AC 2010-163: FIRST USE OF A PROTOTYPE NATIONALLY-NORMED ASSESSMENT EXAM FOR EET PROGRAMS

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Development of a Prototype, Nationally-Normed Assessment Exam for EET Programs

Abstract

For many years, faculty and administrators of electrical/electronic engineering technology (EET) degree programs have voiced a need for a comprehensive, nationally-normed exam, available to all EET graduates, that would provide a valid assessment of the cumulative skills of students completing their programs. ABET's adoption of outcomes-based accreditation criteria, which emphasize assessment and continuous program improvement based on objective measurements, heightened the importance of such a exam. As a result, the Electrical and Computer Engineering Technology Department Heads Association (ECETDHA) undertook a project beginning in 2007 to develop just such a test. Several key accomplishments were necessary for this project to be successful. Among these were (1) quantification of the true level of interest for such a test within the EET community and the level of financial support that could be generated from those interested, (2) recruitment of expertise in standardized exam development, (3) identification of key topics to be covered by testing, (4) recruitment of topic experts to develop and validate exam matter, (5) implementation of beta testing validation of the completed product, and last but not least, (6) acquisition of funding to support the development and exam validation effort.

As of August 2009, all of these tasks have been completed successfully for a 'core topics' EET exam, and the exam is now being readied for its first official offering to EET programs across the country. This paper and presentation will document the details of how these tasks were completed, the results of the beta test validation, and, if possible, the results of the first official offering should those results be available by the time of the ASEE conference.

Background

For years there has been an ongoing discussion among members of the electrical and electronic engineering technology (EET) community about the need for better tools to assess the overall effectiveness of academic programs and the cumulative knowledge and skills of graduates from those programs. One oft-mentioned tool deemed useful for this purpose is some form of general overview exam, similar in concept to the Fundamentals of Engineering (FE) exam. In fact, some baccalaureate EET programs use the FE for this purpose. Unfortunately, the FE is not available to all EET programs, either because state registration policies prohibit its use or because many EET programs are 2-year associate degree programs. More important, most EET professionals feel the FE is not generally well-aligned with the content and objectives of EET programs, and thus not an effective evaluation tool even if available.

Discussions of this nature were a recurring, but unaddressed, topic in meetings of the Electrical and Computer Engineering Department Heads Association (ECETDHA) until early 2006 when the group decided to undertake a project to address the need. That decision came about because of a serendipitous meeting between a member of the Association and several representatives of the Society of Manufacturing Engineers (SME). At that meeting, the SME, which has a long and successful history of developing and managing standardized certification exams, was describing

their initiative to offer their test development and management services to other fields outside of manufacturing. That meeting led to the SME making a similar presentation to the Association, and the identification of a proven test development system led the Association to undertake an investigation of the true level of interest in standardized exams for the EET community. That decision ultimately led to the creation, testing, and trial implementation (currently underway) of what is hoped to become a 'nationally-normed' assessment exam for core electrical/electronic concepts.

Justification for Exam Development

Obviously, development of an exam would require funding. Before the Association could pursue funding, it was necessary to determine if the interest in the EET community for an assessment exam was truly sufficient to justify a development effort. This question was answered via a series of surveys of both the Association membership and the broader audience of the Engineering Technology Division (ETD) listserv.[(i)] The surveys asked respondents first to indicate if they had an interest in a normative assessment exam, and if so, to identify the EET-related disciplines for which they would find such an exam useful. They were also asked to estimate, if an exam was available, how many students they would expect to have take the exam each year, how frequently they would use an exam, and how much they would be willing to pay for testing. Finally, they were asked to identify the level of program they represented.

To summarize, the survey results indicated a broad-based interest in assessment testing. Positive responses were received from a range of EET-related disciplines and programs. As might be expected, the majority of the interest was from baccalaureate programs in the core disciplines of electrical and electronics. Nonetheless, there was non-trivial interest from ancillary disciplines and from 2-year programs. In the aggregate, the results did indicate a potential level of interest adequate to financially support a test should one be available. Survey questions and a compilation of the results are documented in the reference, which can be viewed on the Association's page of the ETD website.[(ii)]

The key results, however, had to do with the costs which respondents were willing to pay for access to testing. Respondents were asked to identify a price level at which they would be willing/able to take advantage of testing, and to estimate how many students they would test each year at that price level. Those results provided a basis for estimating a price point that would maximize revenue from an ongoing testing program. When these results were reviewed with the SME, it was concluded that there was likely adequate support to maintain a testing program should an ongoing testing program be put in place. Of course these results related to operation and maintenance of an ongoing testing process. Armed with this result, the Association membership decided to initiate a project to create and try out an assessment exam.

