the plasma ranged between 0.5 to 0.7. If the lymph radioactivity is not measured, $R_l^{(t)}$ can be considered as being approximately 0.6 $R_p^{(t)}$, for periods after equilibration, and accordingly the tissue space can be estimated in normal animals without tapping lymphatics, with an accuracy of about ±20%.

There are numerous reports in the literature (reviewed by Drinker [*3*]) on the albumin concentration of the lymph in different parts of the body, and the Bollman (*12*) type of cannulation enables a crude estimation of the relative quantity of lymph in different parts of the body.

The tissue space of any part of the body can also be estimated as follows: The plasma volume of an organ or given part of the body is determined by injection of I^{131}-tagged albumin, and the organ activity is measured after the mixing time of 5–10 min (*13*). Similar determinations of organ activity are made after equilibration. These measurements may be made with ease with the aid of the gamma ionization chamber (*14*). The organ activity after equilibration is due to the combined albumin activity in the blood and tissue space of that organ. Thus, the following values are obtained: (*a*) plasma volume, (*b*) organ plasma volume, (*c*) combined organ radioactivity in plasma plus lymph, and (*d*) activity per unit volume of plasma. The unknown is (*e*), activity per unit volume of lymph, which is a function of the albumin concentration of the lymph. The protein concentration of the lymph of different organs or parts of the body is known in the literature (*3*). Using these values, the tissue space (volume) can be calculated in a manner similar to that outlined above.

A more precise determination can be made by actually measuring the lymph activity and by remeasuring blood plasma and organ plasma volumes after equilibration with a different isotope—e.g., C^{14}.

These considerations probably apply to all mammals. Under pathological conditions resulting in increased permeability, the ratio of albumin concentration in the lymph to that in the plasma may approach unity, thus setting an upper limit for the lymph space. In our experiments the lowest conversion factor (ratio of albumin concentration in lymph to plasma) was 0.5. It is possible that with some pathological states the conversion factor is even lower.

At present I^{131}-tagged albumin (*15*) is the best for this purpose. Albumin naturally labeled with C^{14} would be preferable.

The approximate tissue space (volume of lymph) can be estimated by measuring the quantity of labeled albumin per unit volume of blood plasma after mixing time, and of blood and lymph after equilibration time. After allowance for metabolism the loss in blood activity during equilibration time is a function of the albumin mass in the lymph. In normal dogs and some other species, a conversion factor of 0.6 can be used if lymph activity is not measured. The loss in plasma activity multiplied by this conversion value (ratio of albumin concentration between lymph and plasma) is proportional to the tissue space (lymph volume).

Mathematically this may be expressed as follows:

$$R^* e^{-kt} = R_p^{(t)} \, (V_p + 0.6 \, V_l).$$

The conversion factor is raised with heightened permeability, the theoretical maximum being unity. This simple procedure enables approximation of the lymph volume without sampling lymph.

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A Multirange Recording and Control System for Electrical Measurements

J. C. Pigg

Oak Ridge National Laboratory,
Oak Ridge, Tennessee

In studying the effect of nuclear reactor irradiation on the electrical properties of semiconductors, it is desirable to record automatically the temperature and resistivity during irradiation as a function of exposure time. One records (1) the output voltage of a thermocouple, (2) the potential drop across a fixed portion of the sample, and (3) the current as determined by the potential drop across a standard resistor.

The change in resistance of the sample under bombardment may be of the order of a few per cent over time periods of several days, as in the case of low resistivity P-type Ge, or it may be several orders of magnitude in a few hours as in the case of Si and Cu_2O: thus resistances from 0.001 ohm to 100 megohms have to be measured and recorded directly to within ±0.1% accuracy. The temperature may vary from −78° C to 50° C in a single experiment. In addition, it is frequently desirable to expose two or more samples simultaneously for comparison purposes. Some samples—e. g., rectifiers—are non-ohmic, in which case current or voltage has to be held constant at predetermined values.

A device fulfilling these requirements has been constructed and is now in use at this laboratory. The instrument consists of a multipoint potentiometer strip chart recorder, the necessary current and voltage control circuits, an essentially infinite impedence voltage-measuring device, the necessary automatic switching and scale-changing circuits, and a system of component terminals which facilitates the use of those components necessary for a given circuit (Fig. 1).

