DEPARTMENT OF ELECTRONICS AGH UST

LABORATORY
OF
ELECTRONIC ELEMENTS

MOS Transistors

REV. 1.0a

1. THE GOAL OF THE EXERCISE

- to get acquainted with basic operation of MOS transistors,
- plotting of DC current vs. voltage characteristics of n-MOSFET and p-MOSFET constituting complementary pairs in CD4007 (Fig.1).
- determination of basic parameters of the transistors (based on characteristics).

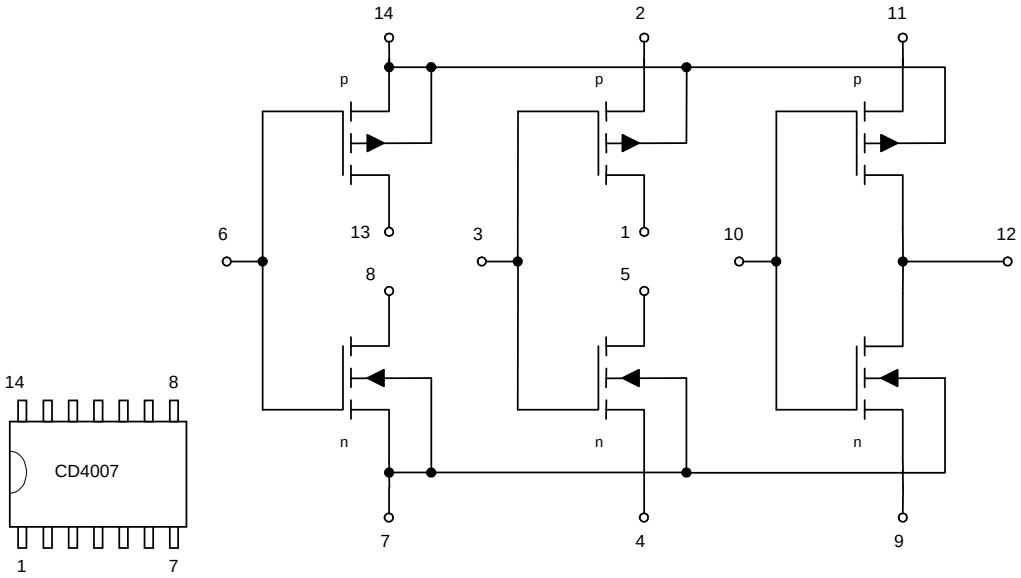

Fig.1. Schematic diagram of the integrated circuit CD4007

2. THE UTILIZED MODELS AND ELEMENTS

During the exercise, the following components will be used:

- NI ELVIS Prototyping Board (ELVIS) connected with PC,
- Virtual measurement devices: Virtual Instruments (VI):
  - `Digital Multimeter (DMM),`
  - `Two-Wire Voltage Analyzer (2-Wire)`
- external multimeter and power supply,
- set of components shown in Table 1.

Table 1. Electronic elements required to perform the exercise

Integrated Circuit	CD4007 (or equivalent)

3. PREPARING THE DRAFT

3.1. Draw the transfer and output characteristics of enhanced MOS transistor, *n*- channel and *p*- channel.

4. THE COURSE OF THE EXERCISE

4.1. DC transfer characteristics of n-type MOS transistor

Arrange the measurement setup according to Fig. 2, choosing one of the transistors available in CD4007. Carry out measurements to get a DC transfer characteristic $I_D = f(U_{GS})$ of the n-MOSFET transistor in the range of positive gate voltages from U_{GS} = 0 to 10 V, and constant U_{DS} = 5 V. Set the increment of U_{GS} to 0,25 (or any other else suggested by teacher).

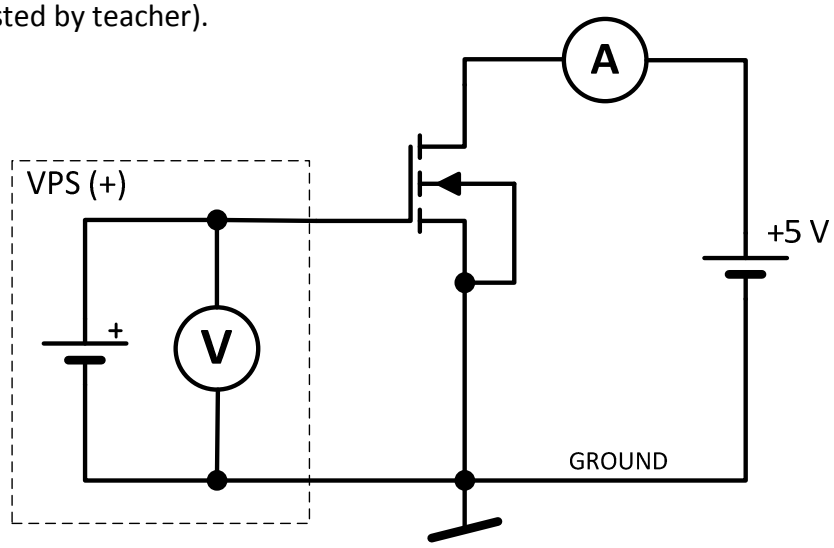

Fig. 2. Scheme of the measurement setup for obtaining DC transfer characteristics of **n-MOS** transistor

