National Aviation University

Department of Electronics, Robotics, Monitoring and IoT Technologies

Course: “Analog and Digital Instrumentation”

Experiment 1 “Digital Multimeter”

Prepared by Prof. V. Ulansky

Kyiv 2020

I. Objective

To become familiar with a digital multimeter (DMM) and how it works. At the same time to become familiar with diode and transistor testing.

Equipment List:

- **Agilent multimeter 34401A**
- **Diodes: 1BH62, 1N3661, 1N3893, 1N3494, 1N4001**
- **Transistors: 2N3904, 2N3019, 2N3393, BC107BP**
- **Resistors: 1 kΩ, 1.24 kΩ, 1.6 kΩ, 3.9 kΩ, 4.7 kΩ, 8.2 kΩ, 10 kΩ, 16 kΩ, 24 kΩ**
- **Milliammeter**

II. Specifications of Agilent DMM 34401A

Measurement capability

• 6½ digit resolution

• 10 measurement functions: DC/AC voltage, DC/AC current, 2- and 4-wire resistance, diode, continuity, frequency, period

• Basic accuracy: 0.0035% DC, 0.06% AC

• 1000 V max voltage input, 3 A max current input

Performance

The Agilent 34401A multimeter gives to engineers the superior performance for fast, accurate bench and system testing. The 34401A provides a combination of resolution, accuracy, and speed that rivals DMMs costing many times more. 6½ digits of resolution, 0.0015% basic 24-hr DCV accuracy, and 1,000 readings/s direct to GPIB (General Purpose Interface Bus) assure you of results that are accurate, fast, and repeatable.

Accuracy Specifications ± (% of reading + % of range)[1]

Function	Range[3]	Frequency, etc.	24 hour[2] 23 ± 1 °C	90 day 23 ± 5 °C	1 year 23 ± 5 °C	Temperature coefficient 0 – 18 °C 28 – 55 °C
DC voltage	100.0000 mV		0.0030 + 0.0030	0.0040 + 0.0035	0.0050 + 0.0035	0.0005 + 0.0005
	1.000000 V		0.0020 + 0.0006	0.0030 + 0.0007	0.0040 + 0.0007	0.0005 + 0.0001
	10.00000 V		0.0015 + 0.0004	0.0020 + 0.0005	0.0035 + 0.0005	0.0005 + 0.0001
	100.0000 V		0.0020 + 0.0006	0.0035 + 0.0006	0.0045 + 0.0006	0.0005 + 0.0001
	1000.000 V		0.0020 + 0.0006	0.0035 + 0.0010	0.0045 + 0.0010	0.0005 + 0.0001
True rms AC voltage[4]	100.0000 mV	3 – 5 Hz	1.00 + 0.03	1.00 + 0.04	1.00 + 0.04	0.100 + 0.004
		5 – 10 Hz	0.35 + 0.03	0.35 + 0.04	0.35 + 0.04	0.035 + 0.004
		10 Hz – 20 kHz	0.04 + 0.03	0.05 + 0.04	0.06 + 0.04	0.005 + 0.004
		20 – 50 kHz	0.10 + 0.05	0.11 + 0.05	0.12 + 0.05	0.011 + 0.005
		50 – 100 kHz	0.55 + 0.08	0.60 + 0.08	0.60 + 0.08	0.060 + 0.008
		100 – 300 kHz[5]	4.00 + 0.50	4.00 + 0.50	4.00 + 0.50	0.20 + 0.02
	1.000000 V to 750.000 V	3 – 5 Hz	1.00 + 0.02	1.00 + 0.03	1.00 + 0.03	0.100 + 0.003
		5 – 10 Hz	0.35 + 0.02	0.35 + 0.03	0.35 + 0.03	0.035 + 0.003
		10 Hz – 20 kHz	0.04 + 0.02	0.05 + 0.03	0.06 + 0.03	0.005 + 0.003
		20 – 50 kHz	0.10 + 0.04	0.11 + 0.05	0.12 + 0.04	0.011 + 0.005
		50 – 100 kHz[5]	0.55 + 0.08	0.60 + 0.08	0.60 + 0.08	0.060 + 0.008
		100 – 300 kHz[6]	4.00 + 0.50	4.00 + 0.50	4.00 + 0.50	0.20 + 0.02
Resistance[7]	100.0000 Ω	1 mA current source	0.0030 + 0.0030	0.008 + 0.004	0.010 + 0.004	0.0006 + 0.0005
	1.000000 kΩ	1 mA	0.0020 + 0.0005	0.008 + 0.001	0.010 + 0.001	0.0006 + 0.0001
	10.00000 kΩ	100 µA	0.0020 + 0.0005	0.008 + 0.001	0.010 + 0.001	0.0006 + 0.0001
	100.0000 kΩ	10 µA	0.0020 + 0.0005	0.008 + 0.001	0.010 + 0.001	0.0006 + 0.0001
	1.000000 MΩ	5.0 µA	0.002 + 0.001	0.008 + 0.001	0.010 + 0.001	0.0010 + 0.0002
	10.00000 MΩ	500 nA	0.015 + 0.001	0.020 + 0.001	0.040 + 0.001	0.0030 + 0.0004
	100.0000 MΩ	500 nA ll 10 MΩ	0.300 + 0.010	0.800 + 0.001	0.800 + 0.001	0.1500 + 0.0002
DC current	10.00000 mA	< 0.1 V burden voltage	0.005 + 0.010	0.030 + 0.020	0.050 + 0.020	0.0020 + 0.0020
	100.0000 mA	< 0.6 V	0.010 + 0.010	0.030 + 0.005	0.050 + 0.005	0.0020 + 0.0005
	1.000000 A	< 1.0 V	0.050 + 0.010	0.080 + 0.010	0.100 + 0.010	0.0050 + 0.0010
	3.00000 A	< 2.0 V	0.100 + 0.010	0.120 + 0.020	0.120 + 0.020	0.005 + 0.0020
True rms AC current[4]	1.000000 A	3 – 5 Hz	1.00 + 0.04	1.00 + 0.04	1.00 + 0.04	0.100 + 0.006
		5 – 10 Hz	0.30 + 0.04	0.30 + 0.04	0.30 + 0.04	0.035 + 0.006
		10 Hz – 5 kHz	0.10 + 0.04	0.10 + 0.04	0.10 + 0.04	0.015 + 0.006
	3.00000 A	3 – 5 Hz	1.10 + 0.06	1.10 + 0.06	1.10 + 0.06	0.100 + 0.006
		5 – 10 Hz	0.35 + 0.06	0.35 + 0.06	0.35 + 0.06	0.035 + 0.006
		10 Hz – 5 kHz	0.15 + 0.06	0.15 + 0.06	0.15 + 0.06	0.015 + 0.006
Frequency or period[8]	100 mV to 750 V	3 – 5 Hz	0.10	0.10	0.10	0.005
		5 – 10 Hz	0.05	0.05	0.05	0.005
		10 – 40 Hz	0.03	0.03	0.03	0.001
		40 Hz – 300 kHz	0.006	0.01	0.01	0.001
Continuity	1000.0 Ω	1 mA test current	0.002 + 0.030	0.008 + 0.030	0.010 + 0.030	0.001 + 0.002
Diode test[9]	1.0000 V	1 mA test current	0.002 + 0.010	0.008 + 0.020	0.010 + 0.020	0.001 + 0.002

