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ABSTRACT

The ELEXTEC project was initiated to provide better technical education to students enrolled in electronics technology. It was designed to convert a set of materials developed by the U.S. Air Force for teaching electronic principles in a form which could be utilized by civilian technical education institutions. Fourteen colleges participated in the project. The following five courses were developed with a total of 43 modules: Electronic Circuits: DC Circuits: AC Circuits: Active Devices: and Pulse and Switching Circuits. From 20% to 50% of the new printed material for these courses was originated by the project authors. The ELEXTEC staff functionally duplicated the Air Force laboratory training aids. In-house production of the aids was possible. An electronics workshop was used to develop the laboratory aids. The project was evaluated in two principal ways: (1) A report compared student performances in conventional learning situations and the ELEXTEC method: and (2) A private consulting firm was contracted to evaluate the instructors, students, and educational materials. This project showed the cost effectiveness of purchasing Air Force or other governmental materials to be converted for use in technical education institutions. (Author/SK)

TRIDENT TECHNICAL COLLEGE

# The ELEXTEC Project:

## Final Report

January 15, 1979

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## INTRODUCTION

In June, 1975, Trident Technical College in Charleston, South Carolina, initiated the ELEXTEC Project. This project was designed to convert a set of instructional materials which the Air Force had developed for teaching electronic principles to a form which could be utilized by civilian technical education institutions. The ELEXTEC Project was funded by a grant from the National Science Foundation's Division of Science Education Development and Research as part of its Science and Engineering Technology Program. The program has proven to be effective from economic, as well as educational, perspectives.

The technical education system in South Carolina is under the jurisdiction of the State Board for Technical and Comprehensive Education, as are all two-year, state-supported, post-secondary institutions and programs in South Carolina. Local control of these programs and facilities rests with Area Commissions. For example, Trident Technical College is locally controlled by a nine-member commission comprised of members from the three-county service area (Berkeley, Charleston and Dorchester). Trident Technical College is jointly funded by the State Board and the governments of these three counties.

There are sixteen technical colleges and centers in South Carolina. The twelve of these which offer associate degrees in Electrical/Electronics Engineering Technology participated in the ELEXTEC Project, as did Guilford Technical Institute in Jamestown, North Carolina, and the Division of Technology at Georgia Southern College in Statesboro, Georgia. See Appendix 1 for a complete listing of colleges in the project. This consortium arrangement has undoubtedly enhanced the success of the ELEXTEC Project and should be considered in similar future efforts in order to: offset possibly prohibitive costs for a single institution; make the most effective use of available knowledge and experience; and ensure that the end product will be as widely applicable as possible.

The objectives, methodology and results, and evaluation design of the ELEXTEC Project will be described in the following sections. The information in those sections will reflect the five courses which were completed during the project period. These were: Electronic Circuits; DC Circuits; AC Circuits; Active Devices; and Pulse and Switching Circuits.

## OBJECTIVES

The objectives of the ELEXTEC Project were stated in the proposal to the National Science Foundation as follows:

(1) To involve department heads and faculty members at the technical education institutes in South Carolina and several others throughout the nation in a formal modification, evaluation, and field testing of these Air Force materials.

(2) To determine the cost of instituting these materials in two-year institutions.

(3) To determine the extent of modification which is required to use the materials in two-year institutions.

(4) To identify reductions or deletions of expensive training aids where they are of minimal benefit to the course, thereby decreasing the cost to institutions.

(5) To effect national dissemination of the results of the project.

The first objective was accomplished through a series of workshops for the representatives of the consortium schools, and meetings of the National Advisory Committee. The workshops were held in July and December, 1976, and May and August, 1977.

Determining the cost of the conversion of the Air Force materials was a major concern. The basic cost of procuring the complete set of Air Force electronic principles course materials through the Aerospace Education Foundation, for only the cost of reproduction and distribution, was $8,788.00. This included the text, homework study guides, work books, video tape recordings and 35mm slides. The total cost of converting and developing these materials for civilian use was over $200,000. It is interesting to note, however, that information received from reliable civilian sources indicate that the cost of totally developing such a program from scratch would be approximately $10 million.

Although a more detailed description of the methods used to convert the materials will be given later, it should be pointed out that the approximate costs of developing each instructional module is as follows:

Typing - 15 hours
Slides - $60
Slide sorting, tape checking, and proofreading - 15 hours
Instructor as consultant - $300

Thus, if the labor for typing and editing is approximately $3.50/hour, the total cost of each module would be around $465.00.

The ELEXTEC Project's overarching objective was to provide better technical education to the students enrolled in Electronics Technology. Thus, it was a pilot project in the sense that certain economic objectives must be met before the educational process could continue. If either the money or the time necessary for the conversion of the Air Force materials to civilian use was prohibitive, the educational objectives could not be attained.

## METHODOLOGY AND RESULTS

The presentations of the five courses in the ELEXTEC Project were preceded by considerable expenditures of time and money. In many ways, however, this project has proven these expenditures to be cost effective because of the utilization and coordination of existing materials, facilities, and faculty and administrative expertise.

The basis for the entire project was the package on electronic principles prepared by the Air Force. This package included: 2,239 pages of printed material, covering ten subject areas; 1,404 slides; 115 videotaped lectures; and an instructor's manual for each of the ten subject areas. Figure 1 on page 4 shows how the ten Air Force courses were divided into civilian courses.

Within each course, the written material was divided into separate modules, one for each distinct topic within a particular course. This facilitated the integration of the Air Force material into the already established curricula of the technical education system in South Carolina. The modules covered such topics as bipolar junction transistors, field effect transistors, and power amplifiers. The modules were further divided into units. For example, the junction transistor module would have a unit covering the pertinent biasing methods. Since specialized units on multi-source field effect transistors might be covered in several courses (Active Devices, Electronic Circuits, or Pulse and Switching Circuits), it was decided that each unit should be instructionally complete. The number of modules for each course was as follows:

Electronic Circuits - 8
DC Circuits - 6
Active Devices - 11
AC Circuits - 9
Pulse and Switching Circuits - 9

Depending on the course involved, from twenty to fifty percent of the new printed material was originated by the project authors. The Air Force offerings had to be supplemented, particularly in the area of electronics engineering technology. As the table on the following page shows, the only key core course which was not developed was Network Analysis. Since everything for that course would have had to be developed by the project, it was beyond the staff's current resources.

The original Air Force 35mm slides were replaced by a set of overhead projection transparencies. This enabled the instructor to add explanatory notes on sketches to the image, and facilitated his ability to point out important items while still facing the class. The printed text materials contained copies of all the figures, charts, and graphs which appear on the transparencies so the student's attention was not diverted by the need to add them to his notes.

One minor change was made in the videotaped lectures. The students were supplied a worksheet for each such lecture, to be completed during the viewing period. This eliminated passive viewing and provided feedback regarding the student's understanding of the material. However, some of the tapes were found to have unnecessarily long pauses to allow for the completion of some of the worksheet exercises. Reducing the pauses by as much as 90 percent not only saved class time, but also eliminated the distraction of the loud background noise produced during the pauses by the action of the automatic level control in the original audio recording system. The advantage of the excellent visual aids utilized in the videotaped lectures was complemented by the additional benefits of reduced instructor time and, even more importantly, reducing instructor boredom formerly occasioned by having to repeat basic lectures every term.

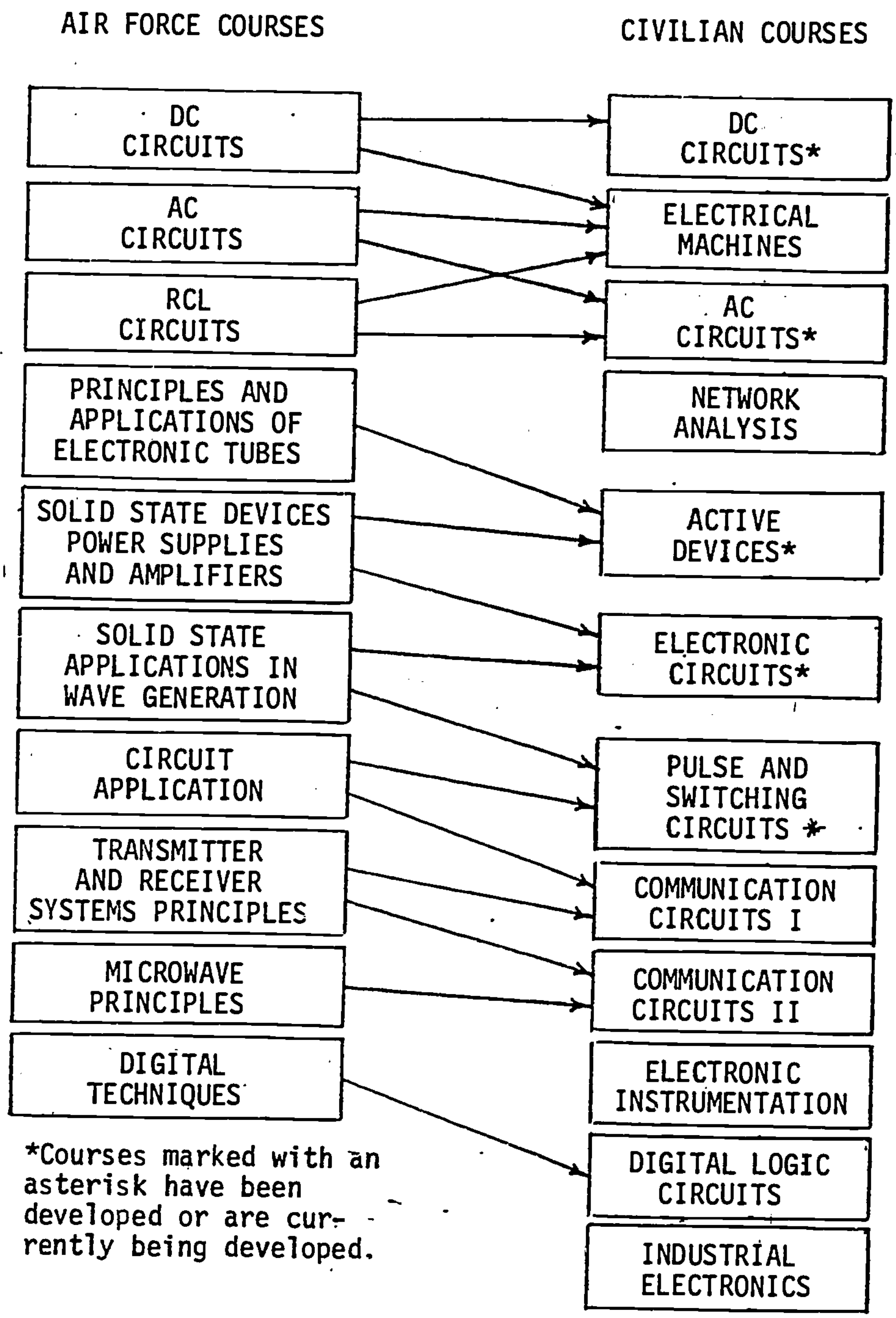



Figure 1. Course Correlation Diagram

## LABORATORY EQUIPMENT AND TRAINING AIDS

The ELEXTEC staff functionally duplicated the Air Force Laboratory Training Aids. All of these aids had laboratory exercises and experiments written for them, and it was correctly assumed that many could be incorporated into ELEXTEC courses.