Funding for Exam Development and Implementation

Survey results indicated potential funding to support a testing program; however, they said nothing about funding the creation of an exam and establishment of a testing program. For that, the Association called on its relationship with the IEEE. The Chair of the ECETDHA is an invited ex-officio member of the Committee on Technology Accreditation Activities (CTAA), which is a sub-committee of the IEEE's Educational Activities Board (EAB). At the time, the Chair of the EAB was Dr. Moshe Kam, who was intently interested in enhancing the IEEE's

involvement in and support of engineering and technical education. This combination provided an opportunity for the Chair of the ECETDHA to present the idea of creating, with the help of the SME, a national assessment exam for EET to Dr. Kam. As a result, Dr. Kam was able to arrange for $75k of funding from the IEEE to support the project. Those funds were used to contract with the SME, with volunteer help from the membership of the ECETDHA, to manage the development of a prototype exam. The contract was officially in place in late 2007.

Exam Development Process

With funds in hand, a five person project management team representing the Association, the IEEE, and the SME was assembled, and the team, under direction of the SME, fashioned a project plan that would produce a prototype exam in approximately one year. The plan included five major elements:

- Recruitment of members of the ECETDHA to serve as content experts,
- Development of a 'body of knowledge' defining the field or electrical/electronic technology,
- Generation of exam questions covering 'body of knowledge' topics,
- Independent review of questions for accuracy, appropriateness, and difficulty, and
- Exam assembly for beta testing.

Recruiting Volunteers: The SME's role in the project was to manage and coordinate test development. Technical content, on the other hand, was strictly the responsibility of the ECETDHA, and was to be provided by volunteers from among the membership. Though the membership had been kept informed of the efforts to put this project in place, and the need for volunteer support should it go forward, no actual call for help was made prior to signing the contract with SME. Thus, the first task was to get people to actually sign on to help. This was done via a broadcast e-mail to the membership announcing funding of the project, describing the project plan, identifying the kinds of support and expertise needed, and asking for members to sign on for one or more of the identified tasks. To the membership's credit, the response was immediate and outstanding. By the time the project was completed, more than twenty different individuals helped create the body of knowledge, generate questions, review and validate questions, or in most cases, help with all three of these activities. The list of names is too long to include here, but the success of this project is due largely to their dedication and many hours of effort writing and reviewing questions, participating in web conferences, and conducting final quality reviews.

Developing a Body of Knowledge: With volunteers in place, the first technical task for the Association volunteers was to assemble a body of knowledge (BOK) for EET. Essentially, a BOK is a detailed topical outline listing the full extent of subject matter encompassed by a specific discipline. As a first step, volunteers were provided with guidance from the SME on the characteristics of a good BOK, including examples from non-electrical disciplines. After reviewing these materials, each volunteer was asked to propose a list of just the major topical areas appropriate to the EET discipline. Those lists were combined and culled to arrive at a single list, which was returned to the volunteers with a request that they expand the major topics in their areas of expertise into two or three additional sub-levels of detail. These expanded lists

were again combined into a single outline and returned to the full team for review. An excerpt of this final list is shown below.

Body of Knowledge Excerpt

1. Basic Concepts of Electricity
   - 1.1. Systems of Units and Notation
     - 1.1.1. Units Systems and Fundamental Units
     - 1.1.2. Standard Notation
     - 1.1.3. Significant digits and rounding
   - 1.2. Voltage and Current Concepts
     - 1.2.1. Voltage
     - 1.2.2. Current
   - 1.3. Conductors and Insulators
     - 1.3.1. Free and bound electronics
     - 1.3.2. Barriers and hindrances to charge movement
     - 1.3.3. Relative conductivity – conductors vs. insulators vs. semiconductors
     - 1.3.4. Breakdown voltage
   - 1.4. Resistivity, Resistance and Color Codes
     - 1.4.1. Resistivity as a material property
     - 1.4.2. Resistance/conductance as device properties
     - 1.4.3. Resistance combinations
     - 1.4.4. Color codes
     - 1.4.5. Resistor types
   - 1.5. Ohm's Law
     - 1.5.1. Linear V-I relationships
     - 1.5.2. Non-linear V-I relationships
     - 1.5.3. "DC" and "AC" resistance

