

Back to Normality - Changes in Time-Effective Logistics of Project-Based Course Electronic Instrumentation after COVID-19 Limitations Release

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Abstract—The classic course Electronic Instrumentation was based on analog electronics - analog sensors, actuators, and amplifiers, and, in most universities, was taught as the theoretical course followed by a specialized and expensive laboratory. The appearance of inexpensive microcontrollers changed the way sensors and actuators are used; hence, our days, Electronic Instrumentation can be taught as "a classic course in the modern envelope": by using as analog as digital elements and by using special programming techniques needed to program microcontroller effectively. This presentation describes changes in the time-effective logistics which was used for eight years to teach this course in the "normal time", in "COVID-19 time", "in the Hybrid time" and, again in the "normal time" by using real electronic components and kits, and by using TinkerCad simulations.

Keywords-project-based learning; time-effective logistics; electronic instrumentation; TINKERCAD.

I. INTRODUCTION

The course "Electronic Instrumentation" is one of the basic courses in the curriculum of an electronic engineer. Most classical books dedicated to this course describe the operation, design, and parameters of different sensors and actuators – for example, temperature sensors and electrical heaters. A significant part of those books discusses analog devices (like analog voltmeters and ammeters) used to measure different physical parameters by using specialized sensors [1] [2]. Books for advanced students additionally discuss calibration procedures, errors, and the reliability of the measurements [3]. Some books provided a detailed description of the full-fledged analog systems designed to control relevant parameters by using specialized sensors and actuators and electronic amplifiers and filters.

In the past, the classic course Electronic Instrumentation was based on analog electronics - analog sensors, actuators, and amplifiers. Hence, in many universities and colleges, this course was taught as a theoretical course – mostly due to the high cost of the real-life systems used in the industry. For example, the description of the course "ENT353 Electronic Instrumentation Systems" claims that "At the end of this course students will be able to demonstrate the ability to design instrumentation system suitable for required parameter measurement, understand the working principle of

instrumentation system, and describe the working principle of various sensing devices" [4].

Many educators in the field of electronic instrumentation have emphasized the importance of practical training: "In most of the following steps: conceive, experiment, design, build, test, improve – practical aspects are critical for understanding the items learned" [5].

Leading educational institutions like MIT [6] and others includes in their curricula of electrical engineering set of laboratories in which basic electronic equipment and real electronics components are used.

Starting from the 80s, electronic analog systems were gradually replaced by digital systems containing "the wonder chip Micro-processor" [7] [8]. Large control panels packed with analog voltmeters, ammeters, and mechanical switches were gradually replaced by small-size digital systems with human-friendly displays. Additionally, the appearance of inexpensive microcontrollers changes the way sensors and actuators are used. Hence, our days, the course Electronic Instrumentation can be taught as "a classic course in the modern envelope": by using as analog as digital elements, plus using special programming techniques. Thus, our days, the programming of Micro-processors has become an important part of the education of electronic engineers.

Online technologies were used by many educators long ago, but these technologies have become vital because of the COVID-19 situation: the situation in education, which is seriously dependent on the epidemiological situation, makes educators look for new ways of education [9]. It became a must to provide a way to carry out electronic experiments and assignments, as in a real laboratory, as in a student's home. An interesting option was to use the online platforms for implementing elements of the Electronics Laboratory by using online electronic simulation platforms like TinkerCad [10] [11].

An additional idea was to lease to each pair of students a specially prepared kit containing real electronic components and an inexpensive microcontroller development board. Then, students would be able to execute assignments at their homes – by using the kit and PC. Some elements of this idea were partly described in [12] [13]. This article describes additional details of the practical implementation of this idea.

Section II describes "Elements of the Course": lectures, exercises, non-obligatory "in-class Micro Exams", "Home Works" and "Micro Projects", including practical details of

how they were provided in “regular times” (when lectures and exercises were provided physically at the campus), in “COVID19” time (when lectures and exercises were provided by using online ZOOM services), in a “hybrid” situation (when some students were physically visited lectures and exercises, while others were used ZOOM translations), and, finally – last semester – “back to normality” – when lectures and exercises were provided physically at the campus.

Section III describes the implementation details of Gmail Protocol which is an important element of time-effective logistics.

Section IV describes details of the logistics of “Micro Exams”, “Home Works” and “Micro Projects”. The logistics of “Micro Exams” are described in subsection ‘A’. The logistics of “Home Works” are described in subsection ‘B’. The logistics of “Micro Projects” are described in subsection ‘C’.