The project staff had considerable experience in producing laboratory training aids, and attempted to design aids which would give maximum usage to the Air Force material. Furthermore, the staff undertook the design of new training aids to cover topics not included in the Air Force material. From the viewpoint of staying inside the budget, this was entirely successful.

Electronic circuits are often too compacted to be easily investigated, probed, and studied. For education purposes, it is well to have simplified circuits spread out for convenient probing and measuring. The Air Force had a number of these circuits built to serve as laboratory training aids. Laboratory exercises based on these were included in the Air Force materials. The original project plan was to have these training aids produced commercially, but the already-mentioned experience of the project staff allowed for in-house production.

A member of the National Advisory Committee for the ELEXTEC Project supplied complete lists of components for the Air Force training aids. This meant that only a physical set-up was needed to permit their construction. Where course material required new training aids, the project staff performed the engineering design work from circuit diagrams supplied by the consultant instructors.

An electronics workshop was fitted out in the area assigned to the ELEXTEC Project at Trident Technical College and part-time students were engaged to assemble the aids. The workshop capabilities included machining, silk screening, assembly, wiring, soldering, and testing. Utilizing part-time student labor whenever semi-skilled help was needed proved to be economical as well as beneficial to the students.

Prior to 1950, electrical education laboratories had essentially only two choices that were within financial reach:

A. They could acquire a stock of components, lead wires and some manufactured terminals and connectors. The student with his soldering iron would have access to this stock of parts and would spend the first portion of the laboratory period assembling his circuit. Since the circuit often would be laid out on a flat piece of wood or plastic, this led to the term "breadboarding".

B. Circuits to be studied could be made up in advance. Often these would be mounted on open sheet metal boxes designed for this purpose. This eliminated the drudgery of breadboarding and let the student concentrate on his job of analyzing the circuit presented. Such laboratory training aids (as built for this project) are durable and may be reused many times.

Electronics Engineers Master (reference catalog) now has over 40 listings under "Kits, Breadboarding". A survey of products proves that most of the drudgery formerly associated with breadboarding may be eliminated for the modest cost of these re-usable accessories and kits. Complete implementation of a course with training aids, which are easy to build, but time-consuming, would probably require more money than an adequate kit of these breadboarding supples. Because course time and the availability of funds must govern the decision for a particular institution, it is difficult to give useful general guidelines for making this choice.

The ELEXTEC Project used the training aids because the staff agreed with the Air Force that the desired training level and pace were best achieved by the use of these aids. However, this should not rule out an institution using breadboarding with the ELEXTEC Curriculum if economic considerations so dictate. It's reasonable that an institution might start with breadboarding intending to build training aids later as time and money permit. This could cause an advantageous mixture of the two approaches.

Reduced examples of the wiring diagrams, which were silk screened and applied to aluminum chassis bases prior to fabrication, can be found in Appendix 2. The cost estimates and components are also listed.

The silk screening was accomplished through the aid of Trident Technical College's Graphic Arts Instructional Department. The 1976 commercial price for this work was approximately $4.00 per chassis, which was considered reasonable. The silk screening also allowed holes to be marked for binding posts, potentiometers, connectors, and transistor sockets. The local commercial silk screener typically took three weeks for a set of training aids while doing it in-house normally only took three hours.

After silk screening, the holes were drilled as marked and the binding posts and other components were mounted. This provided anchoring points for attaching the remainder of the components, usually by soldering. Some components, especially inductors and transformers, were mounted on the edges of the chassis box. Rubber feet were added on the bottom to facilitate stacking during storage. The bottoms of the boxes were left open to permit student inspection and the wiring done to closely resemble the wiring diagram in appearance.

For maximum durability and versatility, heavy, five-way binding posts (H.H. Smith #257) were used for all terminals. Often solder connections were made directly to the shank.

## INSTRUCTION AND STUDENT ACTIVITIES

A current trend in education is that of "teaching for mastery". If subject matter is to be essentially mastered by an entire class, then the adoption of some form of a personalized system of instruction (PSI) is required to provide for the wide variations in individual rates of learning within any typical group of students. The ideal system will:

- motivate students to study,
- provide information in surmountable steps,

- provide sufficient drill and feedback,
- avoid boring a fast student,
- maintain a scheduled rate of progress,
- provide for both self and instructor evaluation of student learning.

The PSI adopted for teaching with the materials developed and produced by the ELEXTEC Project has influenced other aspects of the format in order to promote accomplishment of the objectives for an ideal system. The system has maintained the lecture plan advantage of a scheduled rate of progress which is important in working within the established calendar of the academic year. It also permitted the instructor to inject personal enthusiasm for the subject and to provide leadership and an exemplary code of conduct. Finally, it allowed for the most effective use of the original Air Force material.

A comparison and contrast of the two types of instruction (individually-paced and lecture-based) is outlined below:

(1) Individually-Paced Method

A. Advantages:

1. Students may progress at a pace consistent with their abilities.

2. A student may be recycled until acceptable mastery of individual learning objectives is attained.

3. The student is primarily responsible for learning.

B. Disadvantages:

1. The instructor-student dialogue (interaction) is impaired.

2. There are larger demands upon instructor time (dependent directly on the instructor-student ratio).

3. Students have a tendency to procrastinate and fall behind schedule.

(2) Lecture-Based Method

A. Advantages:

1. The instructor has control over the class as a group.

2. Classroom discussion and instructor-student interaction is enhanced.

3. The instructor's time is effectively utilized.

B. Disadvantages:

1. The instructional method is geared toward the average and below average student; coverage of the materials is limited for the best students.

2. A student must take regularly scheduled exams regardless of his degree of achievement.

3. Many students do not become actively involved in the learning process.

The ELEXTEC Project actually combined the traditional classroom situation and a personalized system of instruction through the use of multi-media aids and a self-test for each unit of instruction. If, after taking the self-test, a student was not ready to advance to the next unit, a synchronized sound-slide program was provided for review of the material. These programs were designed to develop the material in gradual sequences, and great care was taken to anticipate student difficulties. The student then attempted a second self-test to determine his readiness to proceed.

These sound-slide programs were composed by using "storyboard" forms. These forms provided space for presentation of four slides along with their narration on a standard 8½ by 11 inch sheet. The slides were in vertical sequence at the left, narration on the right. This arrangement served as a reminder to avoid excess narration by the originator with an individual slide.

These programs were effectively used by TEC schools with projection equipment that had varying degrees of control. For instance, programs were sometimes used with an instructor operating a separate tape player and manually advancing the slide projector. His familiarity with the program would permit review with very little fumbling.

Students sometimes had only an automatic advance projector on which to show themselves a program. They usually readily learned to stop the program manually whenever the narration indicated student reaction. Unfortunately, the only way to review required a complete re-run. This meant the student would have to again view all the slides up to the desired point of review at which point the student could manually stop the program as desired. This same review technique could be used with a machine with automatic stops and advances since all such machines have an overriding manual stop.

From the beginning, voice and the pulses for stop and advance were recorded simultaneously. Although it was suggested to record the voice first and add the pulses later, the simultaneous technique already had been thoroughly learned. The motions needed in the simultaneous technique created short pauses between the narrations for individual frames to insure no interference between mechanical sounds and voice during play back. These pauses proved valuable when it was desired to change the narration. With the aid of a stopwatch, it became routine to re-do the narration for an individual frame as needed. Therefore, the original simultaneous recording routine was continued.

The script was typed from the originator's storyboard, using the same arrangement; slides on left, narrations on right. This permitted one typing to create both the script and the narration for the storyboard copies that were to go into the instructor's guide. The script copy was assembled between heavy paper sheets in a loose leaf binder. The heavy paper sheets had tabs attached so that pages could be turned quickly with no discernable sound.

The scripts were reviewed for readability. Technical words were indicated phonetically and the reading of mathematical statements was noted. Sometimes editing was needed. The "Pulse and Switching" course includes the terms, "and gate", "nand gate", "or gate", "nor gate", thus creating reading problems. These were resolved by deleting indefinite articles and substituting "also" for "and" as an ordinary conjunction.

Each tape was listened to twice by a technically competent person. The audio portion was first checked for content, and then the slides were run to check for sequencing. For the first check, the listener's concentration was helped if the speed was increased. This was accomplished by slipping a plastic sleeve (a piece of insulation from a small electrical wire) over the capstan drive mandrel of the cassette player. At a speed approximately 1.7 times normal, speech was still intelligible, much time was saved, and alertness was maintained with less effort.

There seemed to be agreement that maximum readability came from slides with white or light colored lettering on a darker background. A standard procedure to produce these was to first obtain a deep contrast black and white negative of the artwork. The artwork must have high contrast and was usually executed on white paper with black ink. Color reversal film was then multiple-exposed with various color lighting involved to obtain the desired effect. The results were excellent but the process was tedious. Also, the process severely limited the resolution, detail and variation of line width that would be possible with a direct procedure on Kodachrome, Ektachrome, or Kodacolor.

Art students were utilized to get the required ink drawings. They were paid at the rate of 75¢ per slide. This enabled them to make nearly minimum wage at the start, and appreciably more after some practice and experience. They were encouraged to work free hand as much as possible. Informality was desired to make it less obvious when a slide was replaced with a corrected or updated one. The artists were also encouraged to use their training to obtain good composition which caused many formidable looking wiring diagrams to be clarified and well organized in the final product.

During the project, 136 programs and 5,100 slides were made. Three of each slide were produced. The first was a practice, the second was a master for future duplication, and the third was a "deputy" master to allow for contingencies.

As was noted above, one drawback to the individually-paced method of instruction is the potential procrastination by students because of a lack of self-discipline. The experiences of the instructors at the institutions participating in the ELEXTEC Project showed that students are actually helped by the discipline of scheduling, and a "timetable" is suggested. It was also found that the older students generally found in the evening programs were better able to adapt to self-study procedures.

