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Redesign of the supply electronics of the temperature gauge in a HF CVD reactor

Rekonštrukcia napájacích obvodov merača teploty v HF CVD reaktore

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Abstract:
HF CVD (hot filament chemical vapour deposition) reactor is a technological apparatus in which carbon nanotubes are synthesized on various substrates. The reactor operates on the principle of pyrolysis of methane and hydrogen. The substrate is placed on a molybdenum holder, several millimetres below hot (2200 °C) tungsten filaments and its temperature during synthesis is optimized to approximately 600 °C. Measurement and control of the temperature of the rotating holder during synthesis are carried out by a temperature gauge with wireless optical data transfer. During operation of the facility a severe drawback was encountered, namely instable supplying resulting in temperature fluctuations in the reactor. This is why another solution has been designed utilizing a switched mode power supply. The measurement string has been simplified by removing mobile contacts and isolation amplifiers that behaved incorrectly – when they became overheated – and distorted the data on temperature. The result of the present work is the design and reconstruction of the circuitry supplying the temperature meter in the HF CVD reactor.

Anotácia:
HF CVD (hot filament chemical vapour deposition) reaktor je technologické zariadenie, v ktorom sa na rôznych substrátoch syntetizujú uhlíkové nanorúrky. Reaktor pracuje na princípe pyrolýzy metánu a vodíka. Substrát je umiestnený na molybdénovom držiaku niekoľko milimetrov pod žeravenými (2200 °C) volfrámovými vláknami a jeho teplota počas syntézy je optimalizovaná cca na 600 °C. Merania a regulácie teploty rotačného držiaku v priebehu syntézy sa vykonáva teplomerom s bezdrôtovým optickým prenosom dát. Počas prevádzky zariadenia sa vyskytol závažný problém, a to nestabilné napájanie, čo viedlo ku kolísaniu teploty v reaktore. To je dôvod, prečo bolo navrhnuté iné riešenie za použitia impulzného napájacieho zdroja. Merací reťazec bol zjednodušený odstránením mobilných kontaktov a izolačných zosilňovačov, ktoré po prehriatí pracovali nesprávne a skresľovali údaje o teplote. Výsledkom tejto práce je návrh a rekonštrukcia obvodov napájajúcich merač teploty v HF CVD reaktore.

MOTIVATION

The existing solution of the temperature gauge was described in detail in [1, 2]. Figure 1 is a photograph of the rotating part on which two printed circuit boards (PCBs) are placed with an isolation amplifier (IA), and with voltage-to-frequency (U/f) and frequency-to-voltage (f/U) converters. The bottom side of the rotating part carries a PCB with emitting diodes. Against the emitting diodes there are placed receiving phototransistors. Another non-rotating PCB carries the circuits for signal processing and filtration. This PCB is connected directly with the control unit of the reactor. The photograph shows also the copper rings connecting the supply voltage to the rotating part of the holder. The whole system is energized from a laboratory supply with symmetrical voltage ±12 V which is subsequently converted to ±15 V by DC/DC converters able to supply a current of up to 100 mA. Their insulation resistance is 1 GΩ. The DC/DC converters supply the preamplifier and the insulation amplifier. The temperature of the holder is sensed by thermocouples placed below the substrate inside the body of the holder. The voltage from the thermocouples is led, via a preamplifier, to the input of the isolation amplifier HCPL 7840. The signal from IA is led to the input of the U/f converter VFC 32 which converts the voltage to the frequency of optical pulses. These pulses are received by phototransistors and in another VFC 32 converter they are converted back to a continual voltage. The signal is then filtered and led to the control unit of the reactor.

RECONSTRUCTION OF THE SUPPLY CIRCUITRY

For resolving the instability of supplying the temperature meter problems a transformer has been used working as a switched mode power supply. The source is operating on the principle of an accumulating converter, the so-called flyback (Fig. 2). Energy is accumulated in the magnetic field of a transformer or in the electric field of a capacitor. The current flows through the primary winding of the transformer, when the transistor is switched on. The energy accumulated in the core of the transformer is released via the current in the secondary winding into the load during the period, when the switch is open. The output voltage can be changed by the turn ratio of the transformer.

The pot-shaped ferrite core P 36×22 of the transformer was produced by Pramet Šumperk, Czech Republic. The coils are wound on two independent frames and slipped over the halves of the potcore overlapping one another. The optical signal passes from the photodiodes into the phototransistors through the central opening.