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In its initial form, the BOK identified twenty different topical areas, and details stretched to almost twenty pages. It clearly represented more than any single academic program could conceivably cover because many of the major topics represented specialty areas that are emphasized by some programs but ignored by others. As a result, a decision was made to limit the initial exam development to 'core' topics, where 'core' was defined to mean those topics that would be expected to be part of any EET program regardless of a specialization it might emphasize.[iii] The content volunteers were charged with examining the full BOK and coming to agreement on which items should remain on the 'core' list and which should be moved to a 'specialty' list. The result was a 'core' BOK consisting of the eight major topics listed below. These core topics were further detailed by approximately 350 subtopics.

Core BOK Topics

- Basic Concepts of Electricity
- Alternating Current (AC) Circuit Concepts
- Basic Circuit Analysis Methods
- Digital Electronics

- Analog Electronics
- Microcontrollers & Microprocessors
- Instrumentation & Measurement
- Practical Laboratory Skills

Question Writing: Agreement on a core BOK was the beginning point for drafting exam questions. The BOK was distributed to the volunteer content experts, and they were asked to identify the topics that they felt best qualified to work on. Simultaneously, the SME organized multiple web-based training sessions to explain how to write effective questions. The training sessions were augmented by standardized question development tools from the SME. These included question writing guidelines, standardized question forms, and rubrics for evaluating the relevancy and validity of questions. All volunteers participated in at least one training session.

Following training, volunteers worked independently to generate questions related to their areas of expertise. Their general guidance was to write at least one question for each BOK sub-topic, and to create questions that varied both in level of difficulty and degree of importance to the main topics. All questions were generated using SME's standard format, which dictated a multiple-choice questions each accompanied by one correct answer and three distracters (distracters such as 'all of the above,' 'none of the above,' '(a) and (c),' etc. were not permitted). Each question was required to have a clear premise ('problem statement'), a correct answer and appropriate distracters, an explicit solution if calculations were required, a published reference validating the problem and solution, identification of the BOK topic addressed by the question, and the author's estimate of both the importance and difficulty of the question. Authors were also asked to assign a type to each question. Choice of type was either 'knowledge,' 'application,' or 'judgment.' Draft question were submitted electronically to the ECETDHA project manager who posted the questions on a password-protected website accessible only by ECETDHA volunteers and the SME and IEEE management group.

Once a bank of questions began to accumulate, biweekly, web-based review sessions were organized and supervised by the SME coordinators. Review sessions served as the first level of independent review of questions. Each session required the participation of at least three ECETDHA volunteers to validate the technical content of questions, guaranteeing that all questions were examined by at least two independent reviewers. Most sessions had more than three reviewers; often there were as many as six or seven. Reviewers also validated, or modified if appropriate, the difficulty and importance ratings and the question type assigned by the authors. If approved, questions were moved to an 'accepted' data base, which was also maintained on the group website where it could be examined by any of the participating members. Questions that did not pass muster were returned to the author with requested changes/corrections, modified by one of the reviewers, or rejected. This question writing process lasted approximately six months and produced over 325 questions that touched on almost all topics in the core BOK.

Second-Level Independent Review: Before an exam could be assembled, the SME development plan called for a final, or second-level, independent review and validation of all questions. This was accomplished by bringing a team of seven volunteer technical experts together for a marathon weekend session at SME headquarters in Dearborn, MI in early February of 2009.

This was truly an 'independent' review because five of the seven reviewers had either not been involved in or had only minor involvement in generating exam questions. Over the course of two days, the team reviewed, validated, and in some cases modified every question in the 'accepted' database. They also provided the final decision on the importance and difficulty ratings and type characterization of each question. By the end of the weekend, the SME had a fully-vetted set of questions to build a prototype exam.