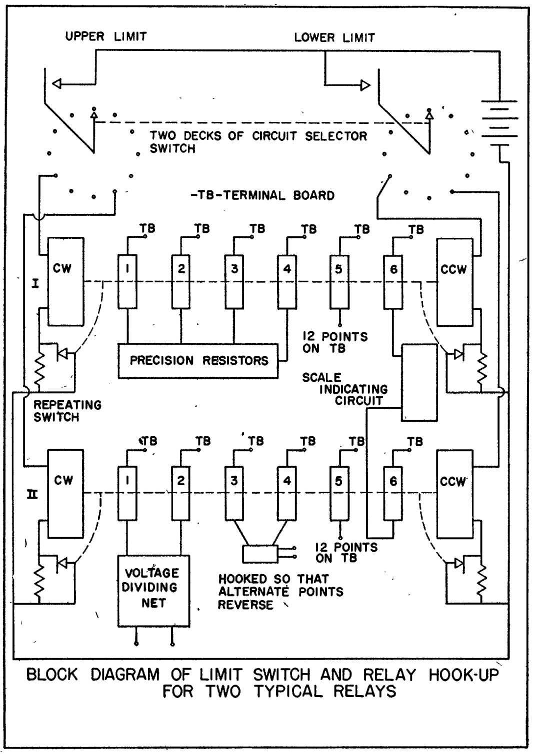

Fig. 1. Block diagram of scale-changing circuit shows two typical relays. Relay I is the type used for current measurement. The current leads to the resistors are I (1 and 4) and the potential developed across the standard resistors is read across I (2 and 3). In 5 all points leading to the terminal board are available, and any desired circuit can be connected through it; 6 is used to select a voltage which records the position of the relay on a free point on the recorder. Relay II differs from Relay I in that poles 1 and 2 select positions in a potential divider circuit for voltage scale changes, and points 3 and 4 are used as automatic reversing switches.

The basic unit is a modified 12-point Brown Electronic strip chart recorder of the potentiometer type employing a 0–3 mv scale. This scale was chosen because this is the magnitude of the voltage from a copper-constantan thermocouple for temperature ranges normally encountered in these investigations. The modifications of the recorder consist of careful shielding from stray pickup, increasing the input impedance and sensitivity of the amplifier corresponding to a model 13-R-23, provision for preamplification, and addition of limit switches and a circuit selector switch mechanically coupled with the Brown printing wheel and input selector switch. Standard parts are used except for the input filter capacitor and input transformer, which are obtainable from the manufacturer of the instrument.

For high resistance work, both for current and voltage drop measurements, a Model 30 Vibrating Reed Electrometer (VRE) (*1*) is used,[1] the low impedance side working directly into the recorder (Figs. 2, 3). Special switches provide direct reading of the thermocouple output on the recorder.

Each unit of the limit switches consists of two mercury switches, and each mercury switch is independently adjustable. This allows two limits to be set simultaneously at the high and low end of the scale. For example, it is desirable to change current or voltage scales whenever the reading falls below 10% of full scale; however, reversal of thermocouple leads is not desirable until the potential goes through zero. A similar arrangement is possible at the high end of the scale.

A 12-point, 6-pole (deck), shorting type rotary switch[2] is ganged with the Brown printing wheel and input selector switch in order to (1) utilize the Vibrating Reed Electrometer for preamplification, (2)

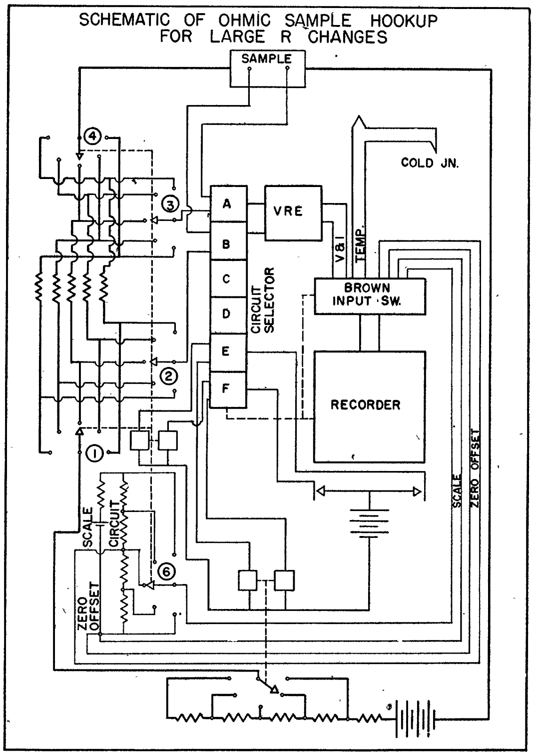

Fig. 2. A circuit for samples with large resistance changes.

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[1] A preamplifier designed by J. L. Horton, of the Instrument Division of this laboratory, can be used for resistances up to 10 megohms. It requires only 3 mv input, the same as the amplifier, and thus no external switching is needed for its use.

[2] The switches used are L & N type 31-3 selector switches. They are designed for this type of operation and are rated as follows: dielectric strength between points and to ground greater than 500 v RMS; continuous current capacity, 5 amps; thermal emf less than 1 μv; contact resistance less than 0.001 ohm; insulation resistance of the order of 10^6 megohms.

select the proper relays, and (3) control external circuitry. Two poles are used for the switches, and the remaining two poles are available for limit switches or external circuit changes.

