Bill Ashmanskas, Physics 364 Lab 1, 2010-09-09

Lab partner: Jose Vithayathil

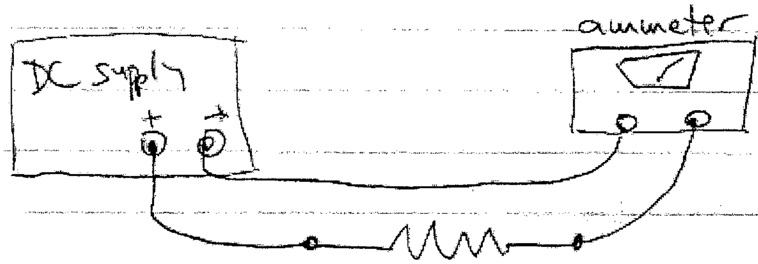
Part 1: using the multimeter

- picked out 1 resistor each from 1Ω, 27Ω, 1K, 12K, 330K drawers
- HP34401A multimeter. resistance mode.
  - (not sure what Ω 2W vs. Ω 4W means. should look this up in manual at some point.)
- using banana-lead cables with handy banana-to-alligator clip adapters.
  - open circuit → "OVLD MOHM"; short circuit → ≈ 0.03 Ω
- measure 1.03Ω (drifts slowly down from ≈ 1.04 to ≈ 1.02 -- probably stray capacitance discharging), 27.0Ω, 989Ω, 11.8K, 331M
  - all well within quoted 5% manufacturer tolerance
- line up resistors with stick gold stripes on RHS for easy reading.
  - brown black gold → 1 0 E-1 = 1.0Ω; RHS gold stripe → 5% tolerance
    - http://en.wikipedia.org/wiki/Electronic_color_code
  - red violet black → 2 7 E0 = 27Ω
    - hard to tell red from orange -- no fun to grow old -- bring reading glasses next time
  - brown black red → 1 0 E2 = 1K
  - brown red orange → 1 2 E3 = 12K
  - orange orange yellow → 3 3 E4 = 330K

- OK, now we'll check Ohm's Law (Yawn?) for these resistors.
  - Aha -- I need my breadboard.
  - Might as well start off with good habits. Use red banana-lead cable to connect red "+" output of +25V supply to red Va; black ("COM" = common ≡ ground) for ground; use little red & blue busses for power distribution, to give me an

excuse to get to know the breadboard

- Work downward from 330K to 1Ω : **330K, 12K, 1K, 27, 1**
  - +1.00V (reads 1.003 but 1% is plenty accurate) to **330K** to ammeter red; ammeter black to ground
    - had to move red cable from volts/ohms to amps jack
    - aha -- 1V/330K ~ 3μA, absurdly small (though meter reads 2.9μA -- cool beans). try 25.0V.
    - OK, meter reads 75.3μA. 75e-6 × 330e3 ≈ 24.8 V -- Ohm's Law works
    - one more point: +9.9V → 29.8μA -- check!
  - **12K**: 12V → 1.02mA -- check
    - 6V → 0.51mA -- check
  - **1K**: 6V → 6.0mA. 3V → 3.0mA. good.
  - **27Ω**:
    - power check: (3V)**2 / 27Ω ≈ 0.3W, a bit high. start at 1V
    - 1V → 30.8mA. seems about right. hmmm, on second thought, I was expecting more like 37mA. It's as if the resistance were in fact 32.5Ω
  - **1Ω**:
    - now 1V seems way too high, as current would nominally be 1A → 1W. start with 0.3V → ≈ 0.1W
    - 0.3V → measure 45.6 mA. weird! would expect 300mA
    - 0.2V → measure 30.8 mA
    - 0.1V → measure 16.0 mA.
    - so it's linear, heading toward ≈ (0,0), but R looks like 6 ~ 6.5 Ω
  - aha! found the HP34401A manual at http://positron.hep.upenn.edu/wja/p364/HP34401A_user_guide.pdf
    - I see on page 216 (specifications), under DC current, a shunt resistance of 5Ω for 10mA and 100mA scales; for 1A,3A scales it is 0.1Ω
    - mystery solved. internal resistance of ammeter is 5Ω
- Now, for 1Ω I'll explicitly measure the voltage across the two leads of the resistor with next-door multimeter and ad-hoc very long cables. (was fooled at first by meter's being in "rear panel" mode. hah.)
  - Vsupply = 100mV → 16mA of current, 16mV drop across resistor. Ohm's Law is safe!

