October 2007

External Assessment

Applied Practical Electronics
Intermediate 1
C119 10

Course Project 2 – Cycle Lights

1 Contents

1. Course Project overview

This specification is in two parts. The first part, the main body of the specification, provides a template for the definition and assessment of the Course Project. The second part, contained in an appendix, is an approved Exemplar Course Project which fits the template. Over time, it is envisaged that additional approved projects will be devised, in which event they will be added to this specification.

The Course Project is a practical activity in which the candidates assemble and test an electronic system. The Course Project integrates the knowledge, understanding and skills gained in the individual course Units. The integrative nature of the project has several advantages. Depth of understanding can be consolidated and there are opportunities for additional, integrated or applied learning. The additional time allowed for project work encourages more complex projects to be manufactured. The project represents an opportunity for candidates to achieve good-quality work and a useful product. In addition, the project is based on earlier experience, so candidates will be able to plan their work with confidence. The Course Project may be introduced at an appropriate stage in the course to allow candidates to develop and integrate their course experiences with a view towards their final assessment.

Assessment will be based on the outcome of the project. An overall grade (A, B or C) will be determined by assessment of each candidate's performance in producing the Project. This assessment will be subject to external verification. To gain the Course award, the candidate must pass all four Unit assessments, as well as the project assessment.

Candidates must undertake an approved project. The given Project has been devised to enable candidates to achieve any grade across the range. The Project provides work across the range of degrees of difficulty so that each candidate may tackle work at an appropriate level, ie to suit his/her performance in the Units. In practice the final grade will be based on the practical performance of each candidate.

The Course Project is concerned primarily with practical activity in the creation of an electronic system and this is the main area of assessment. However, the Project also includes basic skills relating to the planning and evaluation of the activity as well as its development. As an approach to design, candidates are asked to select between design options and give reasons for their choices. Simulation and test activities are also included.

Candidates are provided with a brief and are expected to demonstrate attainment relating to:

- planning the form and detail of the electronic system to be developed
- simulating the electronic system
- selecting and managing materials, techniques and resources
- building component parts of the electronic system
- assembling the electronic system
- testing the electronic system
- evaluating the outcome of the activity.

Candidate evidence is required as follows

- planning of the electronic system
- simulation of the system
- the system hardware
- system test results
- evaluation.

Copies of Units are available to download from the Scottish Qualifications Authority Website www.sqa.org.uk

The Scottish Qualifications Authority Customer Contact Centre is available on 0845 279 1000; e-mail customer@sqa.org.uk

Note:

Please note that this specification should always be used in conjunction with the Applied Practical Electronics (Intermediate 1) Arrangements document. The Arrangements document lays down the overall requirements for this Course. The Arrangements document is available to download from SQA's Website.

2. Recommended entry

The Course Project is a holistic, integrative activity based on the Units in the National Course. For candidates who are undertaking the National Course, it is strongly recommended that the individual Course Units be completed before the candidate embarks on the external assessment.

However, there may be candidates who, for whatever reason, choose to undertake the external assessment on a stand-alone basis. Any such candidates who have not completed or embarked upon the Units of the National Course *prior* to undertaking the external assessment should have demonstrated attainment in, or attained, the following qualifications:

- National Qualifications in Engineering at Access 3
- National Qualifications in Engineering at Intermediate 1
- Standard Grade in any Science discipline
- Standard Grade in Technological Studies
- Appropriate clusters of Units in an Engineering discipline.

Candidates who achieve the external assessment will not be certificated for the Course until they have successfully completed the component Units.

3. Project brief – Cycle Lights

The approved project is concerned with constructing a set of rear lights for a bicycle. Full details of this project are provided in the appendix. Options for implementation of the project are provided in the brief. The candidate selects appropriate options for their project. These options allow for varying complexities of project and so allow for achievement across the range of grades.

4. Outcome coverage

The component Units for the Course are:

Course		
Unit title	**Credit value**	**Unit number**
Electronics	½	D378 10
Practical Electronics	1	D181 10
Wiring and Assembly Techniques	½	D9EP 10
Electronic Simulation and Testing	1	D9EN 10

The Course Project for this National Course should cover a minimum of two thirds of the Outcomes from the component Units. The Outcomes are listed in the following table and at least one Outcome from each Unit should be covered.

Outcome coverage (Cycle Lights)

	Outcome covered
Unit: Electronics	
1. Demonstrate knowledge and understanding related to electronics	Yes
2. Solve problems related to electronics	Yes
3. Use a systems approach to produce a practical solution to simple, real-life problems	Yes
Unit: Practical Electronics	
1. Construct an electronic circuit using a prototype circuit board	No
2. Construct an electronic circuit using stripboard	Yes
3. Construct an electronic system using a Printed Circuit Board (PCB) from a given specification and using individual components	Yes, if 555 timer board is included in the project
Unit: Wiring and Assembly Techniques	
1. Prepare and connect conductors (wire/cable/strip board)	Yes
2. Form a cable loom	Yes
3. Assemble and test an electronic system	Yes
Unit: Electronic Simulation and Testing	
1. Use a computer to simulate electronic systems	No
2. Use a computer to simulate electronic circuits	Yes
3. Set-up and use multimeters to measure resistance, dc voltage and dc current	Yes
4. Use a low voltage dc supply when testing circuits	Yes

5. Subject/occupationally related knowledge and skills

The Course Project allows candidates to develop and apply skills in:

- solving practical problems using electronics
- planning the form and detail of an electronic system
- simulating electronic circuits and systems
- using computer simulation to test an electronic system
- selecting and preparing electronic components
- preparing and assembling conductors and a cable loom
- constructing an electronic circuit
- assembling an electronic system
- setting up and using simple electronic test equipment
- testing an electronic system
- evaluating the outcome of their activity.