## EVALUATION AND RECOMMENDATIONS

The ELEXTEC Project was evaluated in two principal ways:

1. A report comparing student performances in conventional learning situations and the ELEXTEC method.

2. Conserva, Inc., a private consulting firm in Raleigh, N. C., was contracted to evaluate the instructors, students and educational materials.

### Report on Student Performance:

The objective of this report was to obtain before and after comparisons of student performance with the same instructor.

Data was obtained on 10 sets (sometimes two concurrent classes in one set) of students, five sets taught conventionally and five sets with ELEXTEC materials. The results of all the "before" and the ELEXTEC sets are combined since the individual sets were generally quite uniform. The total numbers of students were: 139 taught conventionally and 96 with ELEXTEC. Only those completing the course were counted.

| Grade | Conventional | ELEXTEC |
|---|---|---|
| A | 21% | 29% |
| B | 26 | 33 |
| C | 35 | 23 |
| D | 12 | 11 |
| F | 6 | 4 |
| A and B combined | 47 | 62 |
| D and F combined | 18 | 15 |

### External Evaluation:

Conserva made many recommendations regarding the project itself, as well as its use within a consortium context. An explanation of the evaluation procedure and its major findings are given below.

The evaluation of the ELEXTEC Project, particularly the course EET-215 "Electronic Circuits", was designed to obtain pertinent information from two major sources: (1) the instructors in the Electronics Engineering Technology program (including those directly associated with the teaching of EET-215) and other instructors in the program who were directly connected with the production of instructional materials for other courses in the program, and (2) the students that had been involved in the use of the instructional materials, multi-media devices, and the ELEXTEC equipment that had been designed for use in the laboratory.

The evaluations were intended to determine (a) whether the instructional materials, media and laboratory equipment would enable students to learn the principles and concepts of the electronics circuits, (b) whether the learning took place more readily and the retention of the principles and concepts was noticeably longer, and (c) whether the presentation of the materials enabled students to more readily acquire an understanding of the practical applications of the concepts and principles. Still further, the evaluation was expected to reveal whether time was saved by the instructor and how such saved time was utilized to further benefit the students; also, the uses to which the instructional materials, media and equipment were put during the overall teaching of the eight modules in the Electronics Circuits course. By way of explanation, the investigation was intended to disclose whether or not the materials were used in direct teaching, as auxiliary information, as self-study devices, or as review summarization.

Throughout the section which reports the data and information received during interviews with instructors, and also in the section that reports the data and information received on the student questionnaires, there were many suggestions and statements which related to the strengths and successes of the ELEXTEC materials in the Electronic Circuits course. There were also many other comments and observations reported by instructors and by students which, if taken literally, could be converted into recommendations which the project staff would need to further consider. All of the data in the two sections indicated above should be reviewed thoroughly for suggestions that might prove helpful. The following are major recommendations which should be carefully considered by the project staff, and modifications made where feasible in the present ELEXTEC materials. Further, in the plans for the extended development of additional course and curriculum materials for the Electronic Engineering Technology curriculum, the suggestions may be even more important.

(1) Because of the great flexibility permitted in the technical education colleges to utilize the most profitable and feasible method and/or technique of instruction, the project staff should place greater emphasis upon the appropriate adjustments and provisions in the ELEXTEC materials that would enable each of the respective institutions to utilize the materials in their own way. This is to say that where greater emphasis is needed on the self study aspects of the ELEXTEC materials, more materials should be converted to that procedure. On the other hand, where greater emphasis in the teaching procedures in a technical college is in the direction of heavy concentration of lecture and demonstration, followed by the uses of the ELEXTEC materials for review and summarization, then the further modification of the materials should place emphasis upon those aspects without losing any of the emphasis in the ELEXTEC materials for other instructional procedures. The end result may be different items of information converted and made available to the technical colleges, from which they would select the materials and the teaching techniques that best suited the needs of the instructor and/or the students.

(2) Recommended for consideration by the project staff is the need for the selection of a number of representative technical education colleges, in which the Electronic Engineering Technology program is conducted with the materials made

available through the ELEXTEC process. Then, using the split half method of conducting a control experimental situation, a study should be done to determine the comparative advantages and limitations which result in student learnings, retention of knowledge, motivation for extended study and other characteristics. Such a study represents an urgent need in connection with the ELEXTEC materials, in order that a strong data base be built, upon which judgements of the above nature could be made and plans for the future determined.

(3) The Electronics Engineering Technology curriculum, and particularly the Electronics Circuits course, is heavily theoretical with only occasional references to practical applications of principles and concepts learned in industry and business. It is strongly recommended that the project staff give consideration to somewhat greater emphasis in future curriculum development upon the applications of the concepts and principles to business and industrial situations. In effect, this would provide means through which students would receive a higher level of motivation through revealing the meaningfulness of the theory.

(4) The text associated with the ELEXTEC materials used in the Electronics Circuits course does not generally meet with the approval of either the faculty or the students. This was apparent in the interviews held with the instructors and in the information obtained from the students. Thus, it is recommended that a thorough search be made for a more appropriate text, and that failing to obtain such a text, appropriate curriculum materials be developed to substitute for such a text. This may, indeed, be a time-consuming activity, but profitable in the long-range planning for instruction in the Electronic Engineering Technology curriculum.

(5) It is strongly recommended that the advisory committees associated with the Electronic Engineering Technology curriculum be fully utilized, as they were intended to be utilized for purposes of reviewing curriculum materials with an eye to the currency of the materials and to their appropriateness and relevancy to industrial processes. A review of the schools indicated that some contact had been made with their advisory committees, and that more intense work with the committees was anticipated for the future. The Electronics Engineering Technology curriculum, by its very nature, requires continual input from expert personnel in the industrial and business field, if that curriculum is to maintain a high level of currency. Thus,

it is further recommended that no less than quarterly meetings of the advisory committees be held, and that the full details of the ELEXTEC Project be discussed with each committee. Still further, many of the advantages of close coordination with the advisory committees are mandated in the federal legislation "Vocational Education Amendments of 1976", and these mandates should be properly coordinated with the on-going programs of instruction in the technical education colleges. Several of these mandates are of great importance, and include references to the placement and follow up of graduates, and the input derived which ultimately would serve to modify the curriculum.

FINAL SUMMARY

The ELEXTEC Project, in addition to meeting the objectives of the grant from the National Science Foundation, resulted in the following:

1. Tremendous savings in utilizing an Air Force developed course when one compares the $200,000 used to convert and develop the course for use, to the development of this same course from scratch in the civilian market place for approximately 10 million dollars.

2. Because the original development costs for this course had been paid by the Air Force using tax dollars, the tax dollar served double duty - its use by the Air Force and use of the already developed course in the ELEXTEC Project.

3. With the recommended improvements and modifications, a model course will evolve which could be utilized by other technical education institutions.

# APPENDICES

SOUTH CAROLINA TECHNICAL EDUCATION CENTERS

PARTICIPATING IN THE NSF "ELEXTEC" PROJECT

Aiken Technical College
P. O. Drawer 696
Aiken, South Carolina 29801

Chesterfield-Marlboro Technical College
P. O. Drawer 928
Cheraw, South Carolina 29520

Denmark Technical Education Center
P. O. Box 327
Denmark, South Carolina 29042

Florence-Darlington Technical College
P. O. Box 8000
Florence, South Carolina 29501

Greenville Technical College
P. O. Drawer 5616, Station B
Greenville, South Carolina 99606

Midlands Technical College
P. O. Drawer Q
Columbia, South Carolina 29203

Orangeburg-Calhoun Technical College
P. O. Box 1767
Orangeburg, South Carolina 29115

Piedmont Technical College
P. O. Drawer 1208
Greenwood, South Carolina 29646

Spartanburg Technical College
P. O. Drawer 4386
Spartanburg, South Carolina 29301

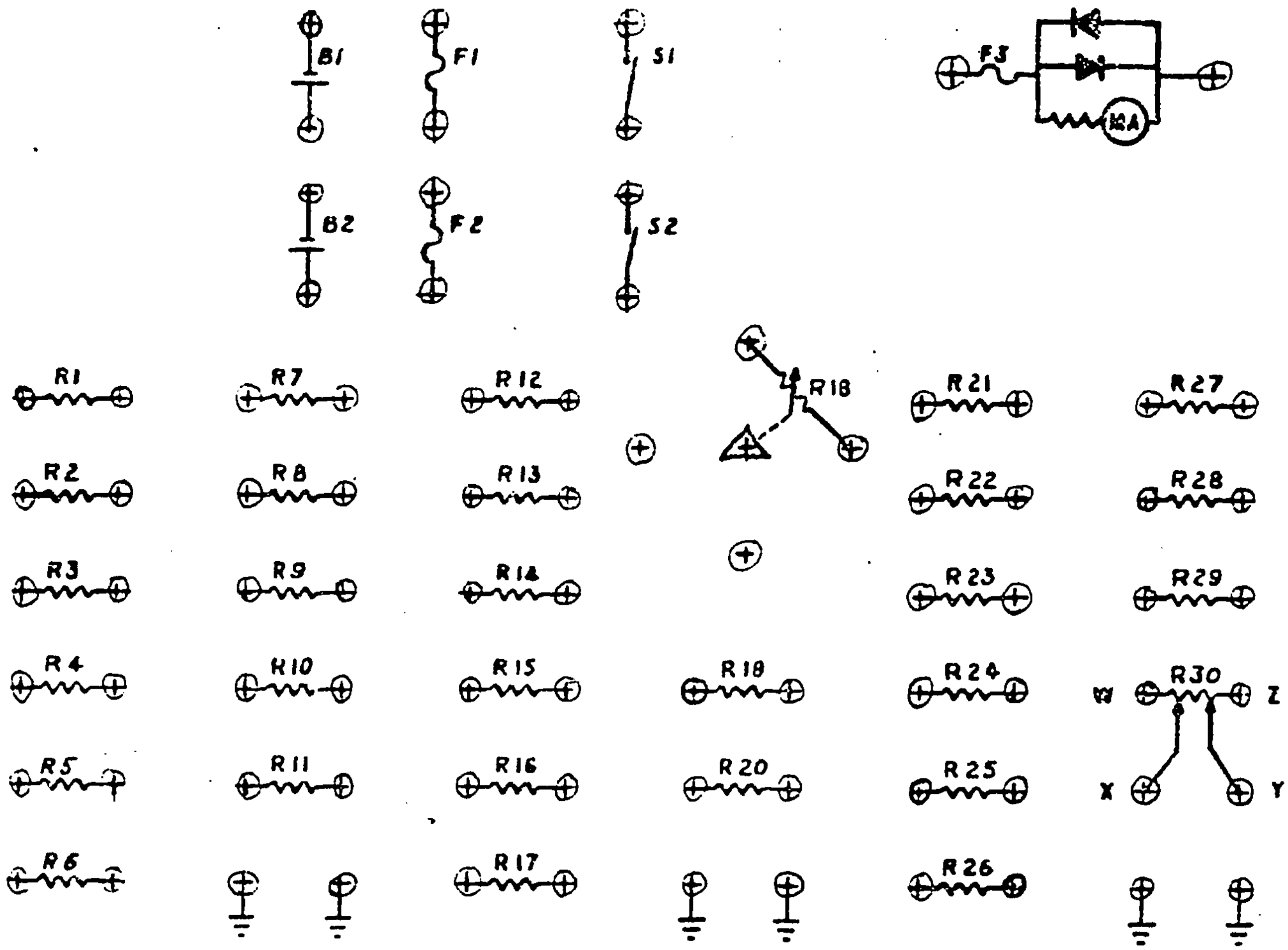
Tri-County Technical College
P. O. Box 587
Pendleton, South Carolina

