OHMMETERS

An ohmmeter measures direct current (dc) electrical resistance (in ohms), a basic electrical quantity. Most commonly, it is one function of a digital multimeter (DMM), which combines voltage (*V*), current (*I*), and resistance (*R*) measurements in one instrument. These three quantities are related through Ohm's law, $V = RI$. Multiple ranges (by factors of 10) are needed to cover the wide range of resistance normally encountered in electrical/electronic devices (0.01 Ω to 10 MΩ). More specialized meters cover much lower and higher ranges (below 10^{-6} Ω and above 10^{15} Ω).

Generally dc resistances are highly linear; that is, they obey Ohm's law to within measurement precision. This is especially true of commercial resistors and of metal conductors such as copper. Three exceptions are (1) temperature-sensitive resistors, which are heated by the power dissipated in the resistor; (2) semiconductor devices such as diodes, which may have very nonlinear I–V properties; and (3) ionic conductors, including biomedical electrodes and aqueous solutions.

Resistance may be measured by applying a known voltage (constant voltage sample) across the device under test and measuring the current that flows, or by applying a known current (constant current source) and measuring the voltage developed across the device. The current and voltage are limited to avoid damage to the device being tested (e.g., 5 V or 10 mA). Ohm's law is used to convert to resistance with the appropriate scaling factors. For example, a 1 mA current source will produce a 1 V drop across a 1 kΩ resistor so that a voltmeter calibrated as an ohmmeter (e.g., 1 kΩ at 1 V) will read the resistance out directly.

Digital ohmmeters have an analog input section with an operational amplifier to supply a constant current (Fig. 1). The amplifier adjusts its output so that the voltage drop produced by the current, across a known internal resistor, is equal to a reference voltage.

Switching the internal resistor changes the current (source) range and thus the resistance range. The operational amplifier will produce a constant current only up to a maximum voltage, which is chosen to be above the corresponding full scale of the readout. In any case, it is less than the amplifier supply (e.g., battery) voltage.

Loading effects of the voltmeter may limit the upper resistance range, as indicated in Fig. 2. An ideal voltmeter would have an infinite resistance and draw zero current. FET input amplifiers approximate this requirement. The meter input resistance R_{mi} and/or input leakage current provides a shunting path to the current provided by the current source so that the effective resistance R_x is reduced. Input impedances over 10^{10} Ω and input under 0.1 nA are readily achievable with FET-type operational amplifiers. Most commercial DMM and DVMs (digital voltmeters) have a built-in dual-ramp-type analog-to-digital converter and also drivers for three or four digital (seven segment) displays.

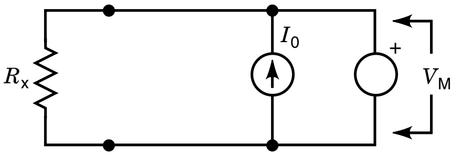

Figure 1. Digital ohmmeter.

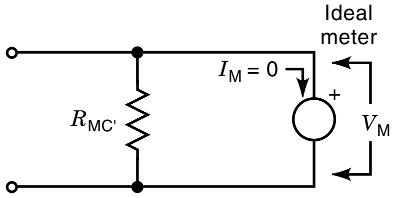

Figure 2. Voltmeter loading effect.

Older design ohmmeters use a moving coil milliammeter or d'Arsonval meter as an analog indicator. As illustrated in