Exam Assembly for Beta Testing: Once the final vetting of questions was done, the involvement of ECETDHA volunteers came to an end. The SME was responsible for creating a representative exam from the question database. The choice of questions for the exam was guided by both the characteristics of the BOK and by the qualitative ratings of difficulty, importance, and question type. The breakdown along these lines is shown in the following table. Under the umbrella of these general guides, the number of questions selected from each major

Question Allocations in Prototype Exam					
Cognitive Type		Difficulty Level		Importance Level	
Knowledge	55	Low	69	Low	12
Application	60	Medium	43	Medium	74
Judgement	5	High	8	High	34
	120		120		120

BOK topical area was done in proportion to the number of sub-topics contained in each BOK area. Main topics representing a greater number of sub-topics got a greater number of questions. Finally, within the topical areas, questions were chosen at random from the set of questions representing the topic. The final exam consisted of 120 questions, which represented approximately one third of the available questions. The exam time was set at three hours.

Beta Testing

The final step in preparing the EET assessment exam for public use was to have a trial run to assess the effectiveness and validity of the product. Once again the management team turned to the ECETDHA membership. In early March of 2009, a call went out to the membership asking for volunteers to administer the prototype exam to their graduating or upper-level students. Testing was offered in two formats, either an interactive, on-line version via the internet or in a traditional paper version. Volunteers needed only provide indentifying information on the student test takers, arrange with the SME coordinators for an on-line testing window or for a packet of test booklets, and provide a proctor to monitor the test. There was no charge for the beta test. On-line test takers had immediate access to their test results. Program administrators received report results electronically once the trial was completed. Paper test takers got similar feedback, but it typically took several weeks to be compiled and delivered.

All beta testing was completed over approximately a three month period in the spring of 2009. Ultimately, twelve domestic and one international (India) schools, representing over 120 students, agreed to administer the exam. The majority of the students were in 4-year programs; however, about 10% were 2-year students. In total, the number of tests was sufficient for a sound statistical evaluation of the efficacy of the test.

For illustration purposes, examples of the kinds of results analysis provided by the SME are attached to the end of the paper, but the summary conclusion was that the test did provide reliable results. Psychometric analyses of individual vs. group responses showed strong correlation, and reliability metrics for the prototype were on par with those from other SME-produced tests when first offered. The only concern related to approximately 5% of the questions for which individual results failed to correlate well with aggregate results. As a final check, a group of the Association volunteers reviewed these questions and made adjustments where they concluded adjustments would increase the clarity of the question. Once that was done, the exam was deemed ready for use.

Conclusion and Future Actions

As of August 2009, all development tasks for a 'core topics' EET assessment exam were complete, and the exam was readied for its first official offering to EET programs across the country. The target date for testing was late fall of 2009. The offering was advertised in the Journal of Engineering Technology, broadcast over the Engineering Technology listserv, and listed on public IEEE and SME websites (www.sme.org/EET). At the time of writing, the results of this first official offering are not available.

Notes

i. The ETD listserv is maintained by Dr. Walt Buchanan of Texas A&M University and represents approximately 4000 individuals actively involved in the engineering technology community.

ii. The ECETCHA area of the ETD website is at www.engtech.org/organizations.php#ECETDHA.

iii. If the core assessment test proves successful, the ECETDHA's plan is to pursue additional funding to develop "add-on" question modules that address the most important specialty areas. That would permit a program wishing to assess performance in those areas to append one or more of these modules to the core test.

Author's Disclaimer

The above paper was originally accepted for presentation at the 2010 Conference for Industry and Education Collaboration (CIEC) in February, 2010; however, scheduling conflicts at the CIEC prevented the presentation from occurring. As a result, the paper was accepted, in its original form, for presentation at the ASEE annual conference. As of the date of this writing, 10 programs representing over 100 students have indicated an intent to use the Assessment Test during the spring semester of 2010. Even more programs have contacted SME with interest in the test, and many of them may also decide to take advantage of the test this spring. In any case, results from most of the test sessions should be available by the time of the ASEE conference. If so, summary information from those tests and the program reactions to them will be included with the presentation of this paper.