An important part of any “time-effective” logistics of that kind is time-effective and fair grading. Details are described in Section V named “Time-Effective logistics of reports checking”.

Section VI shortly summarizes the results of student pools (partly published in the previous publication [13]) and provides some conclusions.

II. ELEMENTS OF THE COURSE

Course Electronic Instrumentation in the new format was provided at the Department of Electronics of Braude Academic College of engineering every semester starting from 2015. Important elements of this course: 13 two-hour frontal in-class lectures, 13 one-hour in-class exercises, three “Home Works”, two “Micro Projects”, and 10 non-obligatory “in-Class Micro Exams” (provided during exercise hours).

“Home works” and “Micro Projects” are executed by pairs of students, whereas “Micro Exams” are individual assignments.

In the “normal pre-COVID-19 years” (from 2015 to 2020), the course “Electronic Instrumentation” was provided on campus. During three semesters starting from March 2020 to August 2021, this course was provided under strict COVID-19 restrictions by using online tools only: ZOOM, TinkerCad, and Gmail. Specifically: lectures were provided by using remote ZOOM sessions, and assignments were executed by using TinkerCad simulations instead of using real components. Starting from October 2021, the course was provided in a hybrid way: lectures were provided at the campus, but with ZOOM “on”, so that students have a choice: to visit the campus or listen to the lectures by ZOOM from outside the campus. “Home Works” and “Micro Projects” were executed by using the kits, but in some situations, students were asked to provide simulations by using TinkerCad and/or MultiSim simulation applications. From October 2022, the course is provided in a “normal in-class” way. However, the practice of using TinkerCad and other simulations in combination with using real components and development boards was found useful for the goals of

the course, hence, currently, this practice is continuing to be used.

III. GMAIL PROTOCOL

In prehistoric pre-computer times, students’ assignments were prepared by using pen and paper. At due time, students put their papers on the educator’s table. Then, the educator physically took those papers to his/her cabinet, checked and graded those papers by using pen and paper, and returned the graded exams to the students. This outdated procedure created a lot of logistics problems and conflicts (like lost papers, non-consistent grading, problems with grades appeal, and others), and, what is more important, it was not time-effective from the point of view of the educator – it was not an easy job to read handwritten texts.

When personal computers became available, students started to print their assignments, but this solved only the problem of reading handwritten texts.

Email services, from their origin, were found instrumental in many businesses in documenting different stages of routine operations. Gmail services were pioneers by implementing some obvious today ideas like online access to all emails from any computer, usage of multiple labels, and simple and fast search in the emails. Hence, free Gmail services were selected for collecting student assignments. It is known that for security reasons, many educational organizations effectively forbid using Gmail services by enforcing the usage of special educational platforms like “MOODLE”. In order to comply with those security requirements, the Gmail protocol described never uses the full names and full IDs of the students. Additionally, for every course, a dedicated Gmail address is used.

From 2015 this Gmail protocol was evolutionarily modified. Currently, the following rules are used.

The dedicated Gmail address is used to collect and store students’ assignments only. Discussions are provided by using official college communication means only.

When the specific assignment is ready, one of the students fills the standard fields of the email:

“To”: in this field, only the address of dedicated to the specific course Gmail must be written.

“CC”: email address of the second student. This requirement is very important as proof that the assignment was sent at due time and to the correct address. Additionally, the second student may validate that the correct version of the assignment was sent.

The “Subject” field was filled by a specially designed alpha-numeric descriptor – “Report ID”. In order to find an optimal format, its structure was modified in some semesters. In the last semester, the following format of the “Report ID” was used:

ABCD-EFGH-Z-YYYY-MM-DD

Where: token “ABCD” contains the last 4 digits in the ID of the first student, and token “EFGH” - contains the last 4 digits in the ID of the second student. In order to prevent ambiguity, it was requested that numerically $ABCD < EFGH$. This rule, in a pseudo-random way, automatically defines who is the first student, and who is the second

student (the first student signs on the kits leasing form). Token “Z” equals to “HW01” for the “Home Work 01”, “HW02” for the “Home Work 02”, and “HW03” for the “Home Work 03”. Homework items were the same for all pairs of students. For “Micro Projects 1”, token “Z” was equal to “MP1V”, where V was the number in the first list of assignments to be executed. Those numbers were set in a pseudo-random way in the range {1..6}. For the “Micro Project 2” token “Z” was equal to “MP2N”, where N was the number in the second list of assignments to be executed. Those numbers were set in a pseudo-random way in the range {1..5}. “YYYY-MM-DD” stands for the year, month, and day of the report. Delimiter “-” was used to make the “Report ID” more readable for humans and to make a search by tokens plain and simple.