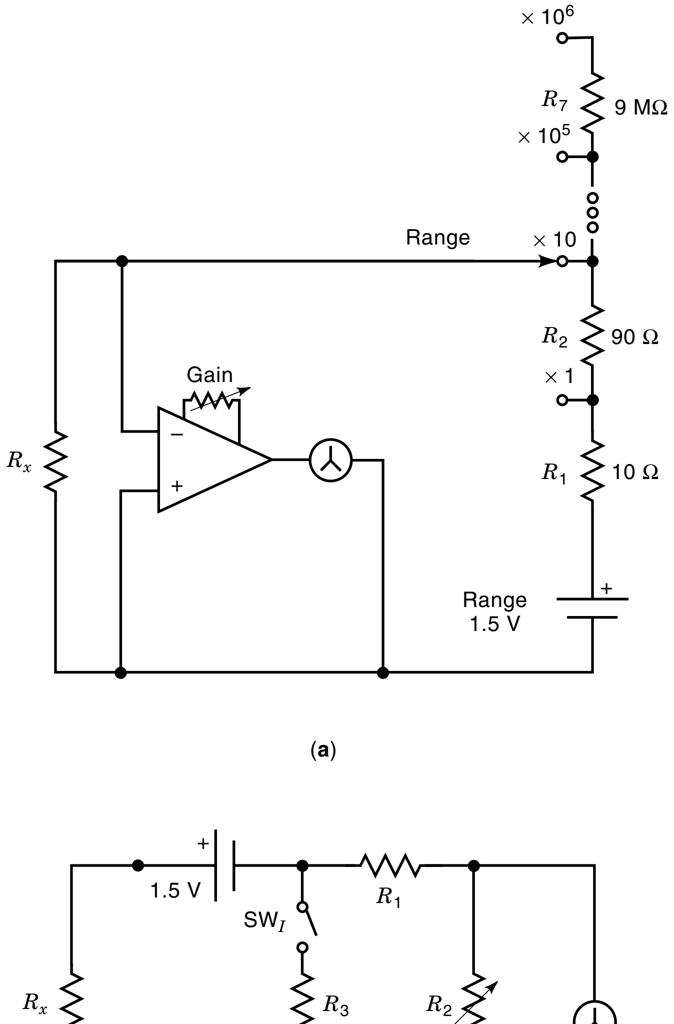

Figure 3. Analog indicator ohmmeters: (a) shunt type and (b) series type.

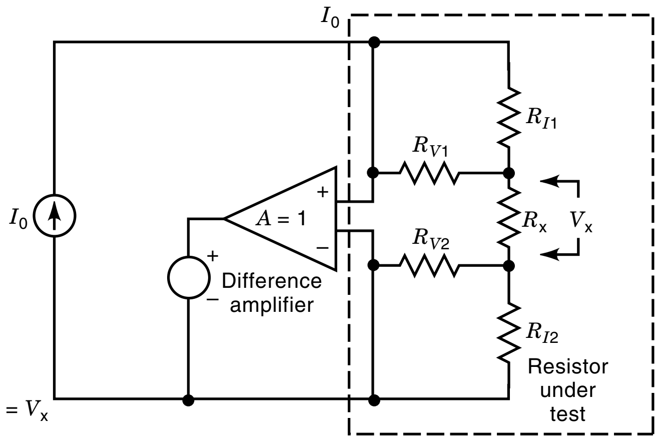

Figure 4. Example of a four-probe or kelvin method of measurement.

Fig. 3, they may use operational amplifiers or other amplifiers. There are two general types: shunt and series. With the series type, the unknown resistance R_x is connected in series with a battery (e.g., 1.5 V) and the milliammeter. A variable resistor R_2 compensates for variable battery voltage. It is adjusted so that the meter is full scale when the leads are shorted ($R_x = 0$). The scale marked on the meter face is nonlinear, a disadvantage, since the current is inversely proportional to the resistance. At the low-current end, the resistance is infinite. This causes increasing crowding and inaccuracy at the high-resistance end of the scale. The resistance range can be reduced by introducing one or more current shunting resistors at position R_3. A multiple position switch SW_i is used for multiple ranges.

With a shunt-type ohmmeter, the unknown resistance R_x is in parallel with the voltmeter readout (Fig. 3b), but the voltage source and standard resistor ($R_s = \mathrm{R}_1, \mathrm{R}_1 + \mathrm{R}_2, \ldots$) is in series. The gain resistor is adjusted so that the meter is full scale at $R_x = \infty$. Half scale corresponds to $R_x = R_s$ and 0 V to 0 Ω. The scale is obviously also nonlinear. The amplifier can be replaced by a milliammeter acting as a finite-resistance voltmeter, but the sensitivity is less.

Low-resistance measurements may be inaccurate because contact and lead resistances become a significant fraction of the measured resistance R_x. Contact resistances in the 0.01 Ω to 0.1 Ω range are common. Often they are not reproducible. To overcome this, a four-probe or Kelvin method of measurement may be used (Fig. 4). A constant current source I_0 supplies the current through the resistor under test. The current passes through the "current" probes or leads with presumably low, but otherwise unknown resistances (R_{I1}, R_{I2}). Assume that the total load on the current source ($R_x + R_{I1} + R_{I2}$) is within its linear output voltage range; the source will deliver the specified current I_0 independent of the load, even if the contact and lead resistances change. The voltage drop as measured across the resistance and also, if unloaded, at the voltage probes or leads V_x is exactly I_0R_x. The differential or instrumentation amplifier, which must have a high common mode rejection and high input resistance, transfers this balanced voltage to the measurement voltmeter, which is unbalanced with respect to ground (one input grounded). Thus $R_x = V_xI_0$, independent of contact resistance. Some ohmmeters (over 20 MΩ) intended for very high resistance such as insulation resistance use a relatively high source voltage (e.g., 100 V or more). This is because insulators will absorb (soak) charge for some time after the potential is applied so that a stable reading in a reasonable time is not obtained unless higher voltages are used. Care must be taken in this case not to damage the device being tested by overvoltage.

Reading List

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OHMMETERS. See BRIDGE CIRCUITS.

OIL. See LIQUID INSULATION.

OIL INDUSTRY. See PETROLEUM INDUSTRY.

1/*F* FLUCTUATIONS. See NOISE, LOW-FREQUENCY.

ONE-PASS SIMULATION. See STACK SIMULATION.

ONLINE DOCUMENT PRODUCTION/REVISION. See ELECTRONIC DOCUMENT PRODUCTION.