6. Candidate evidence requirements

General information

The three stages of the Course Project for Applied Practical Electronics at Intermediate 1 level are:

- **Planning and Simulation**
- **Construction and Assembly**
- **Testing and Evaluating**

Planning and Simulation

The planning activity consists of a structured series of questions and answers. The specific questions posed to the candidates will depend upon the Course Project undertaken. Candidates will be asked to make choices based on options presented to them. For example, they may be asked to select a performance feature, a type of logic gate, a type of wire or a type of connector. For each question, sufficient information should be given to enable them to make a choice. They should be asked to give reasons for their choices.

Every Course Project will contain either some element of circuit and/or system simulation, or some element of test simulation, or all of these. A printout of simulation results forms the assessable element of this activity. The simulation will be assessed for relevance and comprehensiveness (does it simulate/test the specified performance of the system and does it fully simulate/test the system?).

The plan and simulation should be produced in a supervised environment, although candidates may carry out preparation beforehand. Candidates may communicate with each other when producing their plans and simulations but each activity must be tailored to the candidate's own project and the responses should relate to the work to be carried out by the individual candidate.

The work produced should always be the candidate's own. However, teachers/lecturers are expected to provide candidates with advice, guidance and constructive criticism as necessary when they are making their planning choices. It is important to note that, as these choices underpin the rest of the project, centres should ensure that no candidate proceeds to the construction stage until the candidate has devised a system that is potentially workable. The level of support that candidates need to devise a viable system will of course vary from candidate to candidate. Centres should take into account the level of support needed for each candidate when marking. This should not inhibit centres from providing constructive comment nor the candidate from acting on their own initiative and taking on board the advice. In some cases, however, if the level of support and intervention needed is more than that which would normally be seen as reasonable, the authenticity of the candidate's work may be called into question.

If the level of input needed from the teacher/lecturer is above normal (for example, the quality of the plan is such that it would mean that the project would be unworkable if the plan was not revised) then candidates cannot score more than a percentage of the marks allowed for the planning and simulation stage. Specific information is given on this in the section on marking and grading.

Construction and Assembly

Candidates must provide evidence that:

- testifies to the quality of the hands-on practical activity (the assembled system)
- documents the processes underpinning the activity.

All of the evidence should be produced in a supervised environment. Candidates may communicate with each other but should produce work which can be clearly attributed to the candidate as being his or her own.

Whilst assembling their system, candidates will be assessed for adherence to safety guidelines, selection of appropriate tools and methods, the degree of initiative and independence shown.

The assembled system will be assessed for neatness, reliability of connection, quality of solder joints, crimp connections and other interconnections and layout of components.

Documentation which underpins the practical activity should consist of some or all of:

- a system block diagram
- a parts list
- a wiring schedule
- a circuit diagram
- a layout drawing.

The system block diagram will show the main elements within the system and how they are interconnected. The block diagram will be assessed for clarity, neatness and accuracy of labelling.

The parts list will be assessed for accuracy and completeness.

Wiring schedule. Every Course Project will include some element of wiring assembly. This may include power supply connections, interconnection between sub-assemblies, or wiring on one assembly to customise it to a particular application or specification. The wiring schedule will be assessed for accuracy, neatness and clarity.

The circuit diagram will show the detailed elements of the electronic circuit(s). The circuit diagram will be assessed for clarity, neatness and accuracy of labelling and drawing of circuit elements.

The layout drawing will show the physical placement of the components on the logic board. If completed or modified by the candidate, it will be assessed for accuracy and completeness.

Specific information on the allocation of marks is given in the section on marking and grading.

Testing and Evaluating

The test activity should consist of a series of tests on the completed assembly. Sub-assemblies may also be tested to ensure functionality prior to system interconnection. These tests should include power-off continuity or resistance measurements as well as power-on voltage and current measurements. They may include observation of a sequence of events, or responses to inputs. The test results should take the form of a pro forma, which is completed when the tests are performed on the completed system. Expected measurements or pass/fail criteria for each test should be specified in the pro-forma. The test results will be assessed for validity of the measurements and observations made, comprehensiveness, accuracy and clarity.

The evaluation should consist of a structured series of questions and answers relating to:

- any unforeseen events and how they were handled
- the identification of knowledge and skills which have been gained and/or developed
- an assessment of the strengths, weaknesses and quality of any hands-on activity
- an evaluation of the extent to which the assignment met the original brief.

The evaluation activity should be undertaken under controlled conditions to ensure reliability and credibility.

Candidates at Intermediate 1 should be allowed up to 1 hour to complete the evaluation.

Candidates should be allowed to take the written results of their practical activity into the room with them. Centres have the responsibility for ensuring that the material brought in is the candidate's own work.

7. Allocation of marks and assessment arrangements – general information

The assessment evidence for this National Course is internally centre marked and assessed and externally verified by SQA.

