National Aviation University

Department of Electronics, Robotics, Monitoring and IoT Technologies

Course: “Fundamentals of Analog Electronics”

Experiment 1

“The Digital Multimeter”

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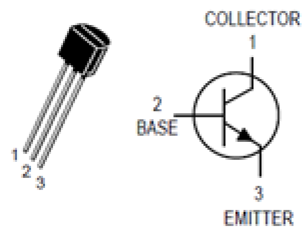
I. Objective

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:

- BC238B Transistor (x4)
- 1N4007 Diode (x4)
- 3.9kΩ Resistor (x1)
- 1.0 kΩ Resistor (x1)
- 390Ω Resistor (x1)
- 100Ω Resistor (x1)
- DMM830B Digital multimeter



II. Specifications of DMM DT838 and HMC8012

The picture to the left depicts a simple DMM similar to those that we will use in the labs in this course. The central rotary knob is used to select the variable to measure: Ohms, AC Volts, DC Volts, DC Amps, Temperature and Gain of Transistors among other variables.

DT838 Digital Multimeter

Specifications

Temperature test, Diode test, Transistor test, Continuity Buzzer

Function	Range	Accuracy
DC Voltage	200mV-500V	±(0.5%+2dgt)
AC Voltage	200-500V	±(1.2%+10dgt)
DC Current	2000uA-10A	±(1.0%+2dgt)
Resistance	200Ω-2MΩ	±(0.8%+2dgt)
Temperature	-40°C-1000°C	±(3.0+2dgt)
Diode Test	Yes	
Transistor Test	Yes	
Continuity Buzzer	Yes	
Power Supply	9V Battery 6F22	
Display Size	16×48mm	
Maximum Display	1999	
Products Size	126×70×24mm	
Product Net Weight	150g	
Color	Black	
Standard Accessories	Test Lead, Battery, Manual, Thermocouple Wire	

(a)

- ☑ 5¾-Digit Display (480,000 Counts)
- ☑ Simultaneous Display of 3 Measurements, e.g. DC + AC + Statistics
- ☑ Up to 200 Measurements per Second
- ☑ DC Basic Accuracy 0,015%
- ☑ 12 Measurements Functions: DCV, DCI, True RMS, ACV and ACI, Frequency, 2- and 4-Wire Resistance, Capacitance, Continuity, Diode Test, Temperature, Power
- ☑ Crisp color TFT display for excellent readability
- ☑ Resolution: 1µV, 100nA, 1mΩ, 1pF, 1Hz, 0,1°C
- ☑ True RMS Measurement AC, AD + DC
- ☑ Mathematic Functions: Limit Testing, Minimum/Maximum, Average, Offset, DC Power, dB, dBm

(b)

Fig. 1. Digital multimeters: (a) – DT838, (b) - HMC8012

All digital meters contain a battery to power the display so they use virtually no power from the circuit under test. This means that on their DC voltage ranges they have a very high resistance (usually called input impedance) of 1MΩ or more, usually 10MΩ, and they are very unlikely to affect the circuit under test.

Typical ranges for digital multimeters like the one illustrated in Fig. 1:
(the values given are the maximum reading on each range)

- DC Voltage: 200mV, 2000mV, 20V, 200V, 600V.
- AC Voltage: 200V, 600V.
- DC Current: 200μA, 2000μA, 20mA, 200mA, 10A*.
  *The 10A range is usually unfused and connected via a special socket.
- AC Current: None. (You are unlikely to need to measure this).
- Resistance: 200Ω, 2000Ω, 20kΩ, 200kΩ, 2000kΩ, Diode Test.

Digital meters have a special <u>diode test</u> setting because their resistance ranges cannot be used to test diodes and other semiconductors.

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 **VΩmA** .
4. Move Rotary selector to **Ω.**
5. Value of display is Resistance.
6. If display shows "**1 .**": this is Overload. Select higher range.

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

IV. Measuring human resistance

- Configure the DMM to measure resistance. Select "**2000k"** range.
- Grab each lead with a different hand.
- If you cannot get a reading, you can by licking your fingers.
- The DMM puts 2.8 V 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. **Select a range** with a maximum greater than you expect the reading to be.
2. **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.

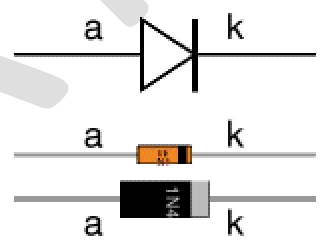
3. **If the reading goes off the scale:** immediately disconnect and select a higher range.

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

- 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).



Diodes

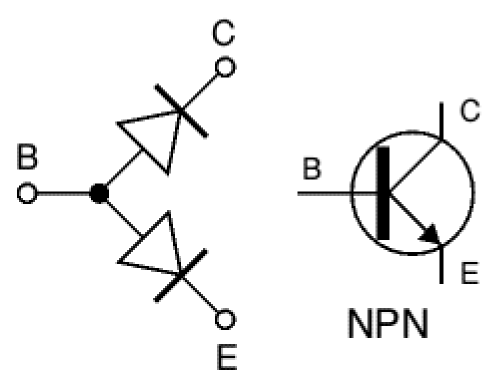
a = anode
k = cathode

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.