The “Text” field was used only to comply with the Gmail rule to fill it in some way and not to send Gmail with this field void. So, students were asked to write there at least two letters, or, some very short text.

The attachment was a PowerPoint file named exactly as described before “report ID”:

ABCD-EFGH-Z-YYYY-MM-DD.pptx

In some cases, students were asked to attach ZIP file, named as

ABCD-EFGH-Z-YYYY-MM-DD.zip

This strong naming policy enabled a simple search by the tokens of the “Report ID”. Two examples of search are presented in Figure 1. On the left is presented an extract of the result of the search of all reports of “Home Work 03” by using the token “*-HW03-*”. On the right is presented the extract of the result of the search of all assignments of the specific pair of students by using the short ID token of the first student: “*-1608-*”.

IV. LOGISTICS OF “MICRO EXAMS”, “HOME WORKS”, AND “MICRO PROJECTS”

The logistics of “Micro Exams” are described in subsection ‘A’. The logistics of “Home Works” are described in subsection ‘B’. The logistics of “Micro Projects” are described in subsection ‘C’.

A. Logistics of “Micro Exams”

Originally, “Micro Exams” were executed in class, during the time of the exercises. In the frames of those micro exams, students were asked to solve on paper a short clearly defined problem, technically close to one of the problems solved during previous lectures and exercises. After a short time (say, 5 minutes), an educator collected papers from the students. The exact time of the start of the specific “Micro Exam” was set by a lecturer in a way unknown to the students.

Later, the logistics of the micro exams was changed. Students were still asked to write the solution on paper, but then they were asked to take a photo of their solution by using a smartphone and email the photo to the lecturer by using the subject field “ABCD-MEZ”, where Z is a number of the “Micro Exam”. It is clear that only emails sent immediately after the “Micro Exam” finish were graded.

When the COVID-19 restrictions were enforced, these logistics was used without changes. During the hybrid semesters, the administrative decision was to permit participation in micro exams only to the students technically present in the class. Hence, it was “return” to the “collection of the papers” logistics. This old and non-reliable practice is still in usage after “back to normality”. Surprisingly, many students started to ask if it is possible to use tablets to solve problems by using handwriting tools (like S-pens). So, considering that nearly all students have advanced tablets, it can be predicted that in the nearest years, paperless logistics will be used for “Micro Exams”.

The first goal of those “Micro Exams” was to provide minimal feedback to the lecturer: what is the level of the student’s understanding of the material learned? The second goal was to provide minimal feedback to the students: do I understand the material learned? This is why during “Micro Exams” students were permitted to use computers and the Internet, and even ask neighbor students for assistance. All the above were permitted because the additional goal of these exams was to enforce students to learn critical staff (for example: correct usage of timers and hardware interrupts) now, and not closer to the end of the course.

Participation in the “Micro Exams” is not a must, however, presenting the solutions to the lecturer may result in some improvement in the final grade. Typically, nearly 50% of students participated in the Micro Exams and nearly 25% of all the students enrolled in the course have got maximal grade improvement.

B. Logistics of “Home Works”

At the beginning of the “normal” semester, pairs of students get from the lecturer a specially prepared kit to be used at their homes to practically implement “Home works”. Specifically, in the frames of the course Electronic Instrumentation, students get: a 37-in-one Sensor kit, an Arduino UNO R3 board, a small-size breadboard, a shield with a small breadboard, a short USB cable, a set of wires, and a plastic box to store relevant staff.

As it was mentioned above, during three semesters starting from March 2020 to August 2021, this course was provided under COVID-19 restrictions. During those semesters, the distribution of real electronic components became at least problematic, but working in pairs with real components became impossible.

The selected solution was to use online TinkerCad simulations. An important feature of this simulation is that it is a free cloud service, without the need for installation or license.

During the exercises provided by ZOOM, the lecturer periodically provided live demonstrations of the TinkerCad operation.

So, during “normal” semesters, students were asked to implement “Home Works” by using real components, prepare a report containing photos of the assembly (step by step) and testing the system in accordance with the lecturer’s requirements, and, to demonstrate the operation of the system physically in the class.