The total mark for the Course Project is 200, (this large mark allocation makes it easier to discriminate effectively between performances of candidates across the various parts of the assessment). These marks will be allocated to assessment evidence from the three Course Project stages as follows in *Table A.*

Table A

Course Project Stage	Assessment Evidence	Mark Allocation
Planning and simulation	Plan and simulation results	25
Construction and assembly	Candidate performance, the assembled system and associated diagrams and documentation.	150
Testing and evaluating	Test results and evaluation	25

Planning and simulation	
Evidence:	♦ Planning (10 marks) ♦ System/circuit simulation and/or test simulation (15 marks) (25 marks in total for this stage)
Conditions of assessment	Supervised
Who assesses it?	Internally centre marked and assessed: Externally verified

Construction and assembly	
Evidence:	♦ use of given information (10 marks) ♦ selection of components (10 marks) ♦ selection of tools and equipment (10 marks) ♦ safe practices and procedures (10 marks) ♦ accuracy and neatness of component placement and forming (15 marks) ♦ quality of solder joints and other connections (15 marks) ♦ neatness and structure of cable loom (15 marks) ♦ system documentation (system block diagram, circuit diagram, parts list, wiring schedule, layout drawing) (15 marks) ♦ functionality of the project (20 marks) ♦ value of the project (15 marks) ♦ complexity of the project (15 marks) (150 marks in total for this stage)
Conditions of assessment	Supervised
Who assesses it?	Internally centre marked and assessed: Externally verified

Testing and evaluating	
Evidence:	♦ test activity and results (15 marks) ♦ evaluation responses (10 marks) (25 marks in total for this stage)
Conditions of assessment	Centre-invigilated
Who assesses it?	Internally centre marked and assessed: Externally verified

8. Grade descriptions – general information

There are four aspects to be considered in determining the grade of award at Intermediate 1:

- the level of difficulty of the project undertaken
- the range of skills demonstrated
- independence of working and the amount of practical assistance required
- the level of skill and accuracy demonstrated.

1 *The level of difficulty of the project undertaken*

The given project contains options at a range of difficulties to allow appropriate grading ie Grade A, B and C. The quality of performance in executing the project, using performance criteria described below, will establish the actual grade awarded to an individual candidate.

2 *The range of skills demonstrated*

Graded marks will be allocated during the project and will assess:

- information read correctly from diagrams and drawings
- effective use of simulation tools
- appropriate selection of components
- appropriate selection of tools and equipment
- safety procedures and practices adhered to
- electronic components listed correctly, selected from stock and inserted in the circuit board
- pre-power-up procedures, fault finding and rectification carried out correctly
- project documentation.

3 *The degree of independence and the amount of practical assistance required*

It is anticipated that most candidates will require some guidance to proceed with the project. The three levels are:

- Project completed with a high degree of independent working with minimal assistance and advice
- Project completed with areas of independent working with assistance and advice given regularly
- Project completed with little independent work with much help and guidance.

4 *The level of skill and accuracy demonstrated (in the practical activities)*

Marking will be based on:

- accuracy and neatness of components placement and fixing
- quality of solder joints
- mechanical strength and electrical continuity of cable/wire terminations
- neatness of cable/harness layout
- quality of work in all areas of the project
- functionality of the project.

To underpin this assessment system there are criteria to which marks are pegged, against which the candidate evidence from each of the three Course Project stages is assessed. The use of such mark categories linked to broad criteria allows for the aggregation of the various parts of the assessment, which do not necessarily have the same weighting in the overall grade. *Table B* outlines the general criteria to be used to assess candidate evidence. The overall grade for the Course Project is determined by the total mark.

Although it is possible for candidates to be given bands 8 and 9 which are described as "fails", no such categories will appear on candidates' certificates.

This National Course is subject to external verification. Verification will normally be based on a sample of 12. The assessor will then apply the standard agreed between verifier and assessor to the remaining candidate work. Verifiers will be trained by SQA to apply national standards. After completing the verification exercise, the verifier will discuss candidates' performance with the centre staff. The visiting verifier will arrive at the verification result. This will either be "Accepted" or "Not Accepted". As candidate evidence becomes available exemplars will be issued to centres as guidance.

Course Project

Table B

Intermediate 1		**Plan and simulation**	**Assembled system and documented evidence**	**Test results and evaluation**	**Total**
Levels of performance: **Broad level-related criteria**	Equivalence to	Mark range	Mark range	Mark range	Mark range
Content and scope: Appropriate for level Treatment: Excellent	Upper A 85 – 100% (Band 1)	21 – 25	128 – 150	21 – 25	170 – 200
Content and scope: Appropriate for level Treatment: Consistently thorough	Lower A 70 – 84% (Band 2)	18 – 20	104 – 127	18 – 20	140 – 169
Content and scope: Appropriate for level Treatment: Thorough in parts	B 60 – 69% (Bands 3 &4)	15 – 17	90 – 103	15 – 17	120 – 139
Content and scope: Appropriate for level Treatment:	C 50 – 59% (Bands 5 & 6)	12 – 14	76 – 89	12 – 14	100 – 119
Content and scope: Appropriate for level Treatment: Adequate only in parts OR Content and scope: Basic for level Treatment: Thorough	D Fail 40 – 49% (Bands 7 & 8)	10 – 11	60 – 75	10 – 11	80 – 99
Content and scope: Appropriate for level Treatment: Generally poor OR Content and scope: Basic for level Treatment: Adequate or poor	Fail Below 40% (Band 9)	<10	<60	<10	<80

Note:
Content and scope: defined as how appropriate or otherwise the candidate interprets the level of demand of the specification
Treatment: defined as how successful or otherwise the candidate tackles the project

9. Grading and marking – detailed information

To complete the internal marking process, assessors are expected to:

- be familiar with, and apply, the broad criteria outlined in Table B
- select a grade appropriate to the candidate's performance using the grade criteria given in Table C
- use observation and judgement to decide on a particular mark for the candidate within the mark range given for that grade criteria
- maintain a brief record of why a certain mark was given (for internal verification purposes)
- follow the internal verification processes within their centre (see the section on internal verification)
- aggregate the internally verified marks for each candidate. That gives a total mark out of 200
- divide that total mark by 2 to give a percentage
- convert the overall % mark for each candidate into a grade and band using Table D
- check the grade already given to candidates against the grade descriptions tabled in (Table E). This is to ensure that candidates have effectively integrated each stage of the Practical Assignment and that the overall grade is a fair reflection of the candidate's work. The grade descriptions are a touchstone against which grades can be checked.