Trident Technical College
P. O. Box 10367
Charleston, South Carolina 29411

York Technical College
U.S. Highway By-Pass 21-A
Rock Hill, South Carolina 29730

APPENDIX 2 - WIRING DIAGRAMS

# DC RESISTOR TRAINER




$50 cost estimate     76 Binding Posts
8x12x3 chassis

Resistor Trainer TR 100/101 Notes

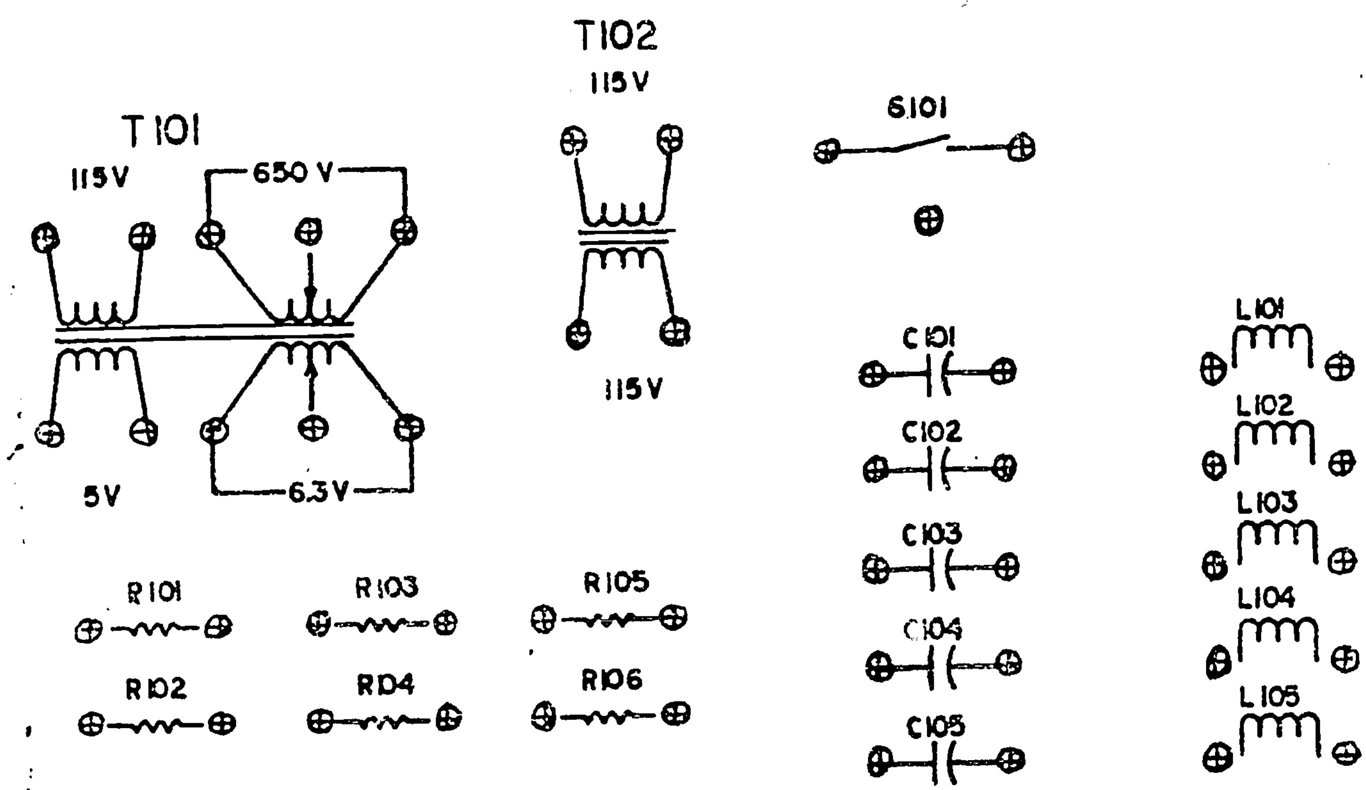
R - 15 Shorted - Conceal short in binding posts-shorting both ends to chassis
R - 16 Open - Use grinder to create open on concealed side of wire wound resistor
R5 thru R10 - Alter bands on one to make it appear out of tolerance.

Values of other R's

| | | | | | |
|---|---|---|---|---|---|
| 1. | 18k | 11. | 10k | 21. | 100 |
| 2. | 6.8k | 12. | 47k | 22. | 100 |
| 3. | 1k | 13. | 8.2k | 23. | 100 |
| 4. | 6.8k | 14. | 15 meg | 24. | 330 |
| 5. | 15k | 15. | shorted | 25. | 68 |
| 6. | 3.9 meg | 16. | open | 26. | 82 |
| 7. | 6.8 | 17. | 56 | 27. | 120 |
| 8. | 270k | *18. | 5k pot | 28. | 150 |
| 9. | 1k | 19. | 10 | 29. | 1800 |
| 10. | 4.7k | 20. | 47k | *30. | 5k wire wound with extra tap |

* #18 Centralab #WN 502
#30 Ohmite #1033
Ammeter-Shurite #3306, 0-50, 10 approx.

# AC INDUCTOR AND CAPACITOR TRAINER TR102




$70 cost estimate
3x12x3 chassis

T 101 Stancor PC8406
T 102 Stancor #06411

L's
101 Stancor C2726 .125H
102 Stancor C2725 .4H
103 Stancor C2721 2H
104 Stancor C2721 2H
105 Stancor C2725 .4H

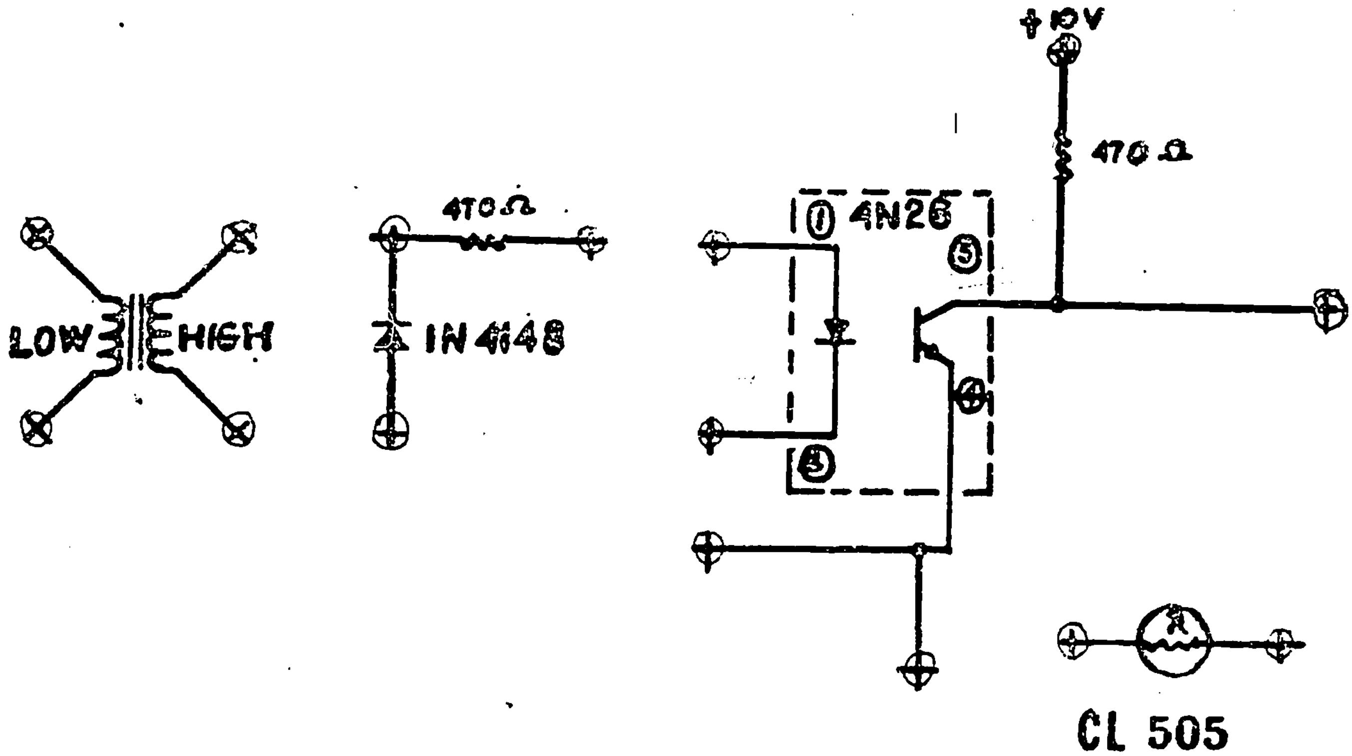
C's
101 .1 uF
102 .2 uF
103 .5 uF
104 1.0u F
105 over 10uF

← better if nonpolarized mylar 300 VDC or more

48 binding Posts

R's
101 100
102 470 ½W or heavier
103 1200
104 4.7k
105 10k
106 100k

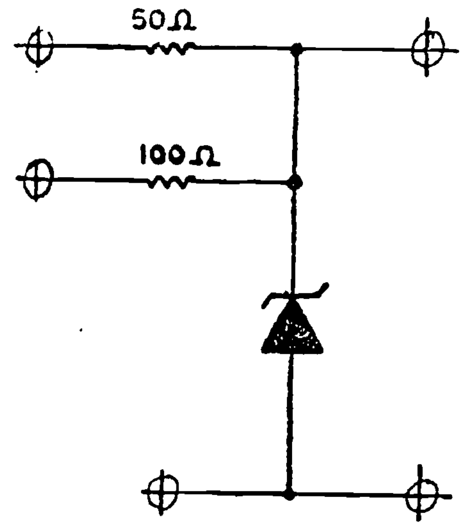
# PHOTOCONDUCTOR CELL




$25 cost estimate
12x7x3 chassis

12.6V filament transformer
½W Resistors 470 - two
15 binding posts
4N26 Coupler, Photo Transistor Output
CL 505 Photocell
1N4148 Diode

