Electronic system for Langmuir probe measurements

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Abstract. A newly developed Langmuir probe system for measurements of current-voltage (IV) characteristics in the tokamak divertor area is presented and discussed. The system is partially controlled by a computer allowing simultaneous and independent feeding and registration of signals. The system is mounted in the COMPASS tokamak, Institute of Plasma Physics, Academy of Sciences of the Czech Republic.

The new electronic circuit boards include also active low-pass filters which smooth the signal before recording by the data acquisition system (DAQ). The signal is thus less noisy and the data processing is much easier. We also designed and built a microcontroller-driven waveform generator with resolution of 1 Ms/s. The power supply is linear and uses a transformer. We avoided the use of a switching power supply because of the noise that it could generate.

Examples of measurements of the IV characteristics by divertor probes in the COMPASS tokamak and evaluation of the EEDF are presented.

1. Introduction
Langmuir probes are known for their ability to provide local measurements of very important plasma parameters, namely, the plasma potential, the electron density and the electron energy distribution function (EEDF) [1-3]. The probes are the least expensive and are still the fastest, most reliable diagnostic tool to acquire local values of the plasma parameters, but their application in strongly magnetized tokamak plasma is still under discussion [4-6].

Since we use the new advanced first-derivative method to evaluate the plasma parameters, the main problem to be solved was eliminating the noise originating from vacuum pumps, magnetic field coils, etc, i.e. noises of non-plasma origin.

In this work we present the new electronic system for measurements of the current-voltage (IV) characteristics in the tokamak divertor area on the COMPASS tokamak.
2. Probe circuit
The device described is the product of two years of research and development after all divertor probes characteristics were taken into account. The differential amplifier, made by Tsv. Popov’s research group (Mladen Mitov, Ana Bankova and collective) was designed for current voltage (IV) characteristic measurements in COMPASS tokamak (IPP, CR) edge plasma. In the previous version of the amplifier, the signal was measured in a fully differential manner. This is why the common mode signal was high (~100 V). Although the amplifier had high common-mode rejection ratio (~77 dB) the signal at the output of the amplifier caused by the ion saturation current and the signal caused by the common-mode signal were comparable. To avoid this problem, we chose to use common ground measuring (while keeping the possibility of fully differential measurements). The common ground measurement has the advantage of absence of common mode signal, and the disadvantage of necessity of a power amplifier in each channel.

The probe circuit used to measure the signal of the divertor probes is presented schematically in figure 1 a, b.

![Figure 1. Schematic diagram of the probe circuit used to measure the IV divertor probes characteristics: a) fully differential measurement, b) common ground measurement.](image)

![Figure 2. Electrical circuit for measuring voltage and/or current by the divertor probes.](image)
The electrical circuit for measuring the voltage and/or current by the divertor probes is presented in figure 2. The amplifiers have characteristics superior to the ones that are currently used. They avoid the main problems previously encountered – the inability to suppress sufficiently the common-mode signal, so that the true signal and the noise generated by the common mode signal were comparable. This necessitated complicated and time consuming data processing. In addition, a set of low-pass filters was added to the amplifier circuit in order to (when necessary) suppress the high-frequency noise generated by the plasma itself. The new cards are second generation electronics, made by Tsv. Popov’s research group in Bulgaria, and are shown in figure 2.

3. Langmuir probe measurements in COMPASS divertor area

The divertor probe system in COMPASS consists of 39 single graphite Langmuir probes embedded in parallel to the magnetic field in the divertor target providing profiles with typical spatial resolution in the poloidal direction down to 5 mm. A sweeping voltage (typically in the range $-100 \, \text{V} - +40 \, \text{V}$) is applied to generate the current-voltage characteristics. The sweeping probe bias $U_p$ (a) and the probe current $I$ (b) during shot 1597 recorded by probe 5 are presented in figure 3.

![Figure 3](image-url)

**Figure 3.** a) Probe bias $U_p$ and b) probe current $I(U_p)$ as a function of the time $t$ during shot 1597 for probe #5.

![Figure 4](image-url)

**Figure 4.** Single IV characteristic, shot #1597 for parallel probe #5, IV 4 (dots).

![Figure 5](image-url)

**Figure 5.** The EEDF obtained by using the first derivative probe method.
The method of evaluating plasma parameters, such as the EEDF, respectively the electron temperature and density, and the plasma potential, have been presented and widely discussed in our previous works [7,8]. Using the data obtained, we can construct the single IV characteristics (figure 4). Figure 5 presents the EEDF obtained by parallel probe #5, shot 1597 (dots). The EEDF can be approximated by a Maxwellian with electron temperature $T_e = (4.1 \pm 0.3)$ eV (solid line). The uncertainties in the values are calculated by regression analysis and the electron temperature was evaluated with accuracy of 7%. The best fit for plasma potential evaluation was sought with an accuracy of about 15%.

Conclusions
A newly developed Langmuir probe system for measurement of the current-voltage (IV) characteristics in the tokamak divertor area is presented and discussed. The system is partially controlled by a computer allowing simultaneous and independent feeding and registration of signals.

The system is mounted in the COMPASS tokamak, Institute of Plasma Physics, Academy of Sciences of the Czech Republic and can also be used for other probes installed in the COMPASS tokamak.

Examples of measurements of the IV characteristics by the divertor probes in COMPASS tokamak and evaluation of the EEDF are presented.

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References
[1] Chen F F 1965 Electric Probes in Plasma Diagnostic Techniques eds Huddleston R H and Leonard S L (Academic Press New York) Chap 4 pp 113-200
[2] Swift J D and Schwar M J R 1969 Electrical Probes for Plasma Diagnostic. (Elsevier, New York)
[3] Hershkowitz N 1989 How Langmuir Probes Work in Plasma Diagnostics I eds Auciello O and Flamm D L (Academic Press Boston) Chap. 3
[4] Demidov V I, Kolokolov N B and Kudriavtsev A A 1996 Probe Methods for Low-Temperature Plasma Investigations (Moscow: Energoatomizdat, in Russian)
[5] Arslanbekov R R, Khromov N A and Kudryavtsev A A 1994 Plasma Sources Sci. Technol. 3 528-538
[6] Godyak V A and Demidov V I 2011 J. Phys. D: Appl. Phys. 44 233001
[7] Popov Tsv K, Ivanova P I, Stockel J and Dejarnac R 2009 Plasma Phys. Control. Fusion 51 065014
[8] Ivanova P, Popov Tsv K, Dimitrova M, Benova E, Bogdanov T, Stöckel J and Dejarnac R 2011 Acta Technica 56 Т71-T83