Table C

Planning and simulation			
Assessable Element	**at Grade A**	**at Grade B**	**at Grade C**
Selection of design options	♦ is completed with a high degree of independent working with minimal assistance and advice ♦ gives clear, sound reasons for the choices made *mark range 7 – 10*	♦ is completed with areas of independent working with assistance and advice given regularly ♦ gives valid reasons for the choices made *mark range 6 – 7*	♦ is completed with little independent work with much help and guidance ♦ gives reasons for the choices made *mark range 5 – 6*
Evaluation responses	♦ fully simulates the system with thorough test simulation ♦ is neat, well-structured and logical *mark range 11 - 15*	♦ tests the basic function of the system with some test results ♦ is adequate *mark range 9 – 10*	♦ simulates at least part of the system or circuit ♦ is basic and fairly neat *mark range 7 – 9*

Table C (continued)

Construction and assembly

Assessable Element	at Grade A	at Grade B	at Grade C
Use of given information	♦ reads information correctly from drawing and diagrams with minimal guidance *mark range 7 - 10*	♦ reads information from drawings and diagrams with some guidance and assistance *mark range 6 - 7*	♦ requires assistance and guidance in reading information from drawings and diagrams *mark range 5 – 6*
Selection of components	♦ correctly identifies and selects all the required parts and components *mark range 7 - 10*	♦ correctly identifies and selects most of the required parts and components *mark range 6 - 7*	♦ correctly identifies and selects some of the required parts and components *mark range 5 – 6*
Selection of tools and equipment	♦ selects the correct tools and equipment for the job at all times ♦ uses tools and equipment appropriately at all times *mark range 7 - 10*	♦ usually selects the correct tools and equipment for the job ♦ uses tools and equipment appropriately most of the time *mark range 6 - 7*	♦ sometimes selects the correct tools and equipment ♦ uses tools and equipment without damage *mark range 5 - 6*
Safe practices and procedures	♦ uses safe practices and procedures at all times without supervision *mark range 7 - 10*	♦ uses safe practices and procedures at all times with some supervision *mark range 6 - 7*	♦ requires supervision in the use of safe practices and procedures *mark range* 5 - *6*
Accuracy and neatness of component placement and forming	♦ similar components are mounted uniformly at the same height ♦ component legs are neatly and evenly pre-formed to fit the footprint *mark range 11 - 15*	♦ some unevenness in component height and uniformity ♦ component legs are pre-formed to fit the footprint *mark range 9 - 10*	♦ components are mounted securely ♦ components fit the available space and do not touch each other *mark range 7 – 9*

Table C (continued)

Construction and assembly (continued)			
Assessable Element	**at Grade A**	**at Grade B**	**at Grade C**
Quality of solder joints and other connections	♦ solder connections are uniform with correct solder fillet ♦ other connections are electrically reliable and use some form of strain relief *mark range 11 - 15*	♦ some unevenness in solder joints ♦ other connections are sound with reliable electrical continuity *mark range 9 - 10*	♦ all connections provide electrical continuity ♦ no dry joints or intermittent connections *mark range 7 – 9*
Neatness and structure of cable loom	♦ loom is neat and orthogonal ♦ tie-wraps and/or spiral wrap is used neatly and effectively ♦ no loose wires *mark range 11 - 15*	♦ loom is reasonably neat ♦ tie-wraps and/or spiral wraps are used ♦ no loose wires *mark range 9 - 10*	♦ wiring is electrically reliable and mechanically secure *mark range 7 – 9*
System documentation (system block diagram, circuit diagram, parts list, wiring schedule, layout drawing)	♦ is comprehensive, neat, well structured and logical *mark range 11 - 15*	♦ is comprehensive *mark range 9 - 10*	♦ is basic and fairly neat *mark range 7 –9*
Functionality of the project	♦ is of high quality, complete, reliable, neat, well-organised and fully functional *mark range 14 - 20*	♦ is of good quality, sufficient, structured, workmanlike and functional *mark range 12 - 14*	♦ is of reasonable quality, adequate and functional *mark range 10 - 12*

Table C (continued)

Construction and assembly (continued)			
Assessable Element	**at Grade A**	**at Grade B**	**at Grade C**
Value of the project	♦ displays a high level of subject/occupational expertise ♦ applies, integrates and consolidates knowledge, understanding and skills effectively and consistently *mark range 11 - 15*	♦ displays a good level of subject/occupational expertise ♦ applies, integrates and consolidates knowledge, understanding and skills fairly effectively and consistently *mark range 9 - 10*	♦ displays an adequate level of subject/occupational expertise ♦ applies, integrates and consolidates knowledge, understanding and skills with some lack of continuity and consistency *mark range 7 - 9*
Complexity of the project	♦ uses more than two logic gates using two or three logic functions (AND, OR or NOT gates) ♦ demonstrates enthusiasm, imagination and initiative *mark range 11 - 15*	♦ uses at least two logic gates using more than one logic function (AND, OR or NOT gates) ♦ demonstrates an accurate and fairly innovative and enthusiastic implementation *mark range 9 - 10*	♦ uses at least one AND, OR or NOT gate ♦ is an acceptable implementation *mark range 7 - 9*