III. Digital Multimeter as an Ohmmeter: Measure Resistance

Procedure for measuring Resistance:

1. Ensure that the power in the circuit under measure is OFF. Ohmmeter applies external current. It can interact with the power in the circuit and damage it.
2. Connect Black lead to **COM.**

3.Connect Red lead to terminal with symbol VΩ .
4.Press button **Ω.**
5.Value of display is Resistance.

Example: Short circuiting leads should result in a very low value of Resistance.

IV. Measuring human resistance

- Configure the DMM to measure resistance.
- Grab each lead with a different hand.
- If you cannot get a reading, you can by licking your fingers.
- The DMM puts a battery voltage between its leads when measuring resistance. Calculate the current that flew through your body when doing this experiment.
- Explain your results.

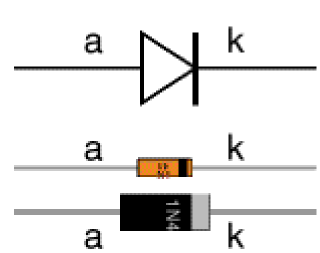
V. Measuring voltage and current with a multimeter

1. **Connect the meter**, making sure the leads are the correct way round. Digital meters can be safely connected in reverse, but an analogue meter may be damaged.
2. **If the reading goes off the scale:** immediately disconnect and select a higher range.

Multimeters are easily damaged by careless use so please take these precautions:

- Always disconnect the multimeter before adjusting the range switch.
- Always check the setting of the range switch **before** you connect to a circuit.
- Never leave a multimeter set to a current range (except when actually taking a reading).
  The greatest risk of damage is on the current ranges because the meter has a low resistance.

VI. Testing a diode with a digital multimeter



Diodes

a = anode
k = cathode

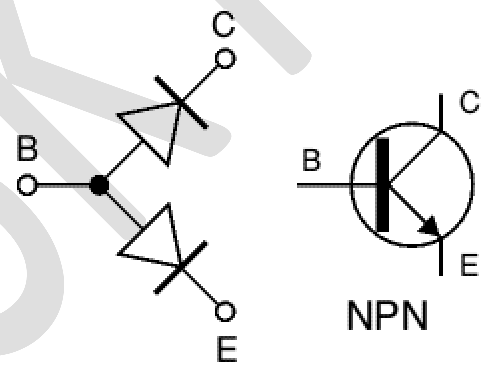
- Digital multimeters have a special setting for testing a diode, usually labelled with the diode symbol .
- Connect the **red** (+) lead to the anode and the **black** (-) to the cathode. The diode should conduct and the meter will display a value (usually the voltage across the diode in mV, 1000mV = 1V).
- Reverse the connections. The diode should NOT conduct this way so the meter will display "off the scale" (usually blank except for a 1 on the left).

