwave treatments. It was designed and built by means of CAD-CAM-CAE applications and machines, and was successfully used for the research during the PhD thesis of Mr. Ursu and for several other research projects.

Of course, further improvements can be added to this device in the future, such as interfaces that communicate with computers fitted with fuzzy logic software [7], so that the parameters of the microwave treatment should be automatically optimized, loaded into the electronic driving device and run accordingly. Also, all the functions of this device can be emulated and even enriched by adequately programming a microcontroller device, using the newest technologies in micro-electronics, computing and programming.

References

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