Example of Test Average for Entire Test Group

The Society of Manufacturing Engineers (SME) Data Summary

Lean Certification & Certification Program

Diagnostic Tool for Employers

Assessment Information	
Test Title:	Electrical/Electronics Engineering Technology (EET)
Test Code:	
Passing Score:	NA (Pilot testing)
Level:	Post Secondary

Scoring Information	
School Name:	Data Summary Programs
Test Date(s):	04/15/2009-06/12/2009
Number of Test Takers:	114
Number of Test Takers Passing:	0 (pilot testing)
Number of Sites:	8
Number of States:	6
Number of Items:	120
Minimum Group Score:	20.8%
Maximum Group Score:	73.3%
Average Group Score:	41.7%
Group Standard Deviation:	11.5
Overall International Average:	42.0%

Body of Knowledge	
1	1.1 Basic Concepts of Electricity
2	2.0 Alternating Current (AC) Circuit Concepts
3	3.0 Basic Circuit Analysis Methods
4	5.0 Digital Electronics
5	6.0 Analog Electronics
6	7.0 Microcontrollers and Microprocessors
7	8.0 Instrumentation and Measurement

The information below is a graphical representation of the scoring data for this testing group. The data table below the chart provides the averages (shown as percentages) for each of the key activities. The numbers above the columns correlate to the Body of Knowledge shown above.

Group and International Average Comparison

	1	2	3	4	5	6	7
Group Avg	58.9	41.2	33.8	50.2	28.6	39.8	34.0
International Avg	58.7	40.9	34.3	50.1	28.8	41.1	34.5

The Society of Manufacturing Engineers (SME) Data Summary

Lean Certification & Certification Program

Diagnostic Tool for Employers

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Passing Score:	NA (Pilot Testing)
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Scoring Information	
School Name:	Data Summary Programs
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Number of Sites:	8
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Number of Items:	120
Minimum Group Score:	20.8%
Maximum Group Score:	73.3%
Average Group Score:	41.7%
Group Standard Deviation:	11.5
Overall International Average:	42.0%

Analysis by Body of Knowledge	Minimum Group Score	Maximum Group Score	Average Group Score	Group Standard Deviation
1.1 Basic Concepts of Electricity	12.5	87.5	58.9	16.3
2.0 Alternating Current (AC) Circuit Concepts	0.0	93.8	41.2	16.4
3.0 Basic Circuit Analysis Methods	0.0	87.5	33.8	19.7
5.0 Digital Electronics	11.5	88.5	50.2	16.9
6.0 Analog Electronics	0.0	61.9	28.6	12.0
7.0 Microcontrollers and Microprocessors	0.0	100.0	39.8	20.3
8.0 Instrumentation and Measurement	0.0	71.4	34.0	16.2

Examples of Group and Individual Test Results

Group Examination Analysis

Test Code: 7763, v1
Test Date: Tuesday, April 21, 2009
Number of Candidates:
Site Code:

Examination Analysis

Number of Candidates:	3
Low Score:	33
Mean:	39
High Score:	44
Number of Questions:	120
Pass Score:	0
International Average:	0.0%
Standard Deviation:	13.9
Standard Error of the Measurement:	4.4
KR20:	0.87

Group Examination Performance

	Level/Title	# of Items in Section	Total Items Seen by Group	Total Items Passed by Group	Performance	Pct
1	1.0 Basic Concepts of Electricity	16	48	42		87.5%
	1.1 Systems of Units and Notation	2	6	3		50.0%
	1.2 Voltage and Current Concepts	1	3	3		100.0%
	1.3 Conductors and Insulators	3	9	9		100.0%
	1.4 Resistivity, Resistance and Color Codes	1	3	2		66.7%
	1.5 Ohm's Law	1	3	3		100.0%
	1.6 Capacitance, Capacitors and Markings	2	6	6		100.0%
	1.7 Inductance, Inductors and Markings	1	3	3		100.0%
	1.8 Power and Energy	3	9	7		77.8%
	1.9 Usage of Basic Electrical/Electronic Test Equipment	2	6	6		100.0%
2	2.0 Alternating Current (AC) Circuit Concepts	16	48	26		54.2%
	2.1 Sinusoidal Concepts	2	6	4		66.7%
	2.3 Inductance and Inductors	1	3	3		100.0%
	2.4 Energy Consumption and Storage	1	3	3		100.0%
	2.5 Capacitive and Inductive Reactance	3	9	5		55.6%
	2.6 AC Impedance/Admittance	2	6	5		83.3%
	2.7 Phase Relationships	1	3	1		33.3%
	2.8 Simplified RC and RL Transients	1	3	0		0.0%
	2.9 Complex Numbers and Phasors	1	3	0		0.0%
	2.10 AC Power, Power Factor and Power Triangle	1	3	1		33.3%
	2.11 Maximum Power Transfer	1	3	0		0.0%
	2.12 Series and Parallel Resonance	2	6	4		66.7%
3	3.0 Basic Circuit Analysis Methods	8	24	13		54.2%
	3.2 Ideal and Practical Source Models	1	3	2		66.7%
	3.3. Kirchhoff's Laws	1	3	1		33.3%
	3.4. Voltage and Current Divider Rules	1	3	1		33.3%
	3.5. Mesh Current Analysis	1	3	2		66.7%
	3.6. Node Voltage Analysis	1	3	1		33.3%
	3.7. Thevenin and Norton Theorems	1	3	2		66.7%
	3.9. Superposition	1	3	2		66.7%
	3.10. Bridge and Ladder Networks	1	3	2		66.7%