VII. Testing a transistor with a multimeter

Set a digital multimeter to diode test, as described above for testing a diode.

Test each pair of leads both ways (six tests in total):

- The **base-emitter (BE)** junction should behave like a diode and conduct one way only.
- The **base-collector (BC)** junction should behave like a diode and conduct one way only.
- The **collector-emitter (CE)** should not conduct either way.

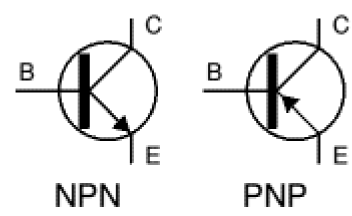


Testing an NPN transistor

The diagram shows how the junctions behave in an NPN transistor. The diodes are reversed in a PNP transistor but the same test procedure can be used.

<u>Types of transistor</u>

There are two types of standard transistors, **NPN** and **PNP**, with different circuit symbols. The letters refer to the layers of semiconductor material used to make the transistor. Most transistors used today are NPN because this is the easiest type to make from silicon. If you are new to electronics it is best to start by learning how to use NPN transistors.



Transistor circuit symbols

The leads are labelled **base** (B), **collector** (C) and **emitter** (E).
These terms refer to the internal operation of a transistor but they are not much help in understanding how a transistor is used, so just treat them as labels!

A <u>Darlington pair</u> is two transistors connected together to give a very high current gain.

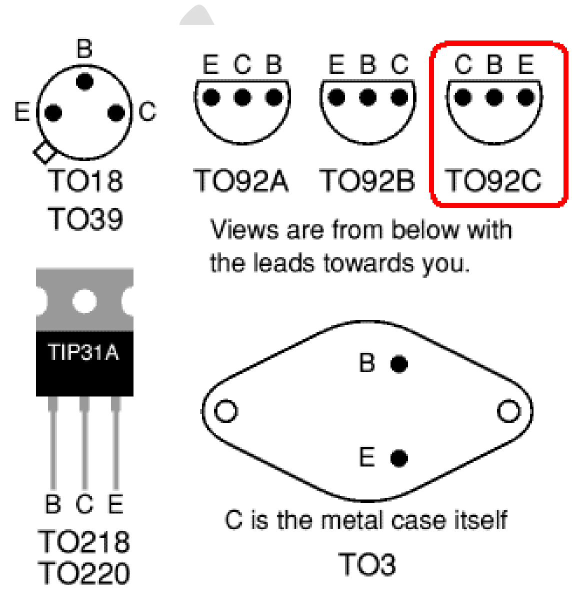
In addition to standard (bipolar junction) transistors, there are **field-effect transistors** which are usually referred to as **FET**s. They have different circuit symbols and properties and they are not (yet) covered by this experiment.

Connecting

Transistors have three leads which must be connected the correct way round. Please take care with this because a wrongly connected transistor may be damaged instantly when you switch on.

If you are lucky the orientation of the transistor will be clear from the PCB or stripboard layout diagram, otherwise you will need to refer to a supplier's catalogue to identify the leads.

The drawings on the right show the leads for some of the most common case styles.



Transistor leads for some common case styles.

Please note that transistor lead diagrams show the view from **below** with the leads towards you. This is the opposite of IC (chip) pin diagrams which show the view from above.

Soldering

Transistors can be damaged by heat when soldering so if you are not an expert it is wise to use a heat sink clipped to the lead between the joint and the transistor body. A standard crocodile clip can be used as a heat sink.


Crocodile clip

Do not confuse this temporary heat sink with the permanent heat sink (described below) which may be required for a power transistor to prevent it overheating during operation.

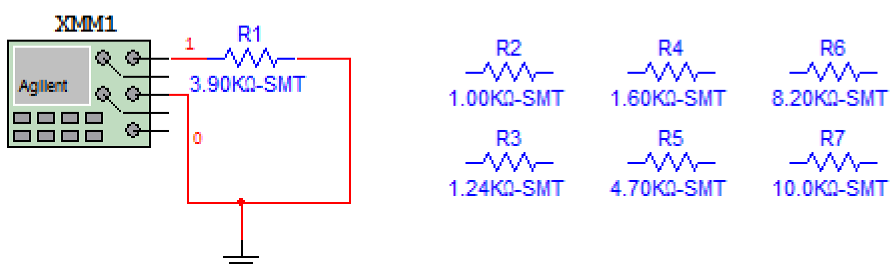
Heat sinks

Heat sink

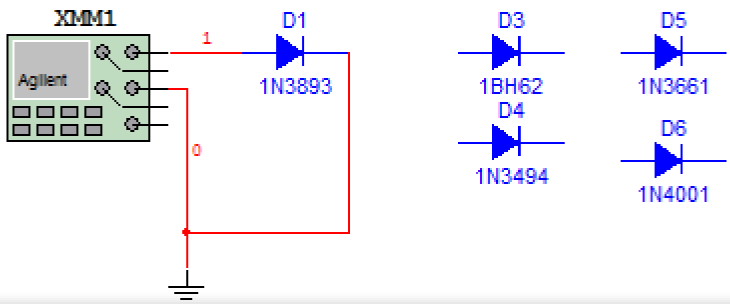
Waste heat is produced in transistors due to the current flowing through them. Heat sinks are needed for power transistors because they pass large currents. If you find that a transistor is becoming too hot to touch it certainly needs a heat sink! The heat sink helps to dissipate (remove) the heat by transferring it to the surrounding air.