4.2. DC output characteristics of n-type MOS transistor

Arrange the measurement setup according to Fig. 3, choosing one of the transistors available in CD4007. Voltage U_{GS} should be provided from the external power supply (in order to get correct results, `2-Wire Analyzer` cannot use ELVIS GROUND). By means of `2-Wire Analyzer`, carry out measurements to obtain the family of output characteristics $I_D = f(U_{DS})$ n-MOSFET for a few gate voltages (e.g.: U_{GS} = 2, 4, 6, 8, 10 V, increment U_{DS} = 0,2 V, U_{DSmax} = 15 V) (or any other else suggested by teacher).

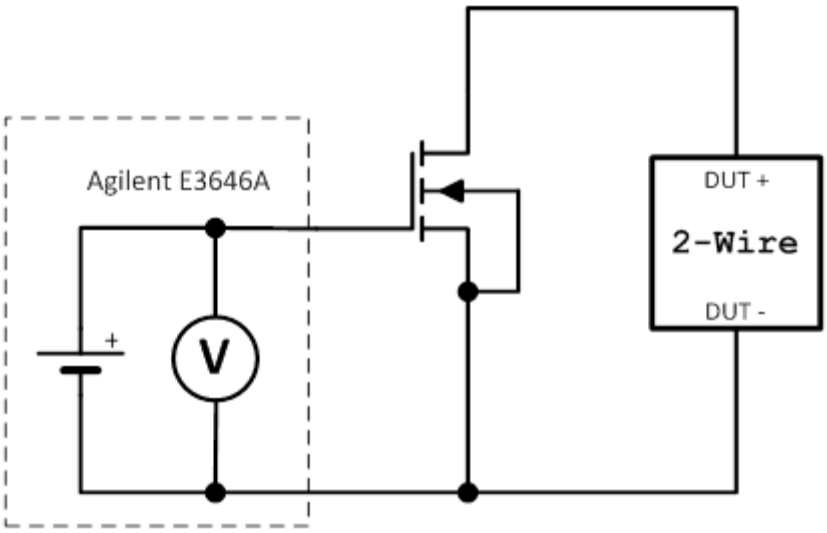

Fig. 3. Scheme of the measurement setup for obtaining DC output characteristics of **n-MOS** transistor

4.3. Investigation of body effect in n-type MOS transistor

Investigated transistor should work in saturation. Such conditions are fulfilled in measurement setup from Fig. 4 when $U_{DS} = U_{GS}$. Arrange the measurement setup according to Fig. 4, choosing one of the transistors available in CD4007. Voltage U_{BS} should be delivered from the external power supply (do not use ELVIS GROUND). By means of `2-Wire Analyzer`, carry out measurements to obtain the family of DC transfer characteristics $I_D = f(U_{GS})$ for n-MOSFET in the range of positive gate voltages U_{GS} = 0 to 10 V, for a few constant values of U_{BS} (e.g.: U_{BS} = 0, –2, –4, –6, –8, –10 V, increment U_{GS} = 0,2 V) (or any other else suggested by teacher).