Testing and evaluation			
Assessable Element	**at Grade A**	**at Grade B**	**at Grade C**
Test activity and results	♦ pre-power-up checks are performed thoroughly ♦ test sequence is logical and thorough ♦ test results are accurate and comprehensive *mark range 11 - 15*	♦ pre-power-up checks are performed adequately ♦ test sequence is logical and adequate ♦ test results check performance of system *mark range 9 - 10*	♦ some pre-power-up checks are performed ♦ test sequence is adequate ♦ test results are valid *mark range 7 - 9*
Evaluation responses	♦ gives clear, valid assessment of project worth ♦ is neat, well-structured and logical *mark range 7 - 10*	♦ gives reasonable, truthful assessment of project worth ♦ is adequate *mark range 6 - 7*	♦ is basic and fairly neat *mark range 5 - 6*

Table D

% Mark range	Grade	Band (for estimates)
85 – 100	A (upper)	1
70 – 84.5	A (lower)	2
65 – 69.5	B (upper)	3
60 – 64.5	B (lower)	4
55 – 59.5	C (upper)	5
50 – 54.5	C (lower)	6
45 – 49.5	D	7
40 – 44.5	Fail	8
less than 40	Fail	9

Grade descriptions for a Course Project at Intermediate 1

Table E

A	B	C
Content and scope appropriate for Intermediate 1		
And looking at the evidence as a whole:	**And looking at the evidence as a whole:**	**And looking at the evidence as a whole:**
A Course Project at Grade	**A Course Project at Grade**	**A Course Project at Grade**
♦ produces high quality, complete, reliable, neat, well-organised, fully functional product evidence supported by neat, well-structured, logical documentary evidence	♦ produces good quality, sufficient, structured, workmanlike, functional product evidence supported by adequate documentary evidence	♦ produces reasonable quality, adequate, functional product evidence supported by basic, fairly neat documentary evidence
♦ is an exercise in which candidates have demonstrated enthusiasm, imagination and initiative in fulfilling the Course Project brief.	♦ is an exercise in which candidates have demonstrated an accurate and fairly innovative and enthusiastic implementation of the Course Project brief.	♦ is an exercise in which candidates have brought an acceptable implementation of the Course Project brief.
♦ is completed with a high degree of independent working with minimal assistance and advice	♦ is completed with areas of independent working with assistance and advice given regularly	♦ is completed with little independent work with much help and guidance
♦ is tightly structured, relevant to the content of the Units and displays a high level of subject/occupational expertise	♦ is well structured, relevant to the content of the Units and displays a good level of subject/occupational expertise	♦ is reasonably well structured, relevant to the content of the Units and displays an adequate level of subject/occupational expertise
♦ applies, integrates and consolidates knowledge, understanding and skills effectively and consistently from the course Units.	♦ applies, integrates and consolidates knowledge, understanding and skills fairly effectively and consistently from the course Units.	♦ applies, integrates and consolidates knowledge, understanding and skills from the course Units with some lack of continuity and consistency.

10. Ensuring evidence is authentic

All activities and documentation should be undertaken and completed under supervised or invigilated conditions. At all times conditions should be controlled to ensure reliability and credibility.

11. Materials and resources

For the approved project, candidates are expected to use the following resources and materials as appropriate:

- computer simulation program
- stripboard
- integrated electronic components (ICs)
- discrete electronic components (resistors, capacitors etc.)
- cable or wire
- connectors
- hand tools and soldering equipment
- safety equipment
- low-voltage power supplies
- test equipment.

It is anticipated that any future approved projects will contain a similar list of resources.

12. Core Skills

Successful completion of this Course Project leads to automatic certification of the Problem Solving Core Skill at Intermediate 1.

13. Re-assessment of outcomes in individual course Units

It may be permissible for activities undertaken or products produced in the Course Project to be used as a re-assessment evidence of completion of outcomes within individual course Units.

For this to be the case, the following conditions must be met:

- the individual Course Unit Outcome must first have been attempted as part of that Unit
- the Course Project specification must clearly identify the Units and Outcomes to which this is applicable
- the activity of product used from the Course Project must meet the Performance Criteria as specified in the individual Unit specification.

Applied Practical Electronics Intermediate 1
Assessment of Project – Marking Scheme

Candidate Name …….

For each assessable element, check the appropriate grade and award a mark within that grade range.

Assessable Element	Grade A	Grade B	Grade C	Mark awarded	Official use
Planning and simulation					
Selection of design options	10 - 7	7 - 6	6 - 5		
System/circuit simulation and/or test simulation	15 - 11	10 - 9	9 - 7		
Total Marks			25		
Construction and assembly					
Use of given information	10 - 7	7 - 6	6 - 5		
Selection of components	10 - 7	7 - 6	6 - 5		
Selection of tools and equipment	10 – 7	7 - 6	6 - 5		
Safe practices and procedures	10 - 7	7 - 6	6 - 5		
Accuracy and neatness of component placing and forming	15 - 11	10 - 9	9 - 7		
Quality of solder joints and other connections	15 - 11	10 - 9	9 - 7		
Neatness and structure of cable loom	15 - 11	10 - 9	9 - 7		
System documentation (block diagram, circuit diagram, parts list, wiring list, layout)	15 - 11	10 - 9	9 - 7		
Functionality of the project	20 - 14	14 - 12	12 - 10		
Value of the project	15 - 11	10 - 9	9 - 7		
Complexity of the project	15 - 11	10 - 9	9 - 7		
Total marks			150		
Testing and evaluation					
Test activity and results	15 - 11	10 - 9	9 - 7		
Evaluation responses	10 – 7	7 - 6	6 - 5		
Total marks			25		
Overall total mark			200		
Overall grade					

14. Utilisation of products produced in course Units

Dependent upon the specific Course Project undertaken, it may be that one or more products produced as part of the individual course units can be used as component parts of the Practical Assignment.