In the “COVID-19” semesters, students were asked to do with TinkerCad simulation actually the same steps as with real components: to position modules and to connect them by wires, but, instead of photos of real components, screenshots of the simulation screens were used. Students were requested to include the link to their TinkerCad simulation in the report so that the lecturer was able to check the layout, the code, and the operation of the system developed by students. The same link was used by students to demonstrate the operation of their system during the ZOOM session.

Figure 2 demonstrates typical extracts from the student’s reports. On the left, the screenshot of the TinkerCad simulation is presented. An educator may immediately see that wire from the button is connected to the inappropriate pin – which is a severe error – hardware interrupt cannot be used as required. On the right, a photo of a real board with real modules and wires is presented. An educator may immediately see that the photoresistor is not in line with LED, which is a problematic layout – leading to a significant error in measurement.

It is clear that if some pair of students had “copied” photos and “code” from the report of another pair of students, this would be immediately revealed. During eight years, such “illegal copying” was revealed less than 10 times.

Figure 3 presents a simplified flowchart of the steps expected to be executed by the educator and by pair of students in the frames of the described logistics for the different situations.

C. Logistics of “Micro-Projects”

In the frames of the course, students were asked to prepare two “Micro-Projects”.

The first micro project was about different types of motors (6V DC, Servo, Stepper, and Brushless). Each pair of students prepared a PowerPoint presentation dedicated to a specific type of motor and to a specific type of electronic controller and, present it in the class (in case of the “regular” semester) or by ZOOM (in case of “COVID-19” semester). In these presentations, students were asked to explain the physical principles of the specific motor operation and explain how this motor can be controlled electronically by presenting the exemplary circuit needed to control this motor from a microcontroller.

The second Micro Project was about the design of an Automatic Measurement System (AMS). However, considering the tight timetable, the quality of those Micro Project reports was not as good as expected. Hence, in the last years, a simpler Manually Controlled Measurement System (MCMS) was asked to be designed and implemented only by using simulations. Each pair of students was asked to develop a different type of MCMS: an MCMS for measuring DC voltage in different voltage ranges, an MCMS for measuring AC voltages in different voltage ranges, etc. Students were asked to prepare the electric circuit of the MCMS, provide relevant calculations, and prepare a simulation of the analog part only. In this case, each pair of students was asked to send a PowerPoint presentation close

to the end of the semester. Grading was provided by evaluating the quality of the report and simulation.

V. TIME-EFFECTIVE LOGISTICS OF REPORTS CHECKING

It is clear that checking 12*(3+2) reports is a time-consuming job. Hence, significant efforts were made to develop time-effective logistics (a set of formal rules) describing how exactly students must prepare and send their assignments.

Figure 4 presents an extract from the specially prepared Excel template. To make grading fast and consistent, a relatively large number of items to be checked are listed in column ‘B’. While grading the specific report, an educator in a very short time finds in the student’s report a slide labeled as in column ‘A’ and, by looking at the photos or screenshots very fast validates if all the requirements were implemented. In case of errors, an educator sets a comment in the relevant cell. To make this process fast, in column ‘J’ typical errors relevant to the specific item and “their price” are summarized, so that the educator puts in the comment only the number of the relevant error. Grading by template was proven as fast and consistent.

VI. CONCLUSIONS

During 10 years, different variants of this time-effective logistics for the different electronic engineering courses were tested. Some results were published before in [12] [13] and reported at a number of international conferences. Unfortunately, in recent years the participation of the students in the students’ pools was minimal or even zero. Considering the semesters when student’ pools were provided, grades provided by students for this course were in the range {4.23...4.94} (by using 1-5 scale) and were in most cases by 0.5 higher than the mean department’ courses grade. In the written comments, most of the students’ remarks were positive, and, the median grade for this course in most of the semesters was 5.0. Additionally, we may evaluate the opinions of the students by using the number of students enrolled in this course. This course is not obligatory course. The number of students that can be enrolled is 24. During nearly all semesters the number of students that were registered for this course was 24, and, in most semesters, a number of students registered themselves on the waiting list. Obviously, not all students have got grades at the end. The numbers for the semesters {2019-03 .. 2022-10} are {24, 24, 23, 18, 21, 23, 22, 24}. By analyzing the number of students that have got grades, one can conclude that the organization and outcome of this course are attractive enough for the students.

Manual management and grading of the student's reports (by using grading templates) was found simple and time-effective, as for the students, as for the educators. An indirect parameter that can be considered as an indirect argument taken into account is a low number of grade appeals – less than 3 per semester.