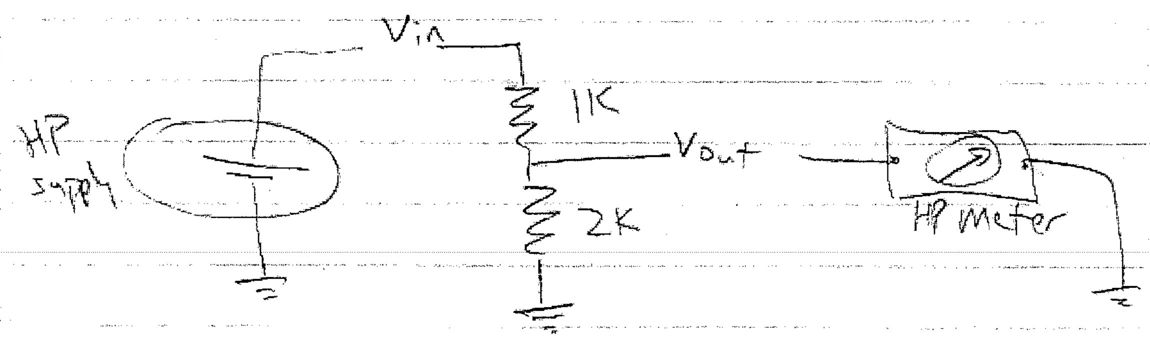


Setup for measuring I vs. V

- supply controls V
- meter reads I
- note 5 Ω shunt resistance of ammeter on low (<< 1A) current scale

Part 2: voltage divider

Voltage divider



Set $V_{in} = 3.0$ V from +25V supply
⟹ measure 2.0 V at meter ≡ V_{out}

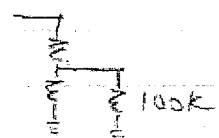
$V_{th} \equiv$ voltage with $R_{load} = \infty$. Since R_{in} of meter = 10 MΩ >> R_{th} (as we will see below), the meter is directly measuring V_{th}.
$V_{th} = 2.0\,V$. By calculation, $V_{th} = V_{in} \frac{R_2}{R_1+R_2}$
$= 3V \frac{2K}{3K} = 2V$. OK.

$R_{th} \equiv$ current with $R_{load} = 0$. Since R_{shunt} of ammeter = 5Ω (from part I) << R_{th} (we'll show), meter is effectively a short circuit. Put meter in DC current mode → measure 3.0 mA.
$R_{th} \equiv V_{th}/I_{sc} = 2V/3mA \simeq 670\,\Omega$.

Calculate: $R_{th} = 1K \| 2K = (2K \| 2K) \| 2K = \frac{2}{3}K$
✓ Check

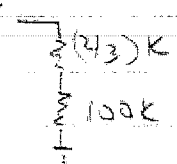
Oops, I meant Isc ≡ current with Rload=0. Rth ≡ Vth/Isc.

Load divider w/ 100K resistor:



I expect negligible change, as $100K \gg R_{th} = \frac{2}{3}K$

predict 2V



$\Rightarrow 2V \cdot \frac{100}{100.67} \simeq 1.99V$

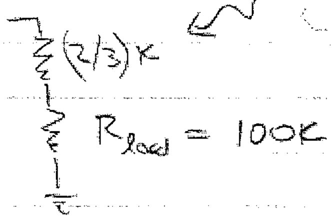
measure ≃ 1% drop: 2.008 V → 1.995 V. good.

Oops, I meant 10mV drop, or 0.5% drop, not 1%.

Now try 3K resistor. Expect $2V \cdot \frac{3}{3.67} \simeq 1.64\,V$

measure 1.64 V. <u>Good</u>

Build 2V



(used 680Ω resistor. Could have used 1K || 2K instead.)

≡ thevenin equivalent

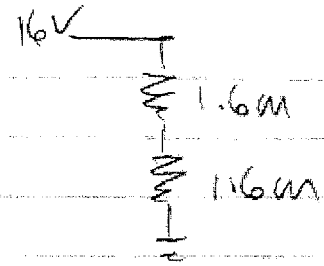
measure 2.009 V at top of divider; 1.995 V at center. As expected, same as original circuit.

Now make R_{load} = 3K. Measure V_{out} = 1.64V.

<u>Good</u>

The equivalent circuit responds under load in the same way as original, i.e. I_{out} vs. V_{out} for equiv ckt ≡ I_{out} vs. V_{out} for original.

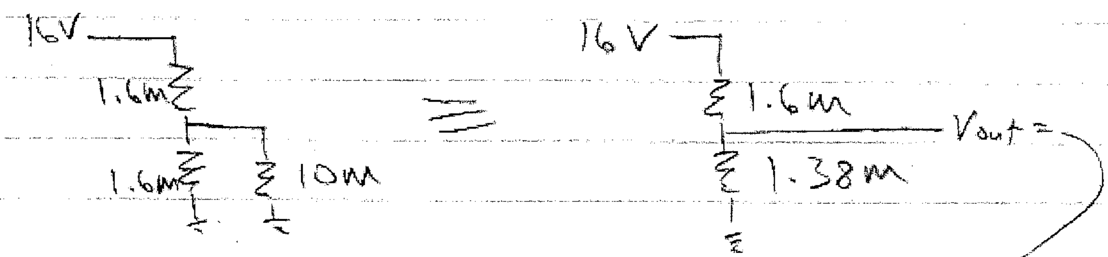
Now build



I inserted ammeter between lower resistor & ground. Measure ≃ 5 μA.
Calculate $\frac{16V}{3.2M} = 5\mu A$. good.

Now measure voltage ("Vout") between two resistors, w.r.t. ground. Measure 7.46 volts.
Weird — expect 8.0 volts.

Notice meter $R_{in} = 10\,M\Omega$.



$$16V \cdot \frac{1.38}{1.6+1.38} = 7.41V$$

aha!