For this to be the case, the following conditions must be met:

- the product to be used must be clearly identified in the Course Project specification
- this applies only to products produced for the following Outcomes:
    - Practical Electronics Outcome 2
    - Practical Electronics Outcome 3
    - Wiring and Assembly Techniques Outcome 1
    - Wiring and Assembly Techniques Outcome 2
- simulation and test results cannot be transferred in this way. The logic circuit or electronic system produced in the Course Project must be simulated and tested as an entity in its own right
- a Course Project consisting wholly of sub-assemblies which have been made as parts of the individual Course Units would only be eligible for an award at grade C.

15. Course Project overview

The internal verifier oversees:

- the internal verification process to ensure consistency of judgment or reliability of assessment. This process will vary according to the nature of the evidence and the number of assessors and sites. It is likely to involve agreement trials and/or marker standardisation. The internal verifier should be a specialist in the subject

- a consideration of whether, in some cases, candidates with similar overall marks/bands have been fairly treated. For example, some candidates may have produced more fully integrated projects than others. This may lead to a reconsideration of marking of the individual components for some candidates.

Note: As the Course Project is internally assessed and subject to external verification there is no need to submit an estimate. At the verification visit, the assessor and verifier will agree the standard and this will be applied to the remaining candidate work. This means that there will be no appeals.

(See *Guide to Assessment and Quality for Secondary Schools* (AA0840/2, August 2003), *Guide to Assessment and Quality Assurance for Colleges of Further Education* (AA0841/3, August 2003) for further information relating to internal verification. A guide to good practice for internal verification is also available.

Appendix A: Practical Assignment — Cycle Lights

A1. Candidate guide - Introduction

At night when cycling on the road you must have a front and rear light. The rear lights on a bike are increasingly made by using a small electronic circuit and a number of light emitting diodes (LEDs). These LEDs can be switched from flashing to constantly on. In this project you will make a set of rear lights for a bicycle.

<u>The project specification</u>

To construct a bicycle rear light.

The complete bike light can be made up of separate units connected by a wiring loom:

- A flasher unit and or a switch unit (for the handle bars)
- A unit containing the battery and electronic circuit (attached to cross bar)
- The rear light or display unit (back wheel).

The rear light assembly is made up of a **minimum** of three LEDs, with the centre LED on while the others can be switched so that they flash alternately*. The entire rear light unit can also be switched on and off.

*when the left hand LED is on the right hand LED is off;
when the right hand LED is on the left hand LED is off.

1. Collect a candidate checklist and you will see all the different parts of the Project.
2. On the following Candidate Help Sheets you will be given a number of diagrams and notes to help you successfully complete the Project.

A2. Candidate guide – Design choices

To help you with the design plan:

You have a choice of circuit layout used in the rear cycle light. The more complicated the circuit layout selected the more marks you can gain.

Circuit A	4 LED display	3 logic gates	2 IC's	most complicated
Circuit B	3 LED display	2 logic gates	2 IC's	
Circuit C	3 LED display	1 logic gate	1 IC	least complicated

Before deciding which circuit to choose, look at the circuit and layout diagrams. This will give you a better idea about which one to choose. Although Circuit C has the least number of logic gates, you will need to make up more wiring looms than with the other two circuits.

The types of wire you can select are either single strand or multi-strand. For soldering onto stripboard multi-strand wire can be more difficult to use. However single strand wire is not as flexible as multi-stranded wire.

The circuit diagram will help you when you come to simulate the circuit.

If you have chosen Circuit B or Circuit C then when you have completed your Project the cycle light should operate as shown below.

SW1	SW2	Left hand LED	Mid LED	Right hand LED
OFF	OFF	OFF	OFF	OFF
OFF	ON	OFF	OFF	OFF
ON	OFF	OFF	ON	OFF
ON	ON	ON flashing	ON	ON flashing

You can add 2 extra LED's in Circuits B and C if you wish.

A3. Candidate guide – System information

Here are the circuit and layout diagrams for Circuits A, B and C.