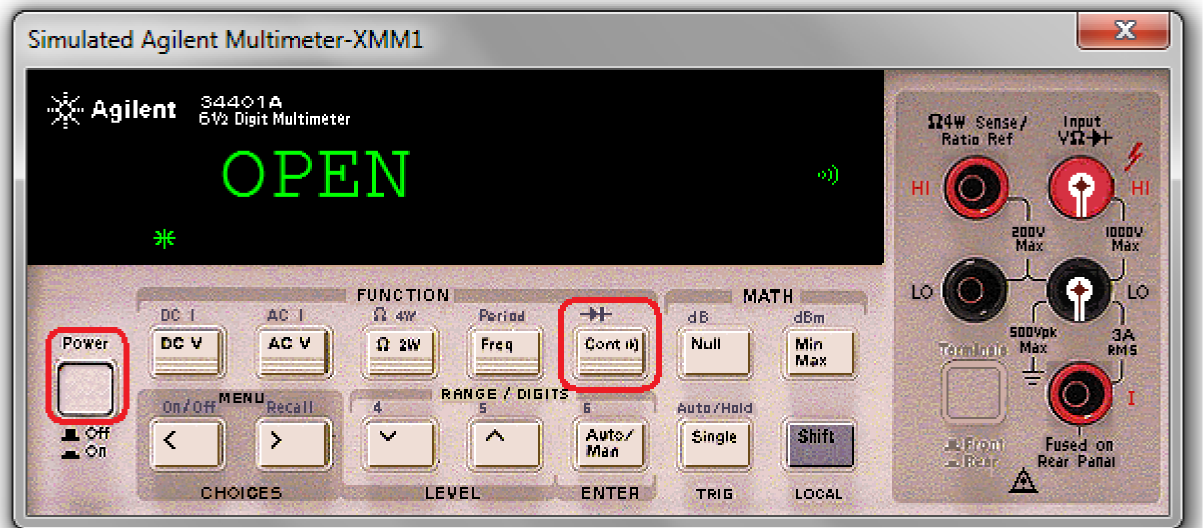
EXPERIMENT PROCEDURE

1. Measure the resistance of each resistor.

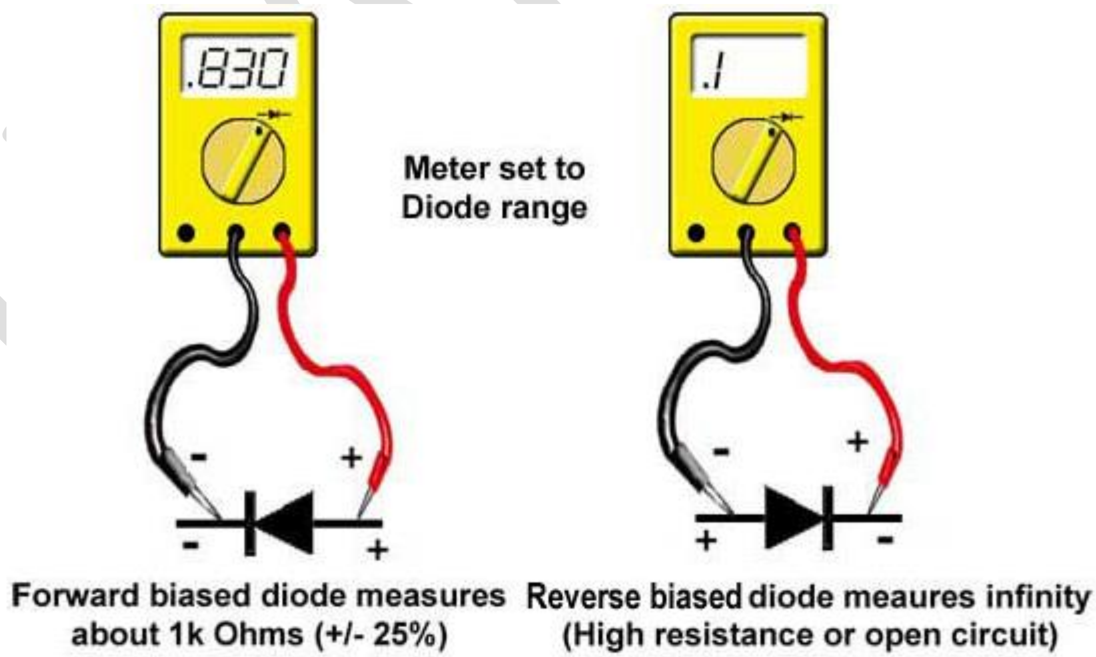


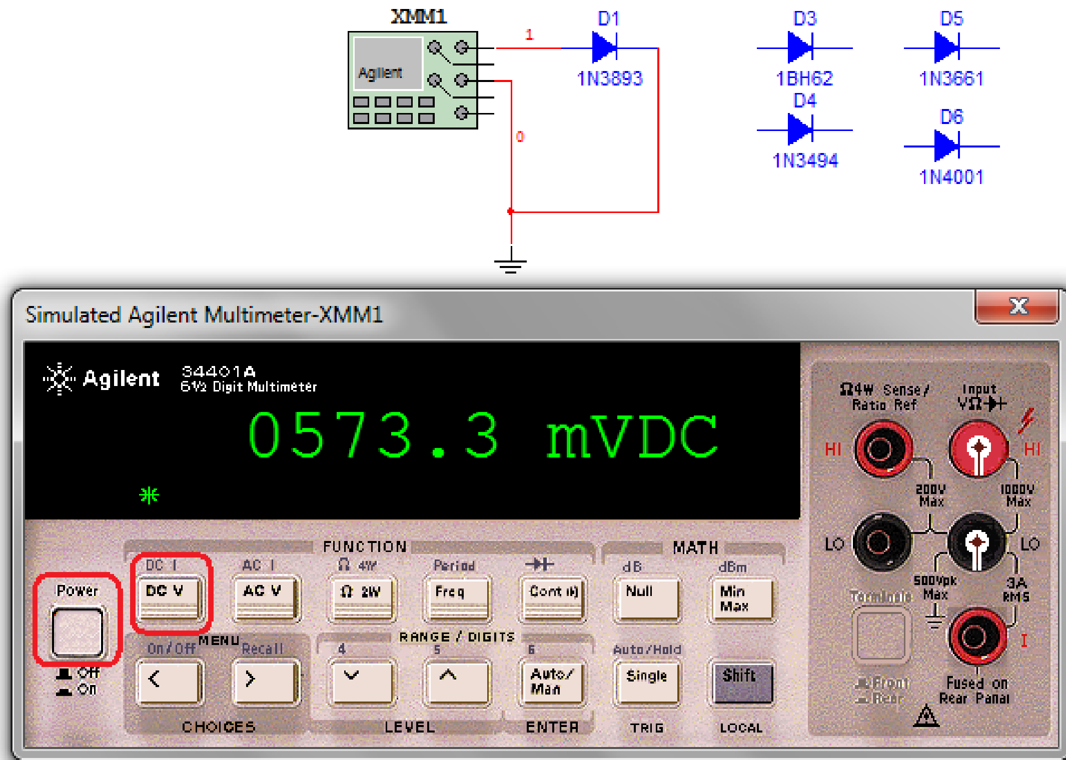
2. Check diodes for continuity
   - Turn on the Multimeter.
   - Put it on Continuity Test by moving the selector switch. (Symbols look like Diode)