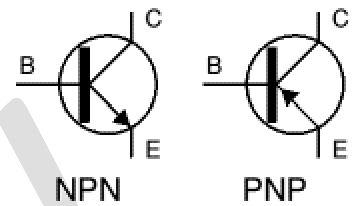


Testing an NPN transistor

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.

Types of transistor

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 Darlington pair is two transistors connected together to give a very high current gain.

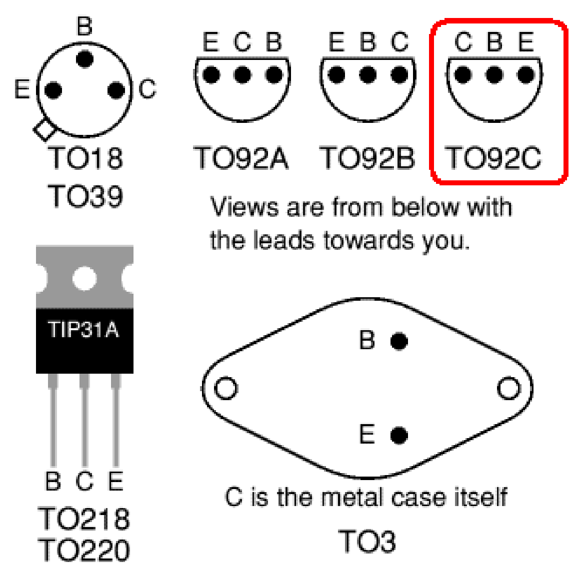
In addition to standard (bipolar junction) transistors, there are **field-effect transistors** which are usually referred to as **FET**s. They have different circuit symbols and properties and they are not (yet) covered by this experiment.

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

Crocodile clip

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.

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.

VII. Measurement of h_{FE} with a DMM

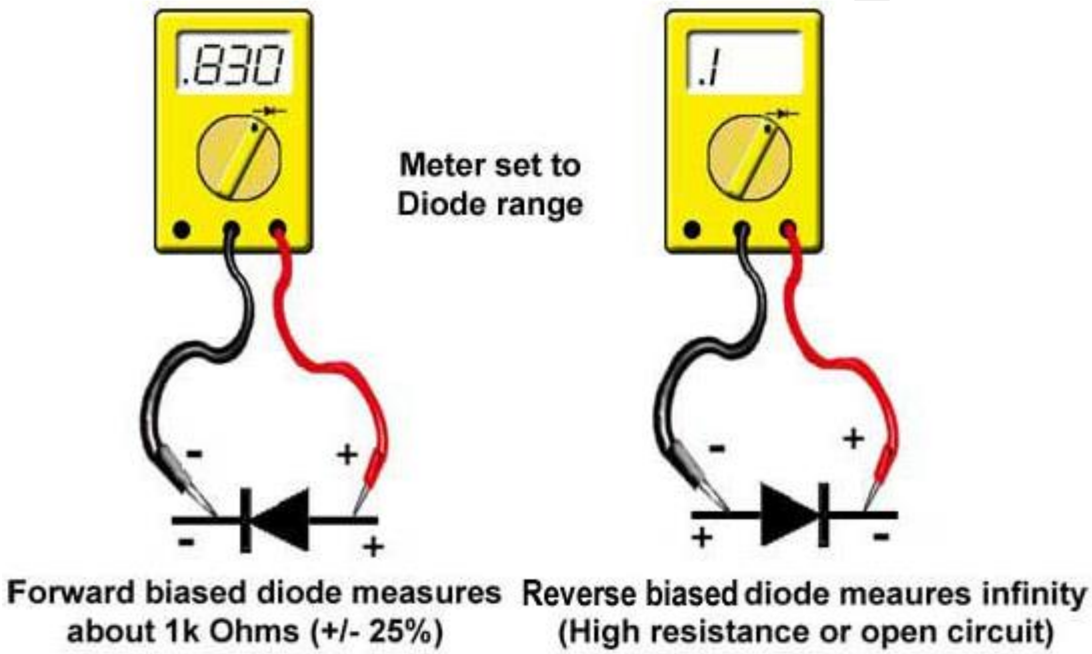
What is h_{FE}? This is the **current gain** (strictly the DC current gain). The guaranteed minimum value is given because the actual value varies from transistor to transistor - even for those of the same type! Note that current gain is just a number so it has no units. The gain is often quoted at a particular collector current I_C which is usually in the middle of the transistor's range, for example “100@20mA” means the gain is at least 100 at 20mA. Sometimes minimum and maximum values are given. Since the gain is roughly constant for various currents but it varies from transistor to transistor this detail is only really of interest to experts.