# SOLID STATE DIODE CHARACTERISTIC



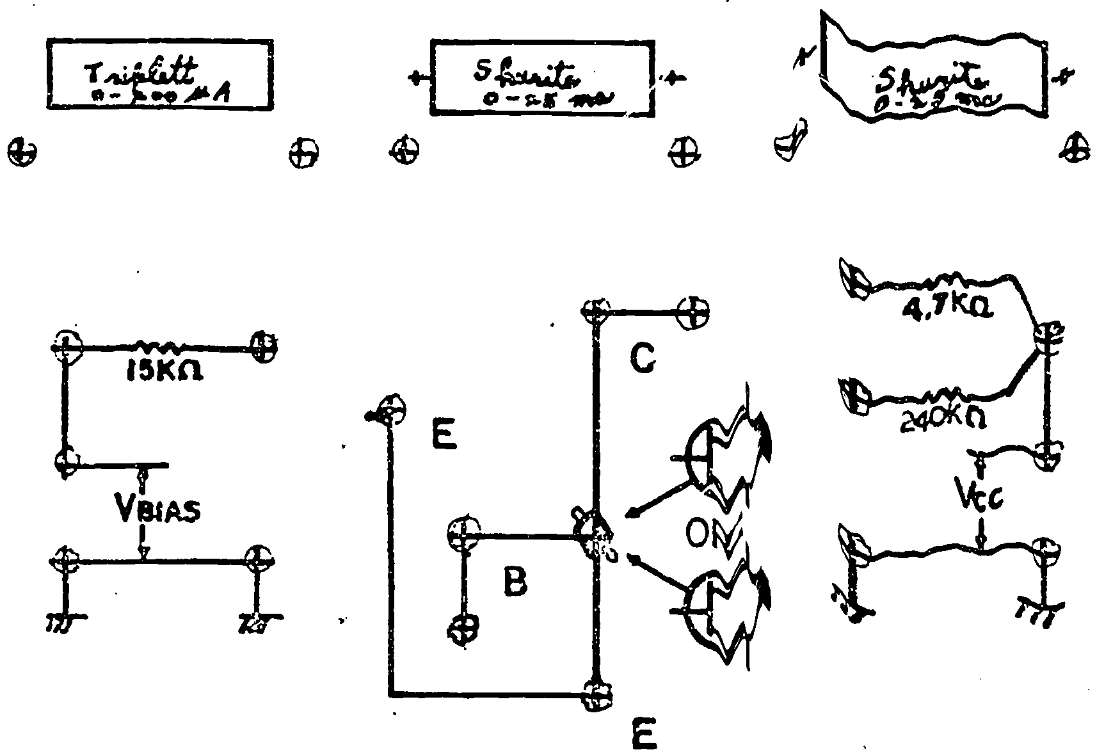

$12 cost estimate
7x9x2 chassis

Zener 1 Watt
1N4740

50 ohms - 11W
100 ohms - 11W

5 Binding Posts

# TRANSISTOR CHARACTERISTICS

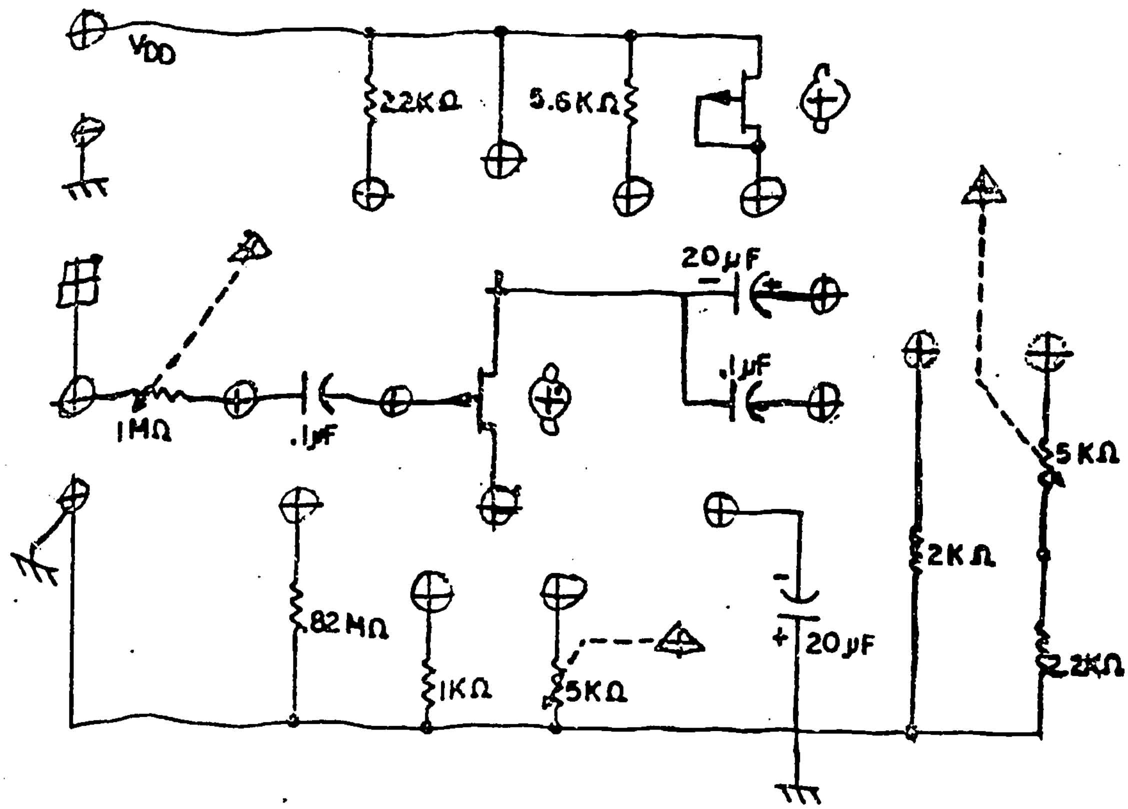



$58 cost estimate
7x9x2 chassis

Ammeters
0-200 uA Triplett model #120
#1060320
two 0-25 mA Shurite #3305

Transistor Socket Cinch $2TS-4
Binding Posts

# FET AMPLIFIER




$29 cost estimate
7x9x2 chassis

two - P channel F.ET ZN4360 and sockets

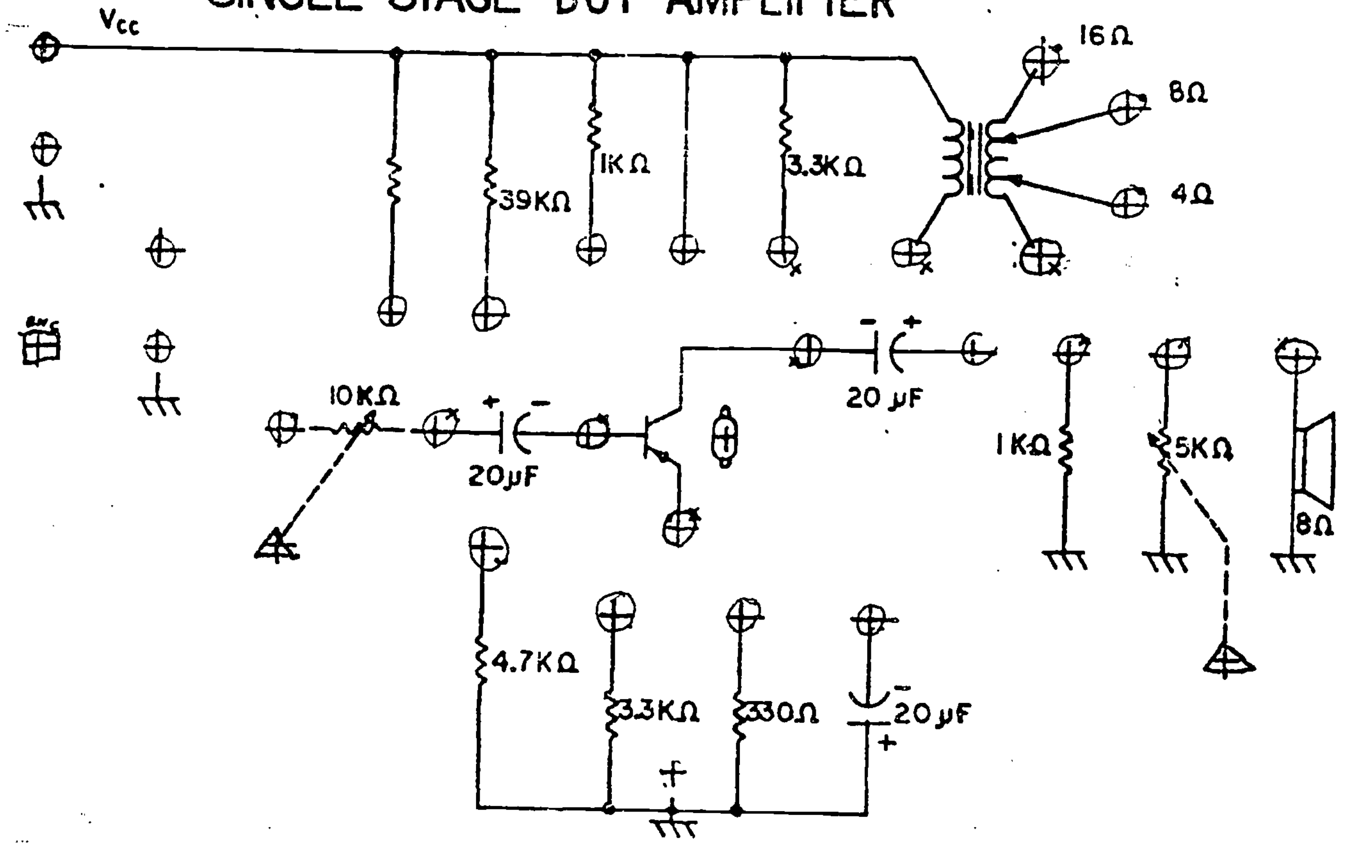
50 VC's
2c uf - two
.1 uf - two

½ W Pots 5k SU14 Mallory Midgetrol - two
1 meg SU 54 Mallory Midgetrol - two

¼W R's
1k
2k
2.2k
5.6k
22k
.82m

BNC connector amphenol #74868

# SINGLE STAGE BJT AMPLIFIER




$40 cost estimate
7x9x2 chassis

Speaker - Inexpensive replacement speaker from Electronic Surplus House, preferably less than 3" dia. mounted on chassis edge

