Heathkit IM-102 (and Weston 1240)

Circuit description of the Ohms function

Definitions:

- IC1 (U101 on the 1240) = Main input amplifier/integrator
- IC2 (U102 on the 1240) = Ohms function test-current-source amplifier
- RIS = reference current source (uses Q3 or U103 on Weston)
- Rs = scaling resistor, part(s) of voltage divider precision resistor network Z101
- Rf = integral resistance of the Ohms function fuse
- Rx = resistor under test (connected to test terminals "V/Ω" and "Com")
- Vrx = voltage drop across Rx (resistor under test)

1) To measure resistance of Rx, the meter passes a known current through Rx and measures the voltage drop across it, Vrx. Vrx is applied to the (+) input of integrator op-amp IC1. Note that for other functions, e.g. Volts or Amps, a different voltage signal source is switched to provide the IC1 (+) input.
2) Even though the IC1 op-amp is functioning as an integrator, because it has negative feedback it is always working to keep the voltage at both inputs the same. Thus, IC1's (-) input will also be Vrx, and the voltage at this (-) input is also applied to the (+) input of IC2. Note that the 100k resistor at the (-) input of IC1 is not significant in this instance, being much smaller that the input impedance of IC1, and the feedback current is coming from the side of the resistor that also connects to IC2.
3) A constant current source (or more accurately a current sink) 'RIS' draws 1mA from the (-) input node of IC2. Because current cannot flow from the (-) input, it passes from IC2's output, through a 1k feedback resistor, and per Ohm's Law it drops 1V across that resistor.
4) In order for IC2 to function as a normal op-amp (with both inputs having equal voltage when there is negative feedback), IC2's output must be equal to Vrx + 1V (i.e. the 1V from the voltage drop from item 3 above, plus the Vrx coming from IC1's virtual copy of the voltage drop across the resistance under test).
5) Since the scaling resistor(s) Rs is connected from the output of IC2 to the meter's "Ohms" input terminal via the Ohms function's fuse Rf, and the resistor under test Rx connects between the Ohms terminal and circuit ground, this forms a voltage divider and thus the voltage across (Rs + Rf) must be (Vrx + 1V) – Vrx, or 1V. Thus, V(rs + rf) is always = 1V, regardless of selected Ohms range (and the value of Rs).
6) The current though Rs (and also through Rf) is then determined only by Rs and will be constant, independent of Rx.
7) With the extremely high input impedance of IC1 (in which situation the added 100k resistance on its (-) input is negligible), the constant current passing through Rs (and Rf) must also all flow through Rx, and by Ohm's Law dropping the originally mentioned Vrx

across that one Rx resistance (the resistor under test). The two op-amps, IC1 and IC2, have Rs, Rf and Rx in their combined feedback loop, and thus are always adjusting to keep Vrs constant at 1V and the current through Rs, Rf and Rx constant (varying only with different Ohms range selections, see item 10 below), and not effected by changes in power supply, etc.

8) In the 200 Ohm range, the only physical resistor in Rs has a 996.5 Ohm value. However, the Ohms function input protection fuse has a nominal resistance (Rf) of 3.5 Ohms, adding up to a 1000 Ohm value for Rs in this range. In higher Ohms ranges, the fuse's resistance is still part of the circuit, but is insignificant.
9) Per all of the above, the constant current through Rs, Rf and Rx will vary according to the resistance of Rs in different Ohms ranges (see item 10 below), but the 1V drop across Rs and Rf is held constant. The voltage across Rx (Vrx) will vary ONLY based on the value of Rx.
10) Table of Ohms function parameters:

RANGE	Rs (including Rf) [selected by range switch]	Constant Test Current	Vrx (at full scale)
200Ω	1k	1mA	200mV (0.2V)
2k	10k	100µA	200mV (0.2V)
20k	100k *	10µA *	200mV (0.2V)
200k	100k *	10µA *	2V
2M	1M	1µA	2V
20M	10M	100nA	2V

* The Range switch keeps Rs the same for these two ranges, thus the constant test current is the same for both ranges (the same switch behaves in a similar way for some of the Voltage ranges). However, a different gang of the Range switch 'shifts gears' of the IC1 integrator circuit between 200mV full scale and 2V full scale, with the 'shift' taking place between the 20k and 200k ranges, as shown in the table above. Thus, the integrator's sudden change in range expectations when switching between these two ranges will compensate for the apparent duplication of range parameters by the Resistance (Ohms) function's circuit as described above.

Note: This circuit made no sense to me during circuit study, and looked like an error in the Heathkit schematic. However, the Heathkit circuit description, while apparently verifying the accuracy of the schematic, made things worse by its poor and inaccurate descriptions. With the schematic on my mind during a flight to Richmond VA, I was starting to imagine what was actually going on that might make sense overall, and had my "Aha!" moment. Later, on perusal of the Weston 1240 manual's circuit description, its different wording made sense with my new understanding.

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