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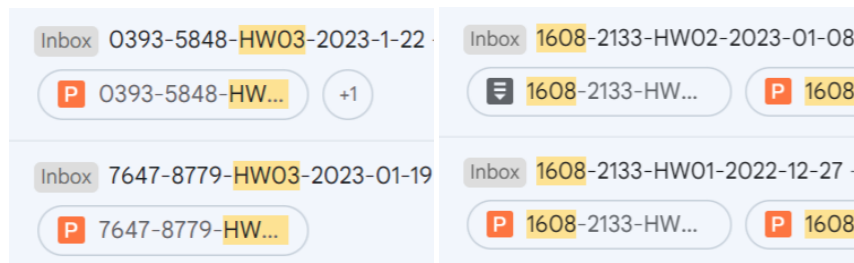


Figure 1. Screenshots of the lecturer's Gmail.

Left: Extract of the result of the search of all reports of "Homework #03" by using token "*-HW03-*"

Right: Extract of the result of the search of all assignments of the pair of students by using the short ID token of the first student "*-1608-*"

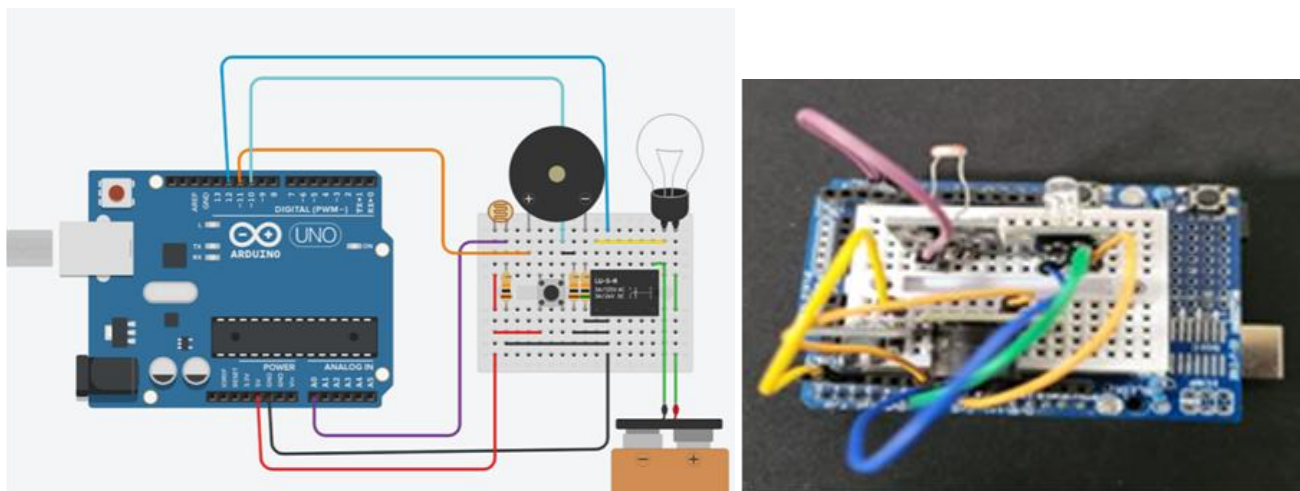


Figure 2. Easy grading.

Left: Screenshot from Version 1 of the Homework 01 report as implemented by pair of students by using Tinkercad simulation.

An error in the wiring can be seen: the pin in the button module is not connected to pin 2 or pin 3 of the Arduino UNO R3 Board.

Right: Screenshot from Version 1 of the Homework 03 report as implemented by pair of students by using a hardware kit.

An error in the layout can be seen: the photoresistor and LED are not in line.