   - Connect two probes of the multimeter to diodes if the multimeter produces a beeping sound then that is known as forward biased (Turned On).





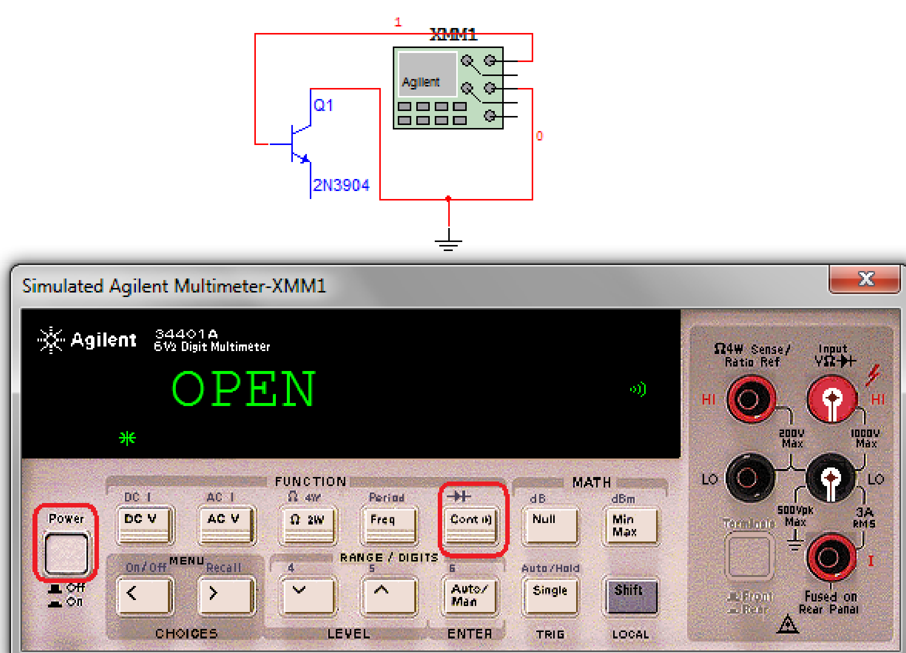
3. Set the function switch of the DMM to diode testing mode and measure the forward bias voltage drop between anode and cathode of each diode.