The automatic scale-changing is accomplished by stepping switches (CW and CCW) actuated by double-acting rotary solenoids,[3] which are energized through the limit and circuit selector switches (Fig. 1). Whenever a point reads too high or too low, the respective limit switch is closed. The circuit selector switch selects the proper relay, and the relay is actuated to change the external circuit to bring the data back on scale. The relays (repeaters) continue to act until the proper circuit change is made. This feature is necessary whenever changes greater than an order of magnitude may be required (Fig. 1).

For experiments in which the resistance changes slowly and the sample is expected to be ohmic, helipots and standard resistors are provided so that the power control units need not be employed. For ohmic samples that have large changes in resistance, a resistor bank can be connected to pole 5 of any unused relay so that the resistance in series with the sample may be varied to keep the voltage reading on scale (Fig. 4).

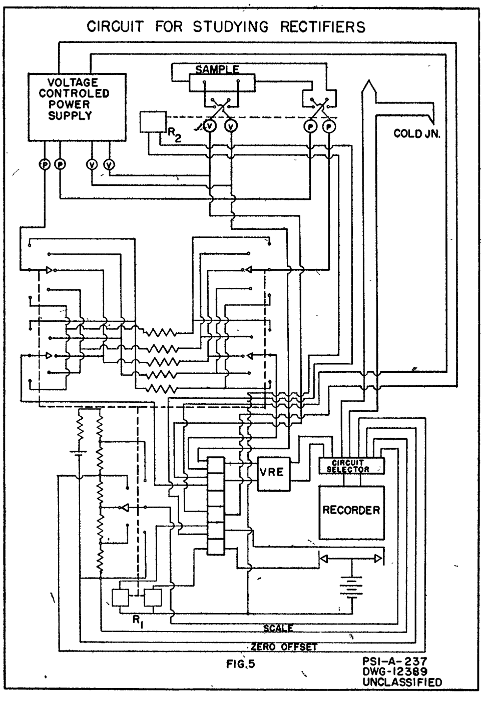

FIG. 3. A circuit for studying rectifiers.

For non-ohmic samples, either the voltage across the sample or current through the sample must be kept constant, and there are times when ohmic samples should be studied under such controlled conditions. Power supplies have been provided for this purpose.[4]

This system is applicable to many types of voltage control and measurement problems. A few are presented to illustrate the manner in which the instrument is being used.

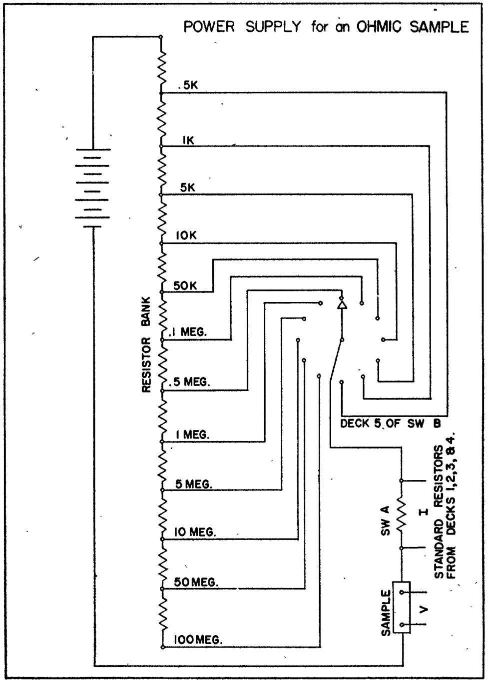

FIG. 4. Power supply for ohmic samples.

The most simple type of circuit is that involved in the study of a slowly changing low resistance ohmic sample. Fig. 5 shows such a circuit with the possible power supplies indicated by dotted lines. The current is read by recording the voltage developed across a standard resistor R_i. The voltage developed across a fixed portion of the sample is read directly. The temperature is recorded as the voltage from the thermocouple.

If no power control is necessary, a battery with a series dropping resistance R_d may be employed. If power control is necessary, the constant voltage or constant current supplies may be hooked into the circuit.

Fig. 2 shows typical circuitry for samples with resistance changes of several orders of magnitude. For simplicity, only 5 points of the relay switches are shown. The relay poles (1 and 4, 2 and 3) correspond to relay I of Fig. 1. The alternate power supplies are not shown. The dropping resistance in series with the battery is varied by means of the limit switches and a

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[3] The relays are double-acting solenoids manufactured by G. H. Leland, Inc., Dayton, Ohio.