Output Transformer Stancor #TA9

BNC amphenol 74868

Mallory Midgetrol SU14 5k ½W
SU20 10k ½W

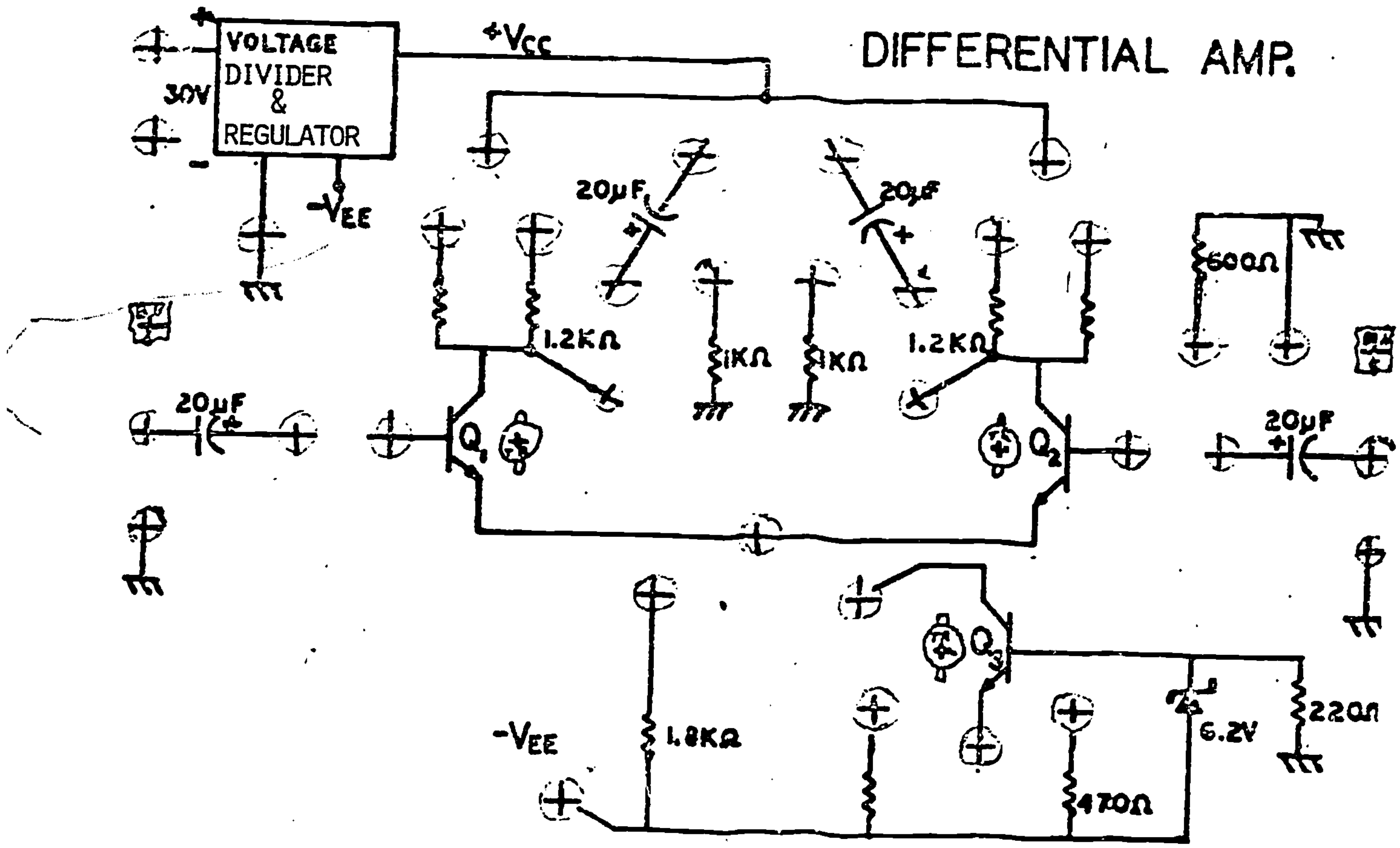
28 Binding Posts
resistors ¼W

50 C's

20 uF - three

330
1k - two
3.3k - two
4.7k
39k

Transistor and socket Cinch 2TS-4
2N2905
PNP




$39 cost estimate
7x12x3 chassis

2 BNC connectors - Amphenol #74686
3 Transistor sockets - Cinch #25T-4
3 Transistors 2N2219 Si NPN BJT
32 Binding posts.

6.2V Zener
1 W

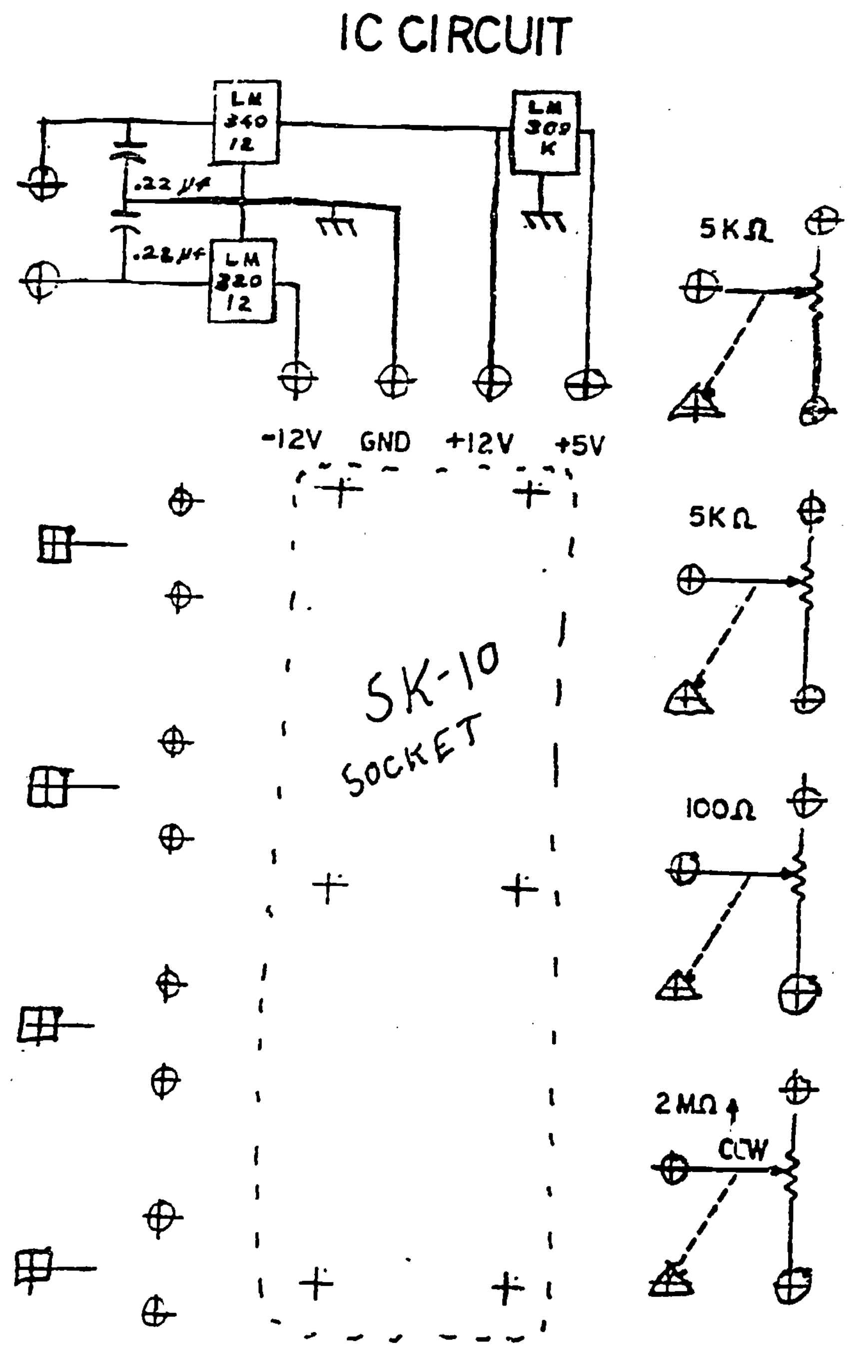
¼WR's

three optional
220
470
600

two 1k
two 1.k
1.8k

50v C's

four 20uF



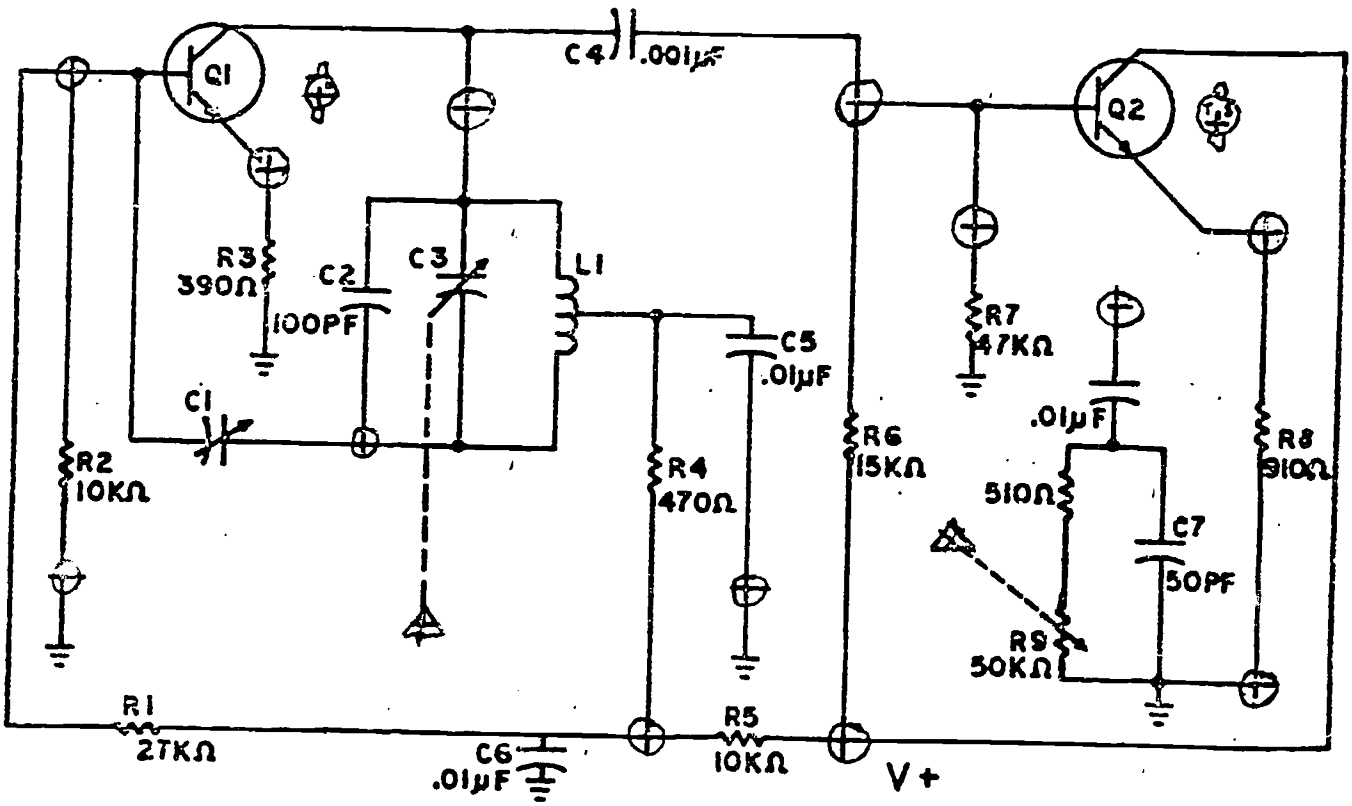

$50 cost estimate   IC socket (from Nine Associates Inc.
10680 Main St.   SK - 10 socket
Fairfax Va. 22030