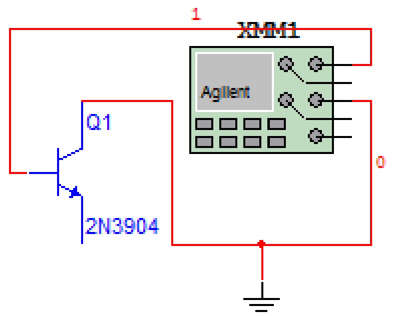


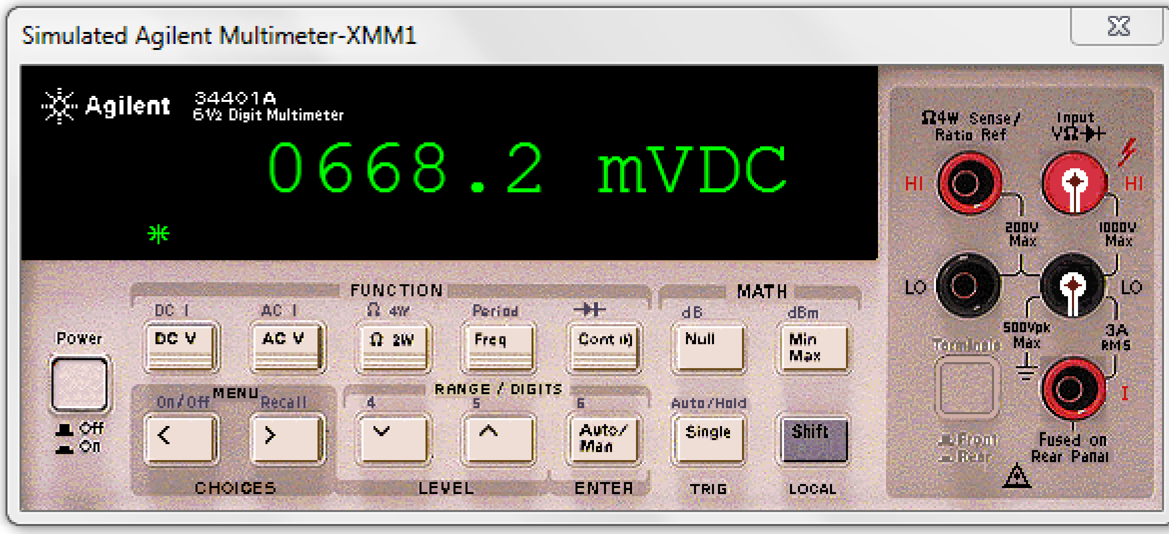


4. Set the function switch of the DMM to diode testing mode and measure the voltage between base and collector, and base and emitter for each transistor **2N3904, 2N3019, 2N3393, BC107BP.**