Student Report

14221335A:

Examination Analysis

Site Code:
Name:
ID: 14221335A
Test Code: 7763, v1
Test Date: Monday, April 20, 2009
Pass Score: 0 points
Pass Percent: 0.0%
Score: 42/120 = 35.0%
Status: Pass

	Level/Title	# of Items in Section	# of Items Passed	Performance	Pct
1	1.0 Basic Concepts of Electricity	16	10		62.5%
	1.1 Systems of Units and Notation	2	1		50.0%
	1.2 Voltage and Current Concepts	1	1		100.0%
	1.3 Conductors and Insulators	3	2		66.7%
	1.4 Resistivity, Resistance and Color Codes	1	1		100.0%
	1.5 Ohm's Law	1	1		100.0%
	1.6 Capacitance, Capacitors and Markings	2	1		50.0%
	1.7 Inductance, Inductors and Markings	1	1		100.0%
	1.8 Power and Energy	3	2		66.7%
	1.9 Usage of Basic Electrical/Electronic Test Equi	2	0		0.0%
2	2.0 Alternating Current (AC) Circuit Concepts	16	5		31.3%
	2.1 Sinusoidal Concepts	2	2		100.0%
	2.3 Inductance and Inductors	1	0		0.0%
	2.4 Energy Consumption and Storage	1	1		100.0%
	2.5 Capacitive and Inductive Reactance	3	0		0.0%
	2.6 AC Impedance/Admittance	2	0		0.0%
	2.7 Phase Relationships	1	1		100.0%
	2.8 Simplified RC and RL Transients	1	0		0.0%
	2.9 Complex Numbers and Phasors	1	0		0.0%
	2.10 AC Power, Power Factor and Power Triangle	1	0		0.0%
	2.11 Maximum Power Transfer	1	0		0.0%
	2.12 Series and Parallel Resonance	2	1		50.0%
3	3.0 Basic Circuit Analysis Methods	8	1		12.5%
	3.2 Ideal and Practical Source Models	1	0		0.0%
	3.3. Kirchhoff's Laws	1	0		0.0%
	3.4. Voltage and Current Divider Rules	1	0		0.0%
	3.5. Mesh Current Analysis	1	0		0.0%
	3.6. Node Voltage Analysis	1	0		0.0%
	3.7. Thevenin and Norton Theorems	1	0		0.0%
	3.9. Superposition	1	0		0.0%
	3.10. Bridge and Ladder Networks	1	1		100.0%
4	5.0 Digital Electronics	26	11		42.3%
	5.1 Numbering Systems and Codes	5	4		80.0%
	5.2 Boolean Algebra and Logic Operations	2	2		100.0%
	5.3 Logic Gates and Standard Symbols	3	0		0.0%
	5.4 Combinational Logic	2	1		50.0%
	5.5 Latches and Flip-Flops	2	1		50.0%
	5.7 Counters and Registers	3	1		33.3%
	5.8 Arithmetic Operations and Circuits	2	1		50.0%
	5.9 Analog-Digital Interfaces (A-D and D-A Circuit	3	1		33.3%
	5.11 Encoders, Decoders and Multiplexers	1	0		0.0%
	5.12 IC Families	2	0		0.0%
	5.20 Memory	1	0		0.0%