7x9x3 chassis

two 5k Pot Mallory Midgetrol #SU14
100 Pot Centralab 5 W control CRL #WN101
2 meg Pot Mallory Midgetrol #SU56

four BNC connectors Amphenol #74868
5 volt positive regulator LM 309k
26 Binding Posts

# HARTLEY OSCILLATOR AND BUFFER AMPLIFIER




$37 cost estimate
7x12x3 chassis

$C_1$ : trimmer C 20-100 Arco #463

$C_3$ : Air variable C 12 - 100 pF

$C_2$ : contained in $L_1$

$L_1$ : transformer JW Miller #2041

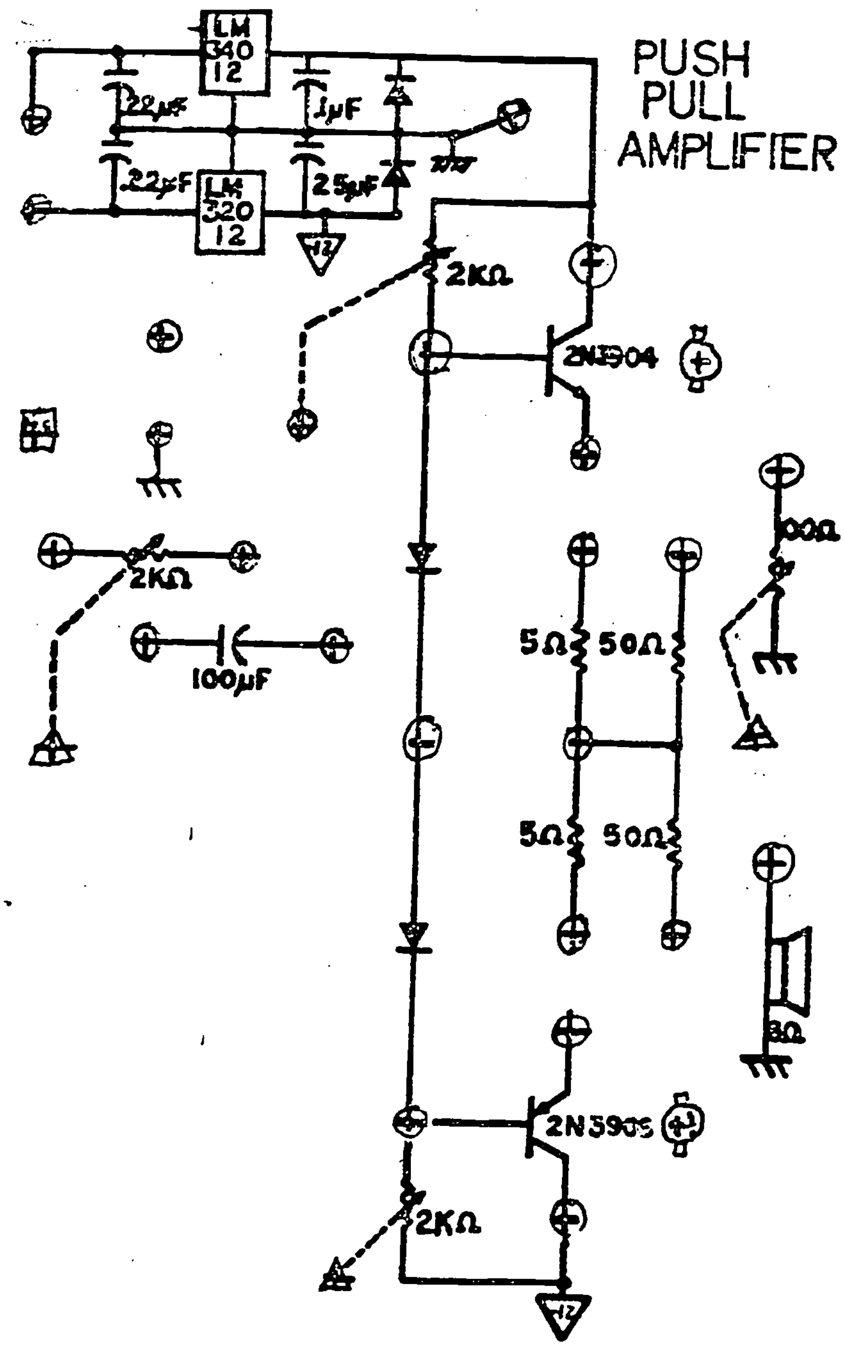
Rg 50k pot Ohmite #CMU 5031
two 2N2219 Si NPN BJT

sockets cinch 2TS - 4

50 VC's
one 5c pF
three .01 uF
one 001 uF

¼WR's
390
470
510
910
10k two
27K
47K

13 B'posts




$38 cost estimate
7x12x3 chassis

100 Mallory Midgetral #TRS 12L ½ W
three 2 k pot Midgetral #SU8 (really 3k ) ½ W

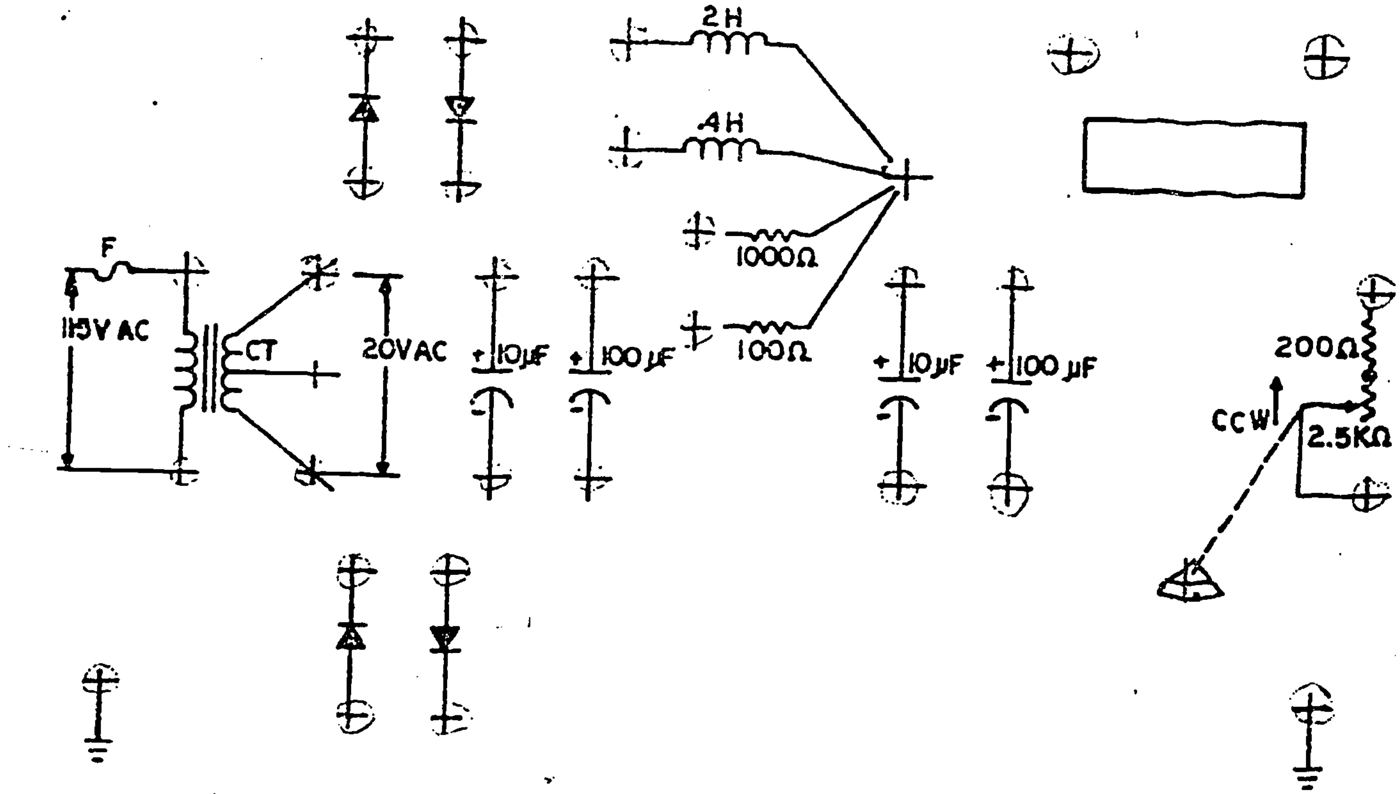
Speaker - Inexpensive replacement speaker
3" dia or less, mounted on chassis edge