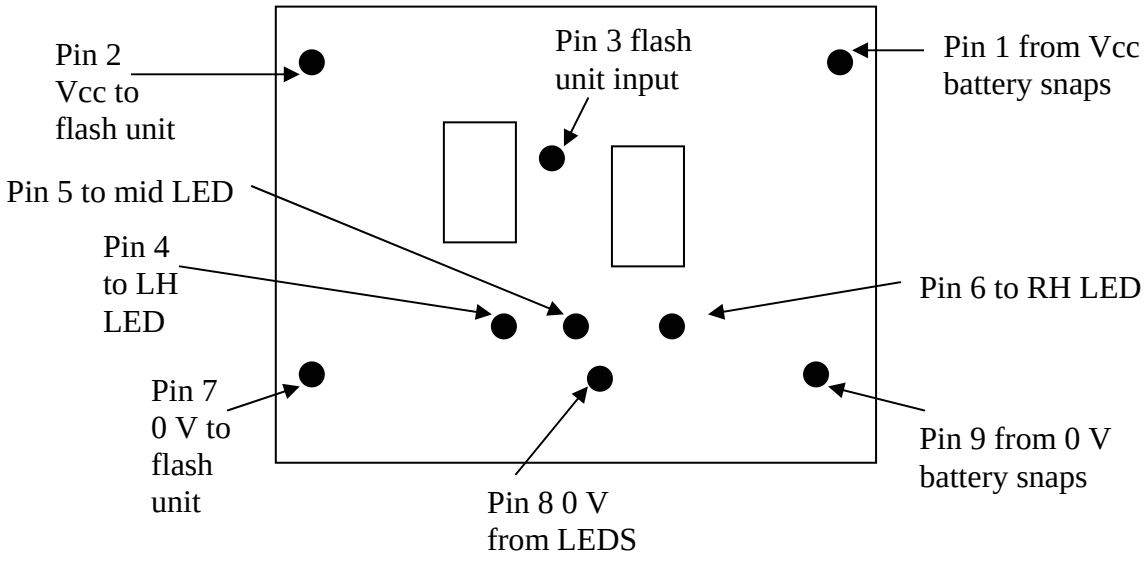
When you come to start circuit construction here are a few helpful hints to help you avoid problems and getting frustrated. Be careful, the list below **does not give you a complete order of construction**, but should help you sequence your work.

- Position both the IC chip holders.
- Cut the tracks between the legs of each IC holder before soldering onto the stripboard.
- Connect in the mid LED first.
- Connect up IC1.
- Connect in the left hand LED.
- Connect IC2 and adjust VR1.
- Connect right hand LED.

Remember to label your wires at each end!

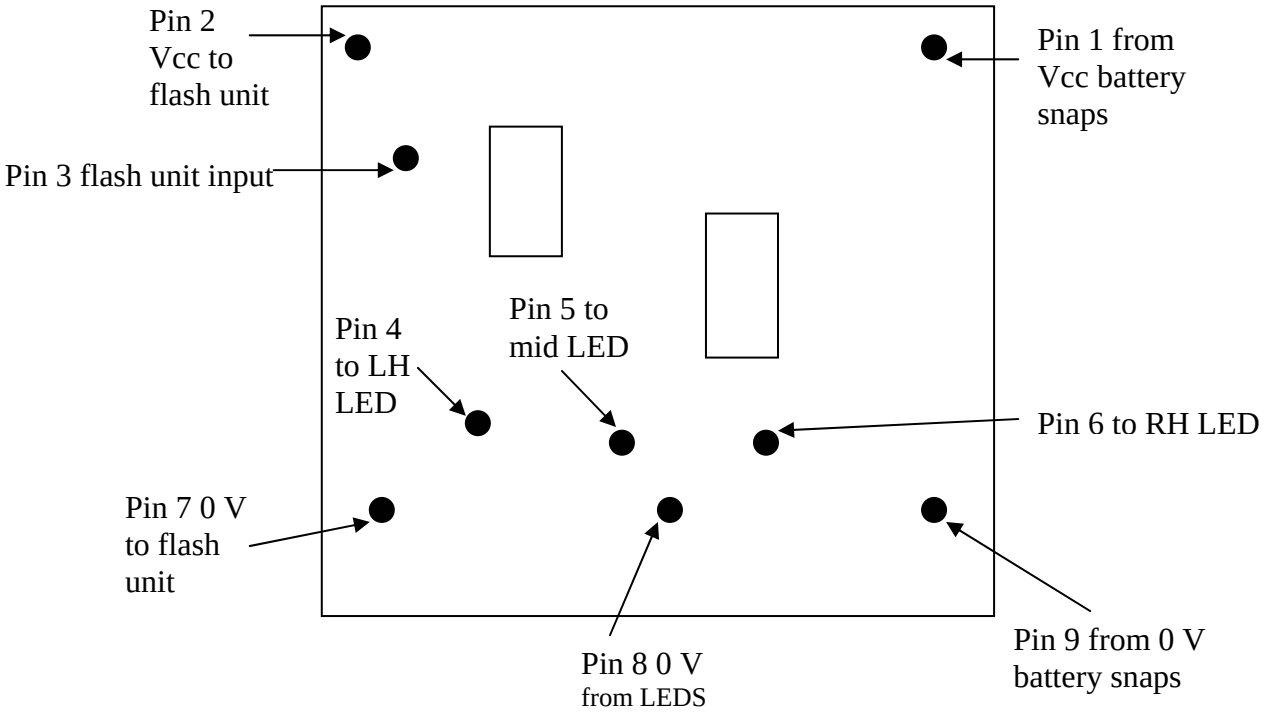
The diagram below will help you to complete the wiring schedule successfully.

Layout A



Pin 1 Vcc from battery	Pin 5 output to Mid LED	Pin 9 0 V from battery
Pin 2 to +9 V input flash unit	Pin 6 output to RH LED	
Pin 3 to input from flash unit	Pin 7 0 V to flash unit	
Pin 4 output to LH LED	Pin 8 0 V to LEDs	

Layout B



Pin 1 Vcc from battery	Pin 5 output to Mid LED	Pin 9 0 V from battery
Pin 2 to +9 V input flash unit	Pin 6 output to RH LED	
Pin 3 to input from flash unit	Pin 7 0 V to flash unit	
Pin 4 output to LH LED	Pin 8 0 V to LEDs	

Adjusting the voltage for ICs

- Set the multimeter to 20 V dc.
- Connect the battery to the battery snaps.
- Turn SW1 ON.
- Connect the common lead from the multimeter to the bottom adjustment pin and the other lead to the top adjustment pin.
- Now adjust VR1 until the multi-meter reads 5 V.