Circuit design of the new supplying system of the temperature meter was simulated in OrCAD (available on the Internet). The simulated variable was the output voltage at a constant current drain. The input data for simulation were obtained by measuring on the old temperature meter. The results of simulation provide the starting point for implementation of the new supplying circuitry shown in Fig. 3.

The grid voltage is connected to a 2×24 V transformer ensuring that the source will operate with a safe voltage with amplitude U_{max}≈50 V. The output voltage from the transformer is rectified and filtered by an electrolytic capacitor and switched by a unipolar transistor into the primary coil of the potcore transformer. A fast diode with a load resistor (the so-called snuber) is connected in parallel with the primary coil to protect the transistor. The rectified and filtered voltage feeds also the positive voltage regulator LM7812 supplying the driver of the transistor during the start-up. Switching of the circuit

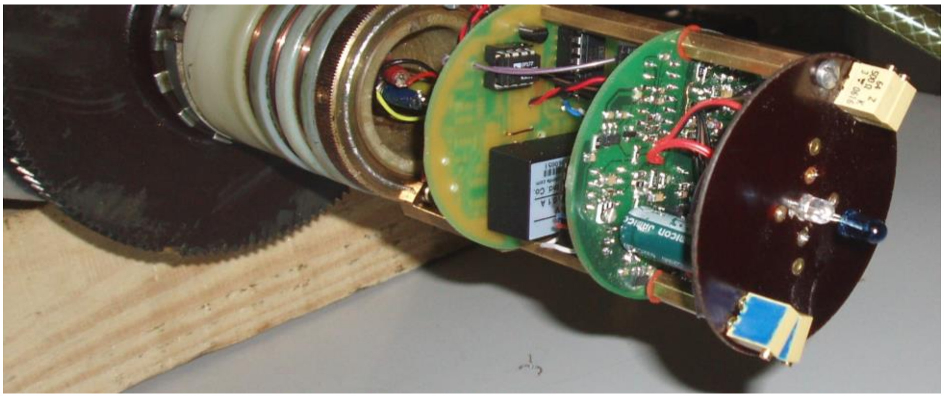

Fig. 1: Rotating part of the temperature meter on which two printed circuits are placed with an isolation amplifier, a voltage-to-frequency converter and optical-to-electrical signal converters.

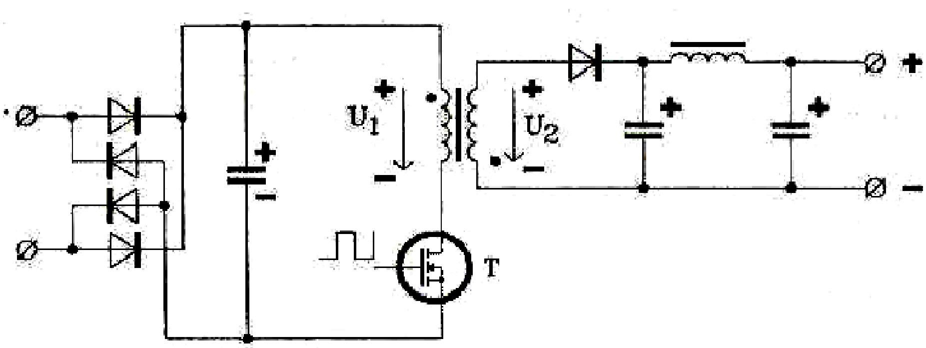

Fig. 2: Accumulating inverter of flyback type. The picture is taken from [3] and modified.

is performed by two precision timers NE555. One of them is connected as an astable multivibrator, the other one as a monostable multivibrator defining the length of generated pulses. The timer in cooperation with the comparator which compares the regulating signal with the voltage on a resistor conducting the current through the primary coil of the transformer create a PWM regulator working in the current mode.

The signal from the PWM regulator is led to the driver and the gate of a unipolar transistor. The driver is fed by DC voltage 15 V from an auxiliary winding of the transformer. Regulation of the output voltage is performed indirectly. The voltage induced on the auxiliary winding is red by a Zener diode and an optocoupler. The output of the optocoupler generates the regulation signal for the PWM regulator.