2 Diodes
16 B' posts
½ WR's

Transistors - complementary pair - both Si BJT
2N 3904, NPN
2N3906, PNP

two transistor socket cinch 2TS - 4

# SOLID STATE POWER SUPPLY



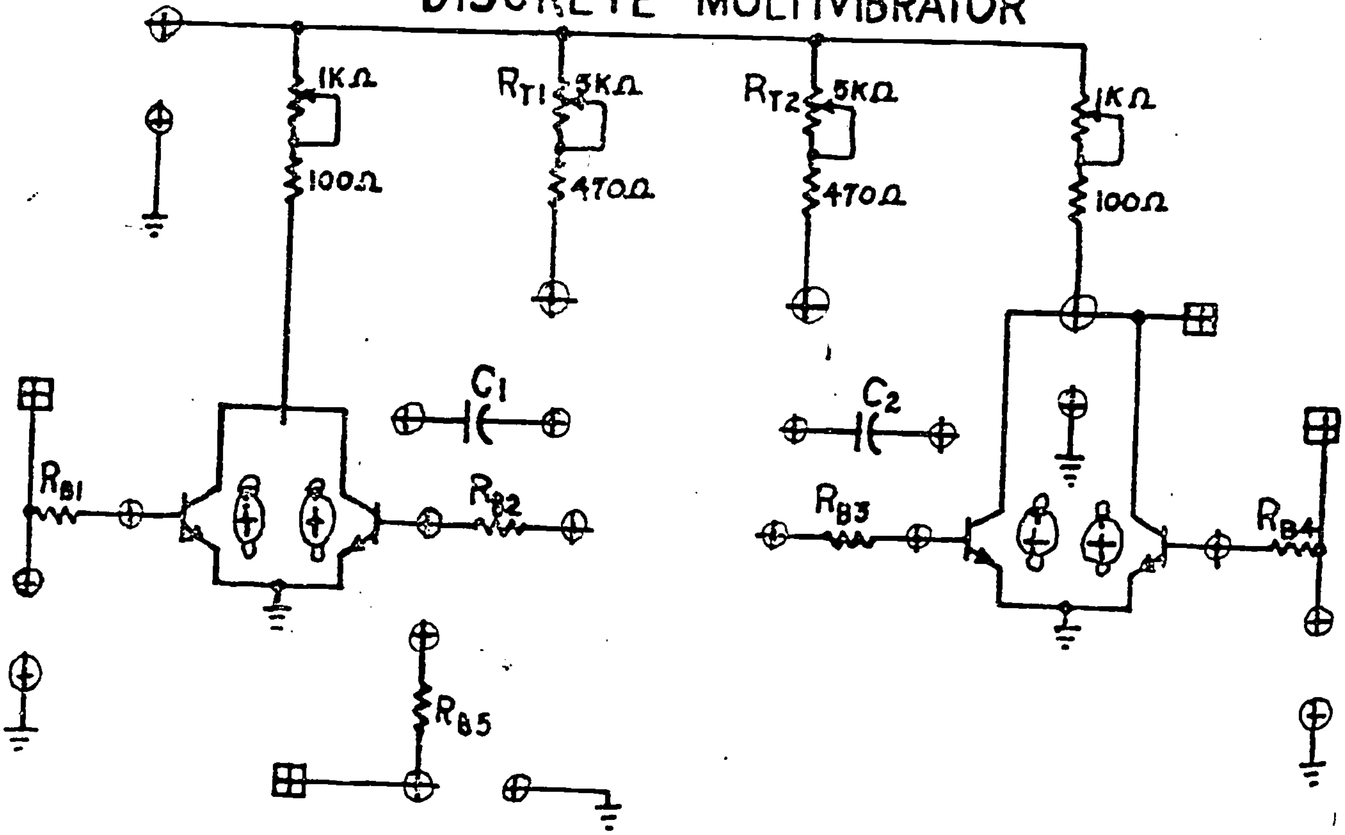

| | | |
|---|---|---|
| $51 cost estimate<br>7x12x3 chassis | Input Transformer<br>2 H choke<br>.4 choke | Stancor #P8604<br>#C2721 |
| Ammeter 0-50 mA<br>Ohmite E0121 | Shurite #3306 | Load 12.5 W Rheostat 2.5k |

1W Resistors 200
100
1k

50 V capacitors two 10uF
two 100uF

4 Diodes
32 Binding Posts

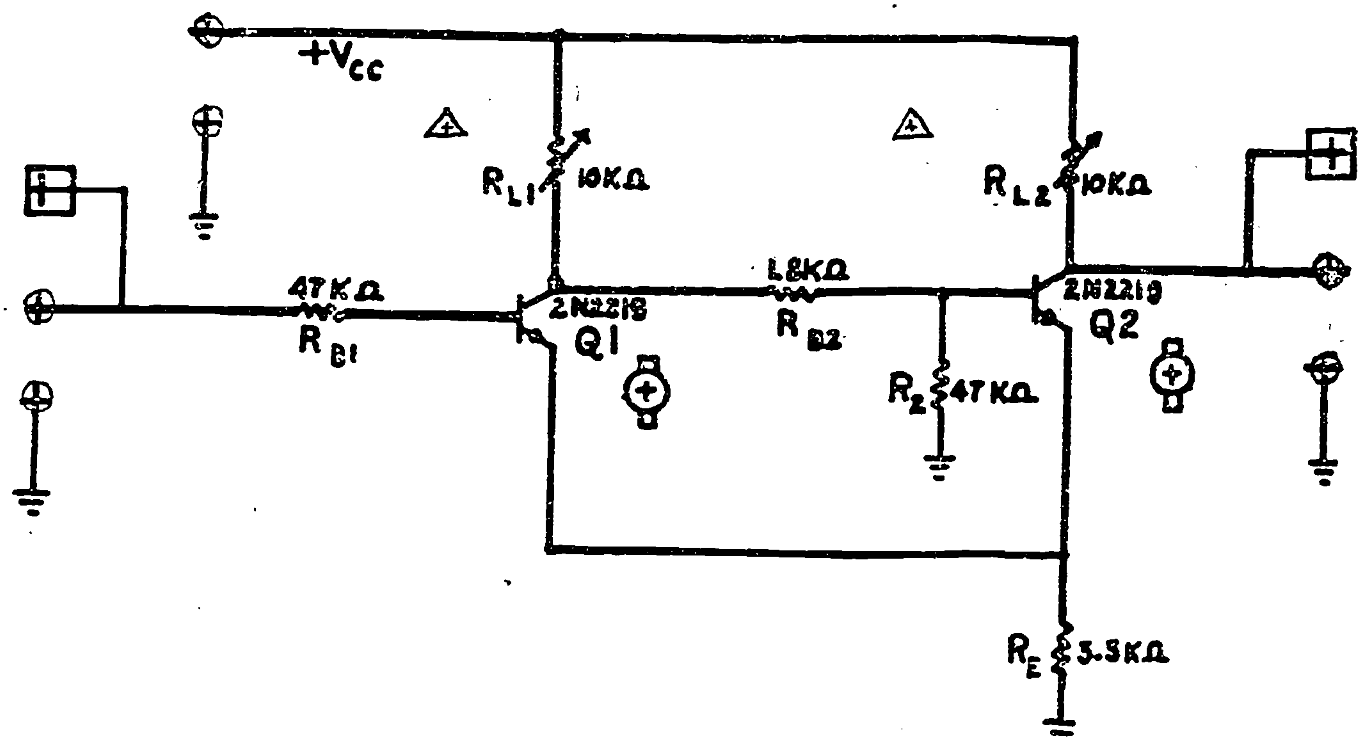
# DISCRETE MULTIVIBRATOR




$35 cost estimate
12x7x3 chassis

Binding Posts - 27
BNC connectors
Transistor sockets -4
Resistors two each 470 Ω, 100 Ω, 1k pot, 5k pot
Loose components for $R_{B1}$, $R_{B2}$, $R_{B3}$, $R_{B4}$, $R_{B5}$, $C_1$, $C_2$

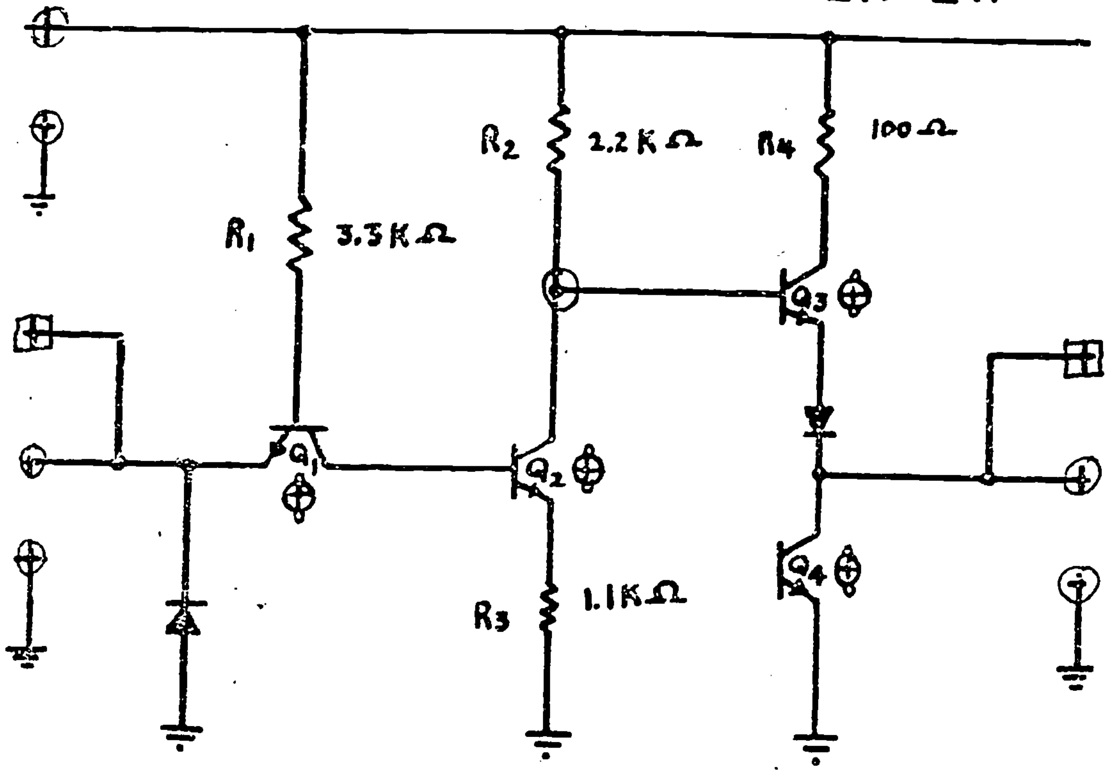
# SCHMITT TRIGGER




$21 cost estimate
12x7x3 chassis

6 Binding Posts
2 BNC connectors
2 Transistor sockets
2 Pots - 10k
Resistors 1.8k
3.3k
47k two

# TOTEM POLE INVERTER




$22 cost estimate
7x9x2 chassis

Transistor Sockets - 4
BNC connectors - 2
Binding Posts - 7
1N 914 Diode
¼W Resistors - 3.3k, 2.2k, 1.1k, 100