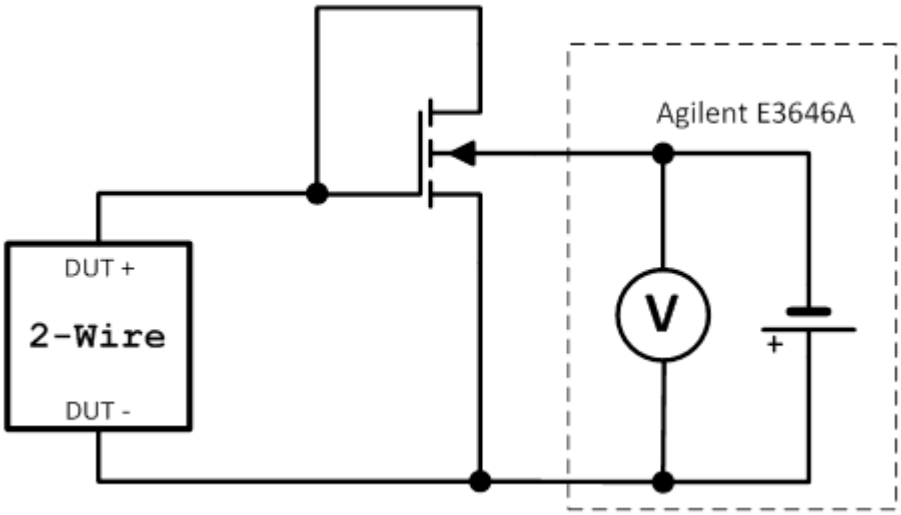

Fig. 4. Scheme for determination of **γ** coefficient of **n-MOS** transistor

4.4. DC transfer characteristics of p-type MOS transistor

Arrange the measurement setup according to Fig. 5, choosing one of the transistors available in CD4007. Carry out measurements to get a DC transfer characteristic $I_D = f(U_{GS})$ of the p-MOSFET transistor in the range of negative gate voltages from U_{GS} = 0 to -10 V, and constant U_{DS} = -5 V. Set the increment of U_{GS} to 0,25 (or any other else suggested by teacher).

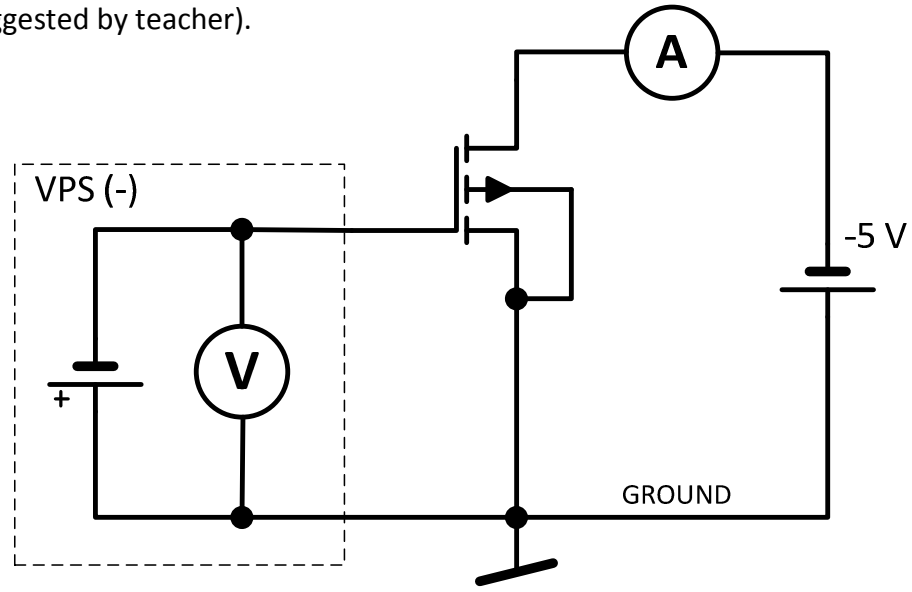

Fig. 5. Scheme of the measurement setup for obtaining DC transfer characteristics of **p-MOS** transistor

4.5. DC output characteristics of p-type MOS transistor

Arrange the measurement setup according to Fig. 6, choosing one of the transistors available in CD4007. Voltage U_{GS} should be provided from the external power supply (in order to get correct results, `2-Wire Analyzer` cannot use ELVIS GROUND). By means of `2-Wire Analyzer`, carry out measurements to obtain the family of output characteristics $I_D = f(U_{DS})$ p-MOSFET, for a few gate voltages (e.g.: U_{GS} = -2, -4, -6, -8, -10 V), (or any other else suggested by teacher).

REMARK: settings of `2-Wire Analyzer` should be as following: start voltage –10 V, end voltage 0 V, increment 0,2 V (U_{DSmax} = –15 V). Then, the characteristics will be drawn "opposite", i.e. from the saturation range to linear, and they will end at zero.