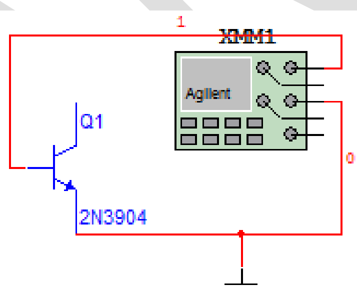
Step 1: between base and collector

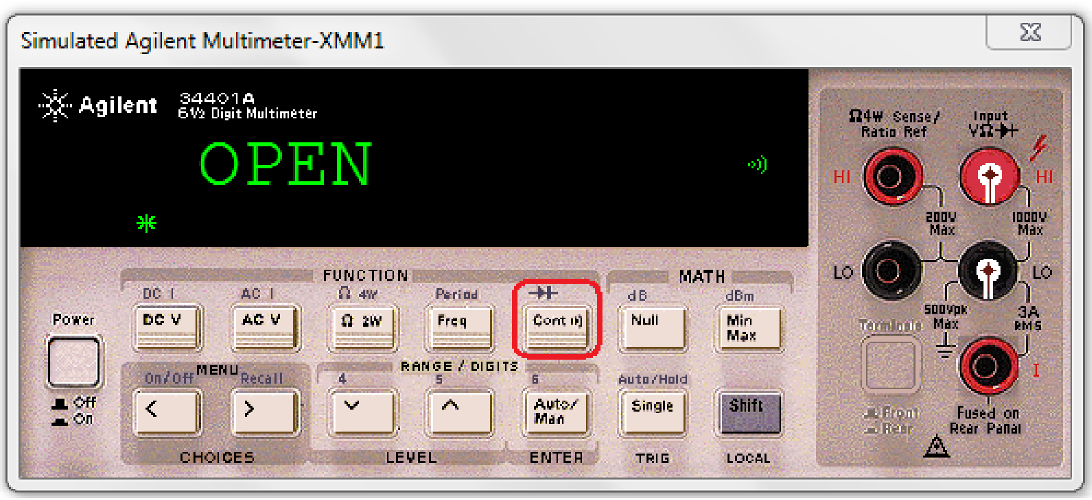


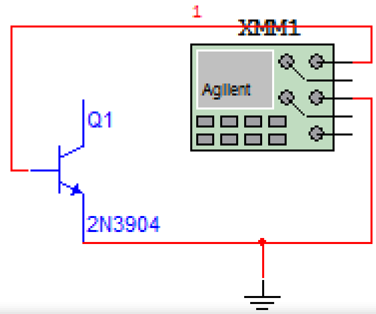


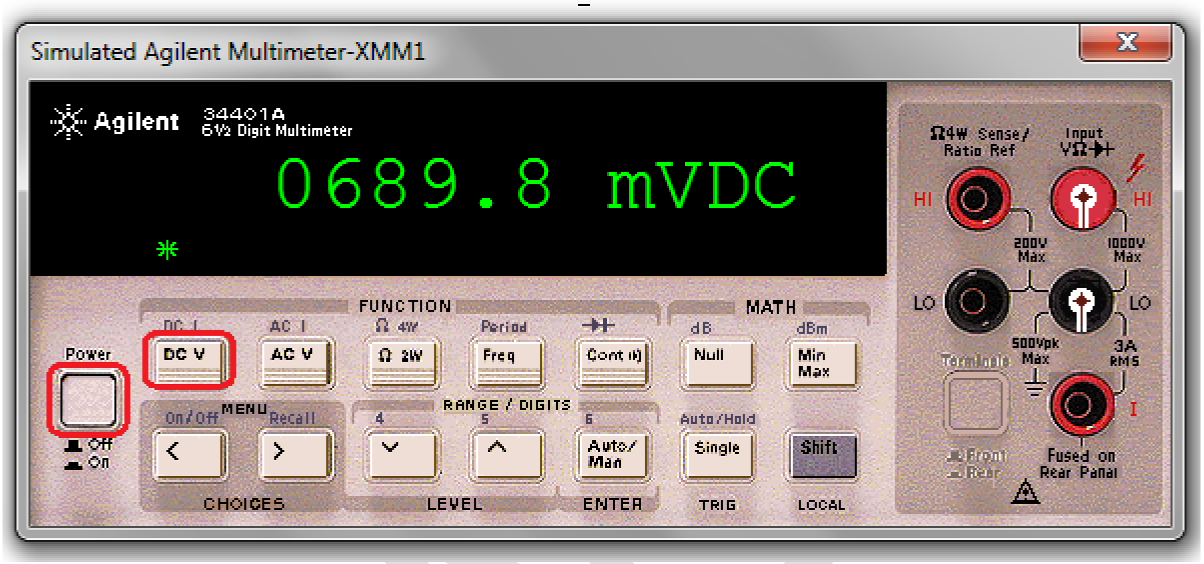


Step 2: between base and emitter

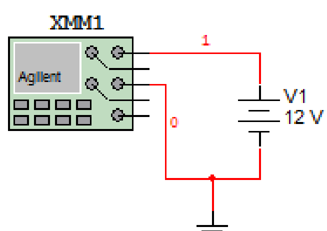






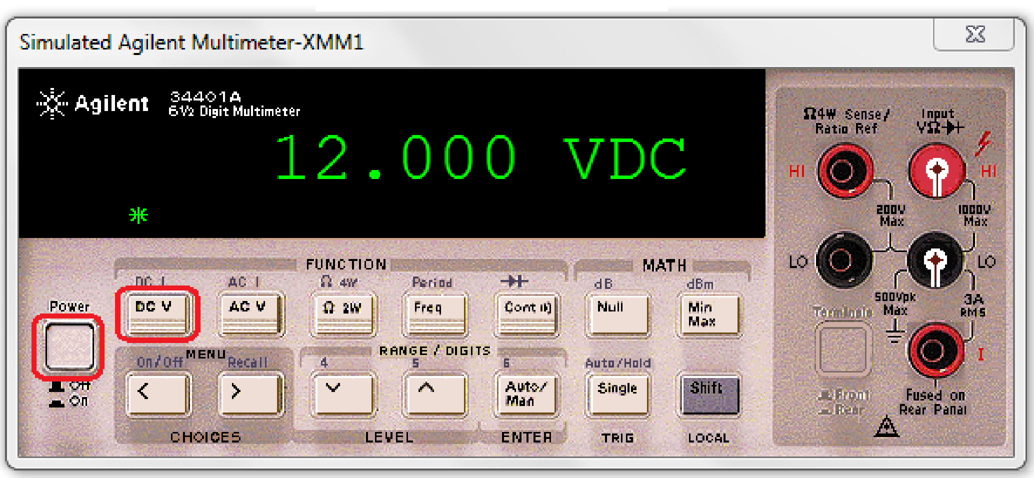


5. DC voltage measurements. Set the function switch to DC V. Measure the voltages indicated on the picture below.

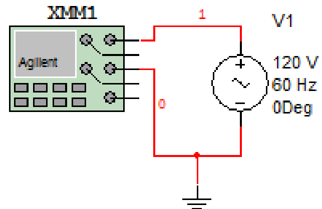


100 mV, 500 mV,

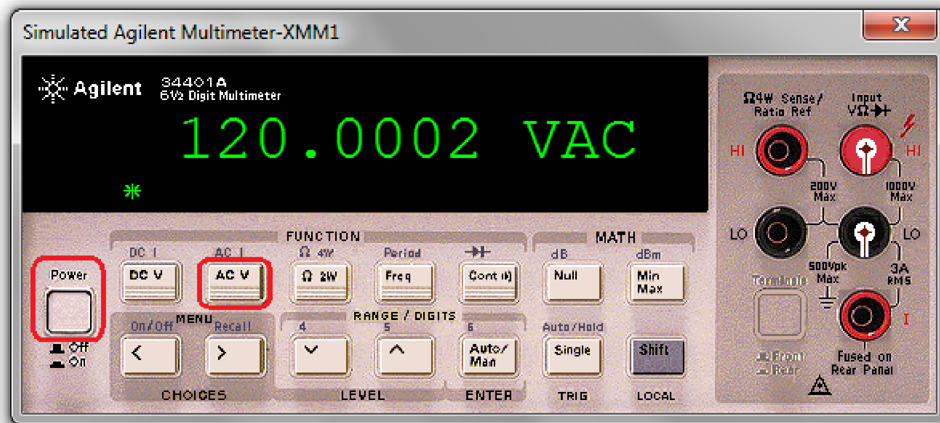
1 V, 5 V, 24 V



