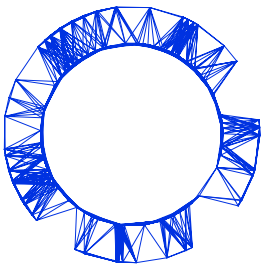
IPhO 2018
Lisbon, Portugal



Confidential

Detailed Marking Scheme Experimental Problem 1

Paper transistor

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July 22, 2018

v1.4

Paper transistor (10 points)

Part A. Circuit dimensioning (2.5 points)

A.1

Apply Ohm's Law	0.1
Obtain the output voltage	0.1
Total	0.2

A.2

Five or more measurement for each resistance	0.3
Calculate the average	0.1
Uncertainty	0.1
Total	0.5

[not reasonable enough number of points, -0.2pt]

A.3

Expression for the resistance	0.1
Obtain $R_\square$	0.2
Total	0.3

A.4

Calculate the weighted average sheet resistance	0.2
Obtain the resistivity	0.2
Total	0.4

[missing the uncertainty, -0.1pt]

A.5

Expression for the theoretical κ	0.2
Measurement of the resistances	0.1
Experimental value of κ and comparison	0.2
Total	0.5

A.6

Measurement of the resistances R_x and R_y	0.3
Total	0.3

[missing units in the table, -0.05pt; mixing up R_x and R_y, -0.1pt]

A.7

Measurement of all V_{out} values	0.3
Total	0.3

[missing or wrong unit, -0.05pt; wrong sign of V_{out}, -0.1pt]

Part B. Characteristic Curves of the JFET transistor (4.5 points)

B.1

Value within 20% of the correct value	0.2
Total	0.2

[missing or wrong unit -0.05pt; missing uncertainty -0.05pt]

B.2

Measurements of I_{DS} (first part)	0.3
Measurements of I_{DS} (second part, at least four sets of measurements for $V_{\text{GS}} < 0$)	0.4
Five or more sets of measurements for $V_{\text{GS}} < 0$	0.1
Total	0.8

[wrong or missing current units, -0.1pt; wrong number of significant digits in table entries, -0.05pt]

B.3

Expression for f	0.2
Total	0.2

B.4

Realize that $R_L = R_{DS}+$ internal resistance of multimeter	0.2
Calculation of R_{DS} from nominal data	0.3
Apply correction factor f	0.5
Subtract the voltage drop inside the multimeter	0.2
Total	1.2

B.5

Plot, at least, five curves (0.1pt each)	0.5
Total	0.5

[use uncorrected V_{DS}, -0.1 pt; wrong or missing axes labels, -0.1pt]

B.6

Obtain the experimental values from slopes	0.3
Plot the graph	0.2
Total	0.5

[any reasonable graph is worth 0.2; no graph analysis required]

B.7

Draw a good plot	0.3
Total	0.3

[wrong or missing magnitudes in axes labels, -0.05pt; wrong or missing units in axes labels, -0.05pt; plot the curve for a wrong V_{DS}, -0.3pt; graph showing unreasonable deviation with respect to the transistor data, -0.2pt]

B.8

Current I_{DSS}	0.1
Obtain V_p using the appropriate graphical method (plotting $\sqrt{I_{DS}}$ as a function of V_{GS})	0.2
Comparison	0.1
Total	0.4

[if V_p is not obtained from an appropriate graphical method, using a plot with linearized data, -0.05pt]

B.9

Plot the transconductance curve	0.1
Obtain g from the slope of the tangent to the curve	0.2
Comparison with model equation (2)	0.1
Total	0.4

Part C: The Paper Thin Film Transistor (2.0 points)

C.1

At least fifteen data points presented in the table	0.8
Total	0.8

[not using the appropriate multimeter range (2000 μA), -0.1pt; missing units, -0.1pt; data deviating too much from the expected behaviour, -0.2pt; IDS for the closed transistor is not the 1st value, -0.1pt; not enough points in the fast changing regime, -0.1pt]

C.2

Draw a good plot	0.3
Show the similarity with two parallel RC circuits	0.1
Subtraction of the long-time constant component	0.4
Determine τ_1	0.4
Total	1.2

[missing or wrong units in the plot -0.1pt]

Part D. Inverter Circuit (1.0 points)

D.1

Measurement of R_L in the correct range	0.1
Measurement of, at least, eight points	0.2
Data showing a clear cut-off (V_{out} should go below 0.1 V)	0.2
Total	0.5

[missing units and/or wrong labels, -0.05pt each; τ_1 not used as time in between measurements, -0.1pt]

D.2

Draw a good plot, including the smooth trend curve	0.5
Total	0.5

[missing units and/or wrong labels, -0.05pt each; non-smooth curve (e.g. trend curve with spikes), -0.2pt]