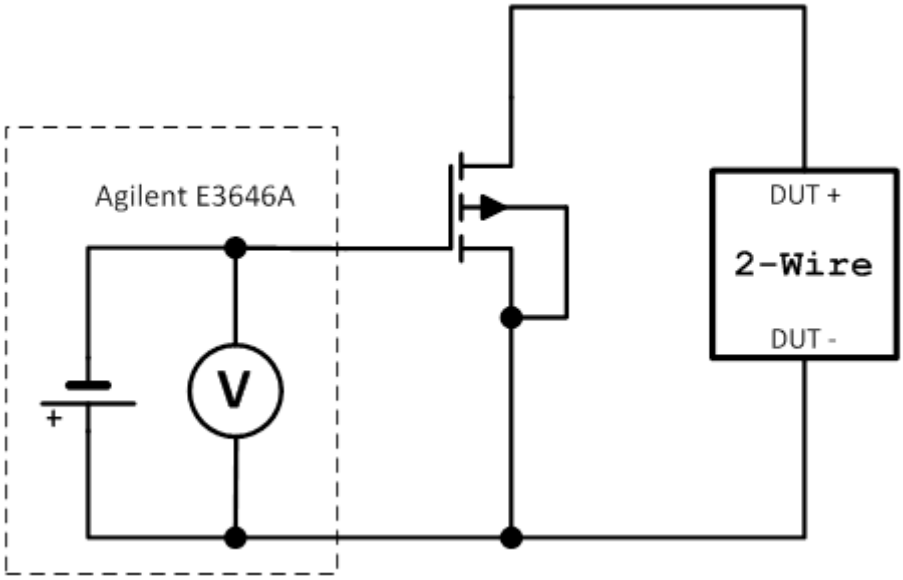

Fig. 6. Scheme of the measurement setup for obtaining DC output characteristics of **p-MOS** transistor

4.6. Investigation of body effect in p-type MOS transistor

Investigated transistor should work in saturation. Such conditions are fulfilled in measurement setup from Fig. 7 when $U_{DS} = U_{GS.}$ Arrange the measurement setup according to Fig. 7, choosing one of the transistors available in CD4007. Voltage U_{BS} should be delivered from the external power supply (do not use ELVIS GROUND). By means of `2-Wire Analyzer`, carry out measurements to obtain the family of DC transfer characteristics $I_D = f(U_{GS})$ for p-MOSFET, in the range of negative gate voltages U_{GS} = 0 to -10 V, for a few constant values of U_{BS} (e.g.: U_{BS} = 0, 2, 4, 6, 8, 10 V, increment U_{GS} = -0,2 V), (or any other else suggested by teacher).

REMARK: settings of `2-Wire Analyzer` should be as following: start voltage –10 V, end voltage 0 V, increment 0,2 V (U_{DSmax} = –10 V).

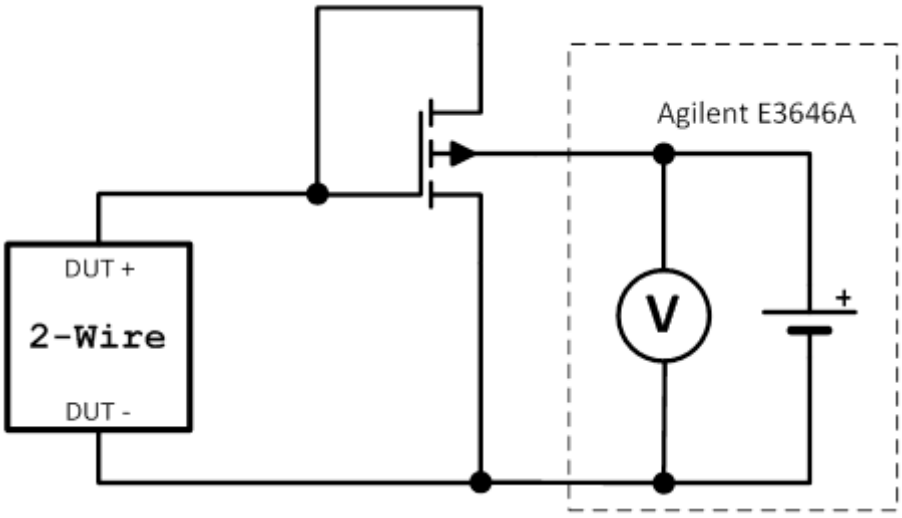

Fig. 7. Scheme for determination of **γ** coefficient of **p-MOS** transistor

5. DATA ANALYSIS

5.1. n-MOS transistor

- Taking into account the results from 4.1, prepare DC transfer characteristics $I_D = f(U_{GS})$. Add to it some auxiliary plot $\sqrt{I_D} = f(U_{GS})$, and then estimate threshold voltage V_T.
- Taking into account results from 4.2, prepare DC output characteristics $I_D = f(U_{DS})$. Draw a border line between linear and saturation areas. Estimate saturation current I_{DSS} for these U_{GS}, for which the output characteristics have been carried out. Then, show the results in table and estimate the λ parameter.
- Taking into account the results from 4.3, prepare the characteristics $\sqrt{2I_D} = f(U_{GS} = U_{DS})$. Then, estimate γ and β parameters. Compare the results with those obtained in the previous point, and comment.

5.2. p-MOS transistor

Taking into account results from 4.4, 4.5 and 4.6, prepare the characteristics and calculations in the same way as for n-MOS transistor.

6. LITERATURE

[1] Lecture (P. Dziurdzia)

[2] Behzad Razavi „Fundamentals of Microelectronics”