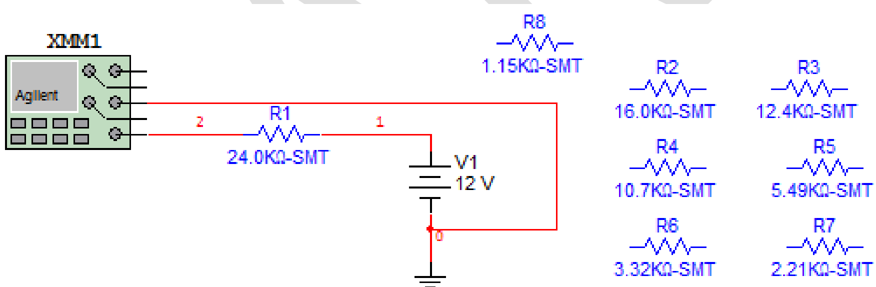
6. AC voltage measurements. Set the function switch to AC V. Measure the voltages indicated on the picture below.



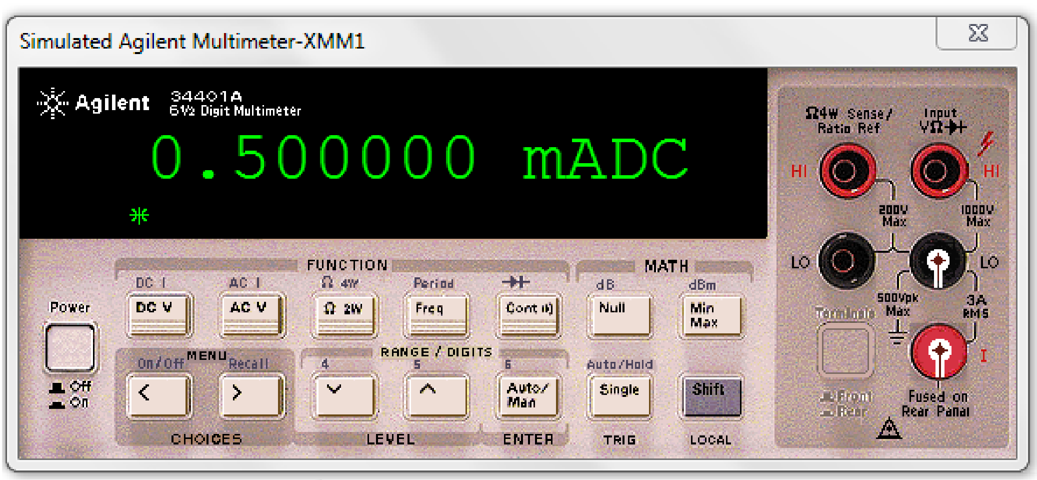
5 VAC, 10 VAC,
24 VAC, 110 VAC,
220 VAC



7. DC current measurements. Measure the DC current for each resistor shown in the picture below.



1. Press Simulation button.
2. Press Power button.
3. Press Shift button.
4. Press DC V button to measure DC current.



8. AC current measurements. Measure the AC current for each resistor shown in the picture below.