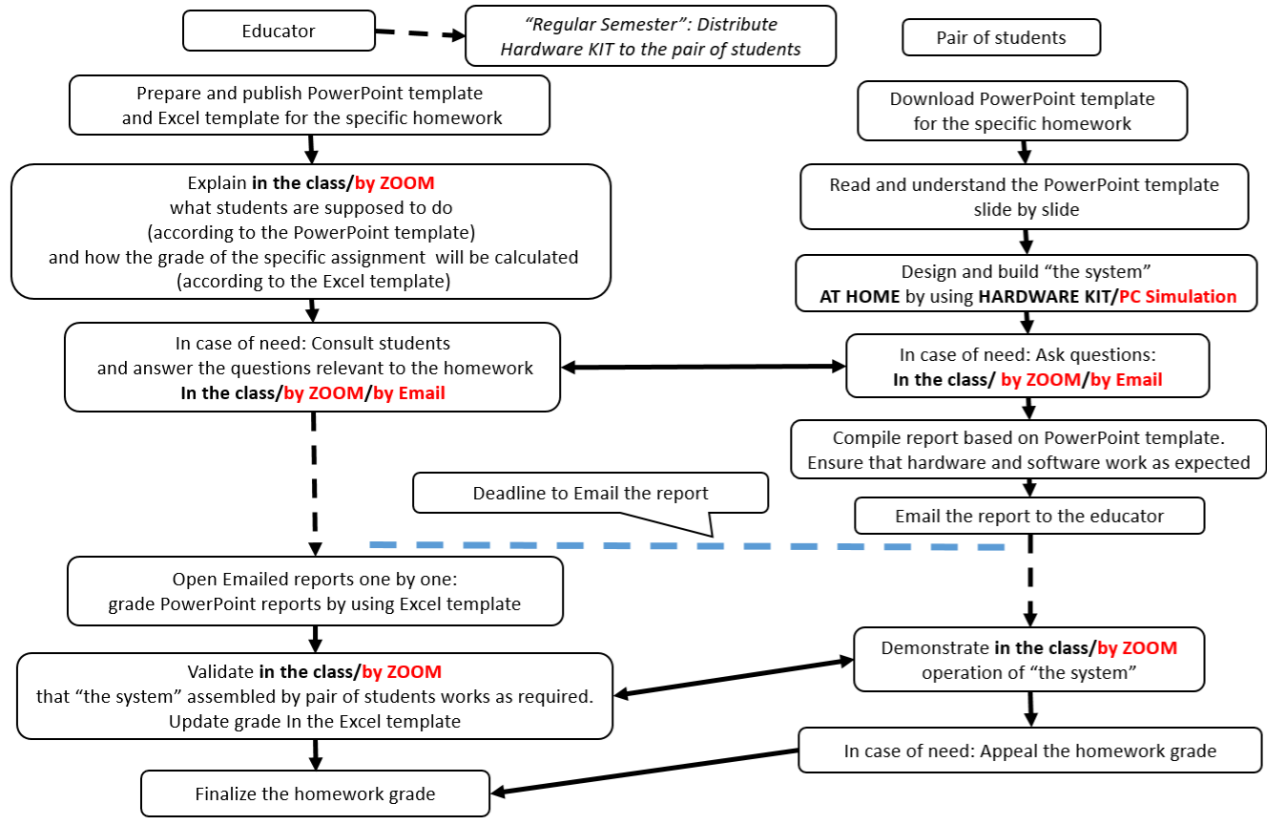


Figure 3. Simplified flowchart of the exemplary homework roadmap. Left: actions of the educator. Right: actions of pair of students

A	B	C	D	E	F	G	H	I	J
Code	Item	Max Grade	7647-8779	3810-7278	1608-2133	0393-5848			Typical Errors
1									
8									
9	P1V.11 Mechanical and Electrical Elements of the motor (drawings with numbered list of parts and explanations)	3		3	3	0	3		
10	P1V.12 Physical principles of the motor operation (drawings, equations and explanations)	3		3	3	0	3		
11	P1V.13 Photos (from Internet) of at least TWO commercially available motors from different companies and with pins explanations	2		2	2	0	2		
12	P1V.14 Important parameters of above two motors (names and typical values and graphs with VALUES) + explanations & comparisons; recommendations which motor to select when and why	4		4	4	0	4		
13	P1V.21 Full Electrical circuit of a motor controller (in case of IC – what exactly is inside IC)	4		4	4	1	2		
14	P1V.22 Photos (from Internet) of at least TWO commercially available motors controllers with pins explanations	2		2	2	2	2		
15	P1V.23 Full electric circuit of the working motor system: containing Arduino, Controller, Motor, External Power supply (if relevant)	4		4	4	4	4		
16	P1V.24 Explanation: how speed and direction of a rotation can be changed by Arduino Commands	4		4	4	0	2		
17	P1V.25 Evaluation of speed (RPM) limits. Explanation of a typical torque behavior	2		2	2	2	2		
18	P1V.3 Numbered List of sources IEEE style	2		2	2	2	2		
19									
20									
	Total	30		30	30	11	26		

Figure 4. Extract from Excel template for grading Micro Project 1.