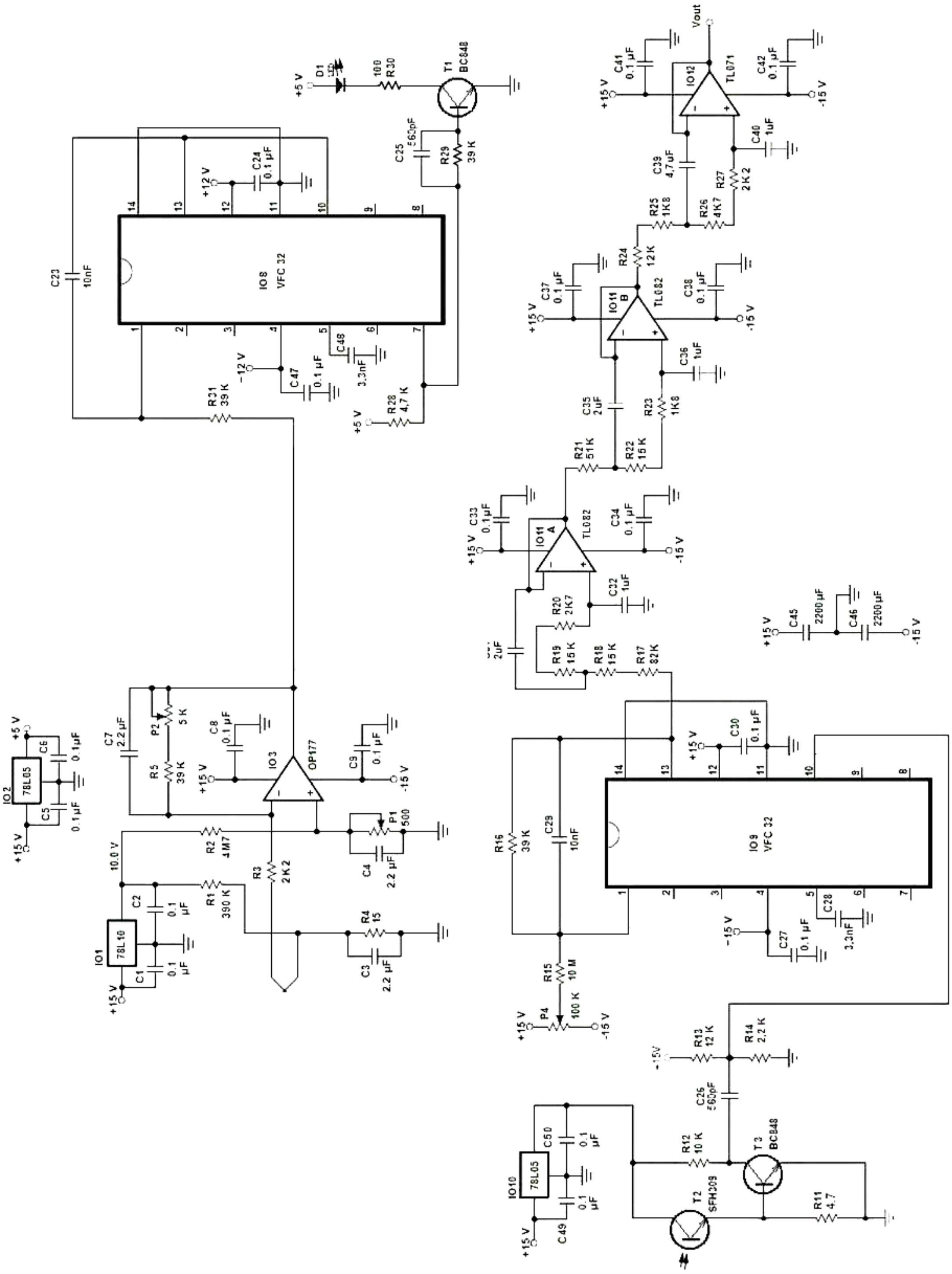

Fig. 3: Full circuitry of the reconstructed temperature meter in the HF CVD reactor. The scheme should be compared with that in Fig. 4 in ref. 2.

CONCLUSION

The hitherto temperature meter has a preamplifier and an isolation amplifier that are galvanically isolated. This isolation is achieved by DC/DC converters. Reconstruction of the supplying circuitry makes the whole transmitting part independent and completely separated from all other circuits of the measuring system. From the existing system it will be possible to leave out the isolation amplifier as well as the DC/DC converters. Hereby the circuitry will be simpler, with low power consumption and without undesirable effects resulting from overheating of the DC/DC converters. Naturally, the circuit elements for setting the offset and voltage amplification have to be adjusted.

ACKOWLEDGEMENT

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