Op amp improves plasma probe's sensitivity

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In measuring extremely small currents, a probe electrode must have its voltage supply isolated from the current amplifier if leakage of the supply currents is not to limit the accuracy of the measurements. The need for such isolation vanishes, however, if the voltage is applied to the probe through an operational amplifier, as shown in the figure.

One use for this technique is in the measurement of the electron density and temperature of a plasma. An alternating voltage is applied to the electrode in contact with the plasma, and currents ranging from milliamperes to picoamperes are collected [*Electronics*, May 25, 1962, pp. 18–19]. The circuit shown here was developed for use in the ionosphere, with the probe projecting from the body of a rocket into the atmospheric plasma.

Voltage E_i is applied at the noninverting input terminal of operational amplifier A_1 and, because of the enormously high open-loop gain of the operational amplifier, appears at the inverting input terminal. This inverting input terminal is connected directly to the electrode without any series resistance so that currents drawn by the probe will not change the probe's voltage level. Operational amplifier A_1 has a field-effect-transistor input with a bias current of only a few picoamperes. Therefore, if I is the current drawn from the plasma, the output of A_1 is given by:

$$E_{o1} = E_i + IR_1$$

The second operational amplifier, A_2, is used as a differential amplifier to prevent applied voltage E_i from appearing at the output. The final output voltage is:

$$E_o = (R_3/R_2)IR_1$$

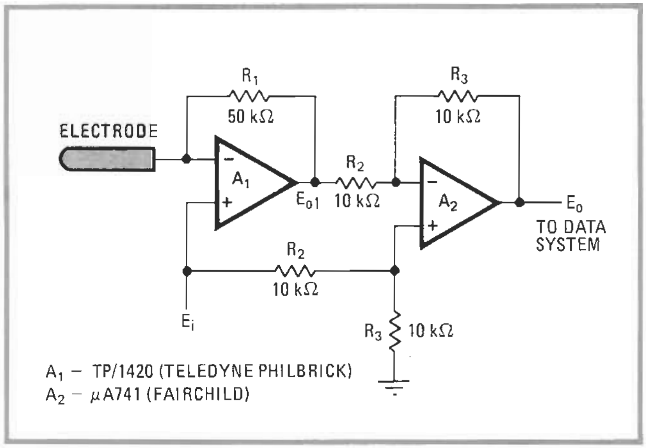
so the current drawn by the probe is given by:

$$I = R_2E_o/R_1R_3$$

The output voltage can be recorded on board the rocket or telemetered to a ground station.

To permit measurements over a large dynamic range—a necessity in most plasma-probe measurements—feedback resistor R_1 may be replaced by a network with a logarithmic response.

The circuit has measured currents from 1 milliampere to 0.1 nanoampere. The bias current of A_1 is only 15 picoamperes, so currents as small as 50 pA can be measured. □



Plasma probe. Rocketsonde studies of density and temperature of electrons in the ionosphere may be achieved by measuring the current drawn to an electrode that projects out and is well insulated from the rocket body. The circuit shown here applies potential to the electrode through an op amp, thus avoiding voltage-supply-insulation problems and leakage errors in current measurement. Circuit measures currents from 10^{-3} amperes down to 5×10^{-11} A.