[4] A constant current power supply has been designed and constructed by F. W. Manning and M. R. Smith, of the Instrument Department of this laboratory. Two power supplies, which can be used for either constant current or constant voltage, have been designed and constructed by B. M. Hilderbrant, of the Instrument Department. One of the latter was designed for use with moderate resistivity samples. The other, because of superior insulation, can be used for samples the resistance of which is of the order of 100 megohms.

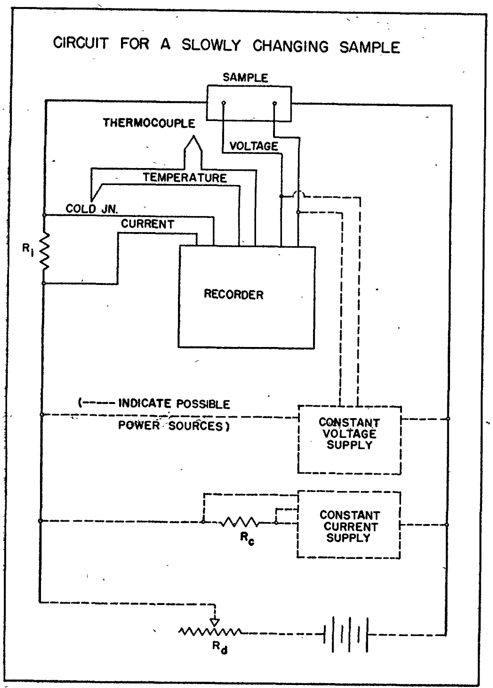

FIG. 5. A circuit for slowly changing samples.

relay in order to keep the voltage on scale. The standard resistances across which the current is read can also be varied by means of a relay to provide for automatic scale changing. Pole 6 of the relay selects a voltage from a scale circuit, which is then printed on the record.

A voltage is applied to the point preceding the series of readings and thus prevents spurious tripping of the relays.

The circuit selector switch is used to select the input to the Vibrating Reed Electrometer and to select the points on which the relays will be actuated. The output of the electrometer, as well as all other voltages, is then applied to the recorder through the recorder input switch.

The simplest use with a non-ohmic sample is the resistance measurement of a rectifier. Fig. 3 shows a schematic circuit of this type. Again, for simplicity, only 5 points are shown on the switches. The current scale, scale indicator, temperature voltage, and current measurement are the same as shown in Fig. 2. By means of relay R_2, the sample is reversed each cycle of the recorder. The voltage-controlled power supply can provide a different voltage for each point. By monitoring the voltage and reading scale indicator for every other current point, and recording temperature once each cycle, 6 points of the rectifier curve can be followed for both directions of the rectifier, giving a complete characteristic curve about once every 2 min.

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An Interpretation of Bond Lengths and a Classification of Bonds

R. T. Sanderson

Department of Chemistry and Chemical Engineering, State University of Iowa, Iowa City

A visualizable representation of atoms in combination which would help to explain observed bond lengths has long been needed. An empirical method of correcting covalent radius sums for electronegativity differences has been proposed (*1*), but objections have been raised (*2*). "Anomalous" lengths of both single and multiple bonds are customarily ascribed to "resonance" among covalent and ionic, or single and multiple bond structures (*3–5*), an explanation which is far from satisfying (*6*) and is artificial in many of its applications, without being completely helpful in permitting a clear concept of the nature of the molecular structures. A method which allows ready visualization and which has been quite successful, not only for estimating bond lengths but also in classifying bond types according to length, is here outlined.

The physical picture permitted by this method is simple and straightforward. It is well known that the electronic spheres of atoms expand when electrons are taken on to form negative ions, and contract when electrons are removed to form positive ions. It seems perfectly reasonable to suppose that such change in size is not restricted to ion formation but occurs much more generally, whenever the electrons involved in a covalent bond spend more than half-time more closely associated with one atom than with the other. This would be in any polar covalent bond.

The time-average equilibrium position of two electrons forming a covalent bond must be such that the attraction of both atoms for the electrons is equal. If the attraction was initially unequal, this means that an adjustment has occurred. In the equilibrium position, the valence electrons must be more closely associated with the atom which initially attracted them more. In effect, this atom has assumed a fractional negative charge. This causes its electronic sphere to expand, so that its radius increases. As its radius increases, its attraction for the valence electrons decreases. The other atom similarly has assumed a fractional positive charge, causing a contraction of its electronic sphere, decreasing the radius. As its radius decreases, the attraction of this atom for the valence electrons increases. This adjustment of the radii of the atoms ceases when their attraction for the electrons has become equal. The bond length is the sum of the *adjusted radii.*

In a covalent bond, the attraction of an atom for the valence electrons is the electronegativity (3). Therefore, if a quantitative relationship between electronegativity and atomic radius were known, it could serve as a basis for calculating the adjusted radii and therefore the bond lengths, assuming the electronegativities to become equal in the process of bond formation.