The relationship between the current flowing through the collector and the current flowing through the base is called the transistor's current amplification coefficient, and is marked as h_{FE}. In our example, this coefficient is equal to:

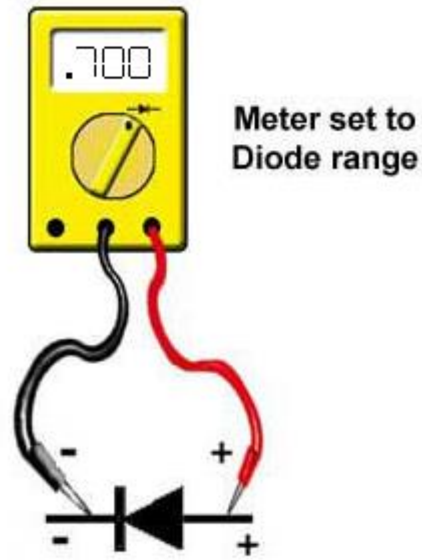
$$h_{FE} = \frac{I_C}{I_B} = \frac{1\text{mA}}{4\mu\text{A}} = \frac{1\times10^{-3}}{4\times10^{-6}} = 250.$$

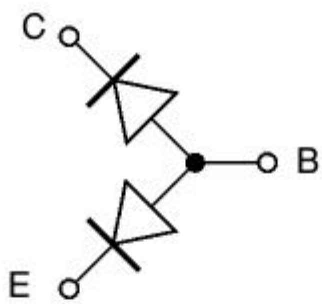
EXPERIMENT PROCEDURE

1. Measure the resistance of each resistor.
2. 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.

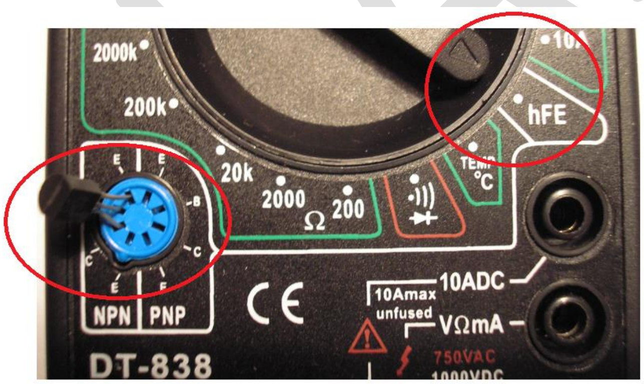


3. Set the function switch of the DMM to diode testing mode and measure the voltage between base and emitter, and base and collector.



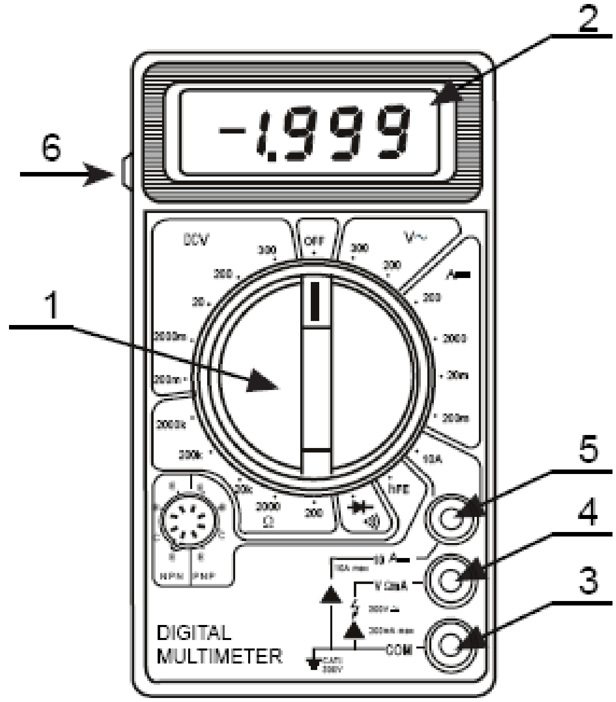


4. Set function switch to h_{FE} position; insert the transistor pins into corresponding slots marked as E (Emitter), B (Base) and C (Collector) on the DMM front panel. Record the measured gain value for each transistor.



APPENDIX

FRONT PANEL DESCRIPTION



1. FUNCTION AND RANGE SWITCH

This switch is used to select the functions and desired ranges as well as to turn ON/OFF the meter.

To extend the life of the battery, the switch should be in the "OFF" position when the meter is not in use.

2. DISPLAY

3 1/2 digits, LCD(12mm)

3. "COM" JACK

Plug in connector for black (negative) test lead.

4. **"VΩmA"** JACK

Plug in connector for red (positive) test lead for all voltage, resistance and current (up to 200mA) measurements.

5. "10A"JACK

⚠ Plug in connector for red (Positive) test lead for current (between 200mA and 10A) measurement. There is no fuse for "10A" jack. To use safely, each measurement can not last for more than 10 seconds, and the interval between each measurement must be more than 15 minutes.

6. LIGHT SWITCH (only for DT830BL)

Switch for " torch light " and " back light ".