A4. Candidate guide – Project stages

To complete the course project you are required to produce the following items.

Planning and simulation

- A design plan
- A computer simulation of your system circuit

Construction and assembly

- System documentation (system block diagram, logic diagram, parts list, wiring schedule, layout drawing)
- The assembled system

Testing and evaluating

- System test results
- An evaluation

The design plan

To do the design plan, you will complete a planning sheet stating what design choices you have made for your project and giving reasons for those choices.

The simulation

You will do a computer simulation of your logic circuit, using the simulation package that you have used before. You will use the simulation to make sure the logic circuit follows your truth table. You may have to change your circuit to make it work.

System documentation

Your system documentation will consist of some, or all, of a system block diagram, a logic diagram, a parts list, a connection list and a logic board layout drawing.

Parts list

This will list the parts you have used in your project.

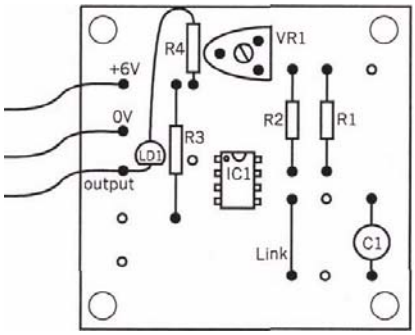
If you have chosen Circuit A, when you have completed your Project the cycle light should operate as shown below.

SW1	SW2	LED 1	LED 2	LED 3 and 4
OFF	OFF	OFF	OFF	OFF
OFF	ON	OFF	OFF	OFF
ON	OFF	OFF	ON	OFF
ON	ON	ON flashing	ON	ON flashing at same time

When LED 1 is flashing ON LEDs 3 and 4 are flashing OFF.

You may alter the sequence of LEDs in Circuit A if you wish.

Whichever circuit you choose to produce flashing LEDs, your system will require the 555 Timer PCB Circuit which you assembled as part of your Practical Electronics Unit.



When you have built your circuit, this is how you should adjust the variable resistor VR1:

- First set your multimeter to the 200 mA dc range.
- Then connect between the battery and battery snaps.
- Complete the circuit between battery and circuit.
- Turn on SW1 and SW2.
- Adjust the variable resistor until the multimeter reads 7 mA. (Circuit B or C).
- Adjust the variable resistor until the multimeter reads 12 mA. (Circuit A).

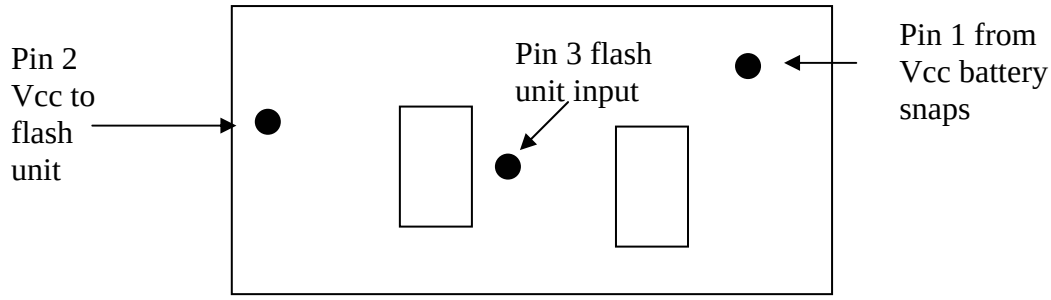
When you come to start circuit construction here are a few hints to help you avoid problems and getting frustrated:

- Position the IC chip holders.
- Cut the tracks between the legs of each IC holder before soldering onto the stripboard.

This is where you will face the greatest challenge to your soldering skills so complete this first. After that the rest of the circuit construction will be straightforward.

Remember to label your wires at each end!

The diagram below will show you how to complete a wiring schedule successfully.



Signal name	From	To	Wire type and colour or identification
+ 9 V	Battery snap	Circuit board Pin 1	Multi-strand red (1)
Vcc flash unit	Logic board Pin2	Flash unit PCB Vcc	Multi-strand blue (2)

A5. Pro Forma

The following pro formas are provided to assist candidates with each of the Course Project stages:

- design cable
- cable assembly connection list
- system testing
- evaluation.

Essential Documentation

Each candidate should provide:

- Design plan
- Simulation printouts
    - circuit with SW1 closed
    - circuit with SW1 and SW2 closed
- System block diagram
- Parts/components list
- Wiring schedule
- Layout diagram – *this can be a photocopy of circuit layout*
- System test results
- Evaluation sheet
- Completed circuit.

Although not essential the **candidate checklist** will allow for easier monitoring of candidate progress and provide the candidate with a useful guide to organising their documentation.

Candidate Checklist

Applied Practical Electronics
Intermediate 1

Circuit Chosen	

Name _____

Centre Name _____

Centre Number _____

	Put a tick in box when completed
♦ Design plan	☐
♦ Simulation printouts	
o circuit with SW1 closed	☐
o circuit with SW1 and SW2 closed	☐
♦ System block diagram	☐
♦ Parts / components list	☐
♦ Wiring schedule	☐
♦ Layout diagram	☐
♦ System test results	☐
♦ Evaluation sheet	☐
♦ Completed circuit	☐

Remember to put all the documentation shown above in order and put this sheet at the front.

Teacher/lecturer's signature _____ Date _____

Name of Candidate

Date

Candidate instructions: Complete all sections of this planning sheet

CYCLE LIGHTS – DESIGN PLAN

First choice — Layout of circuit

Which layout have you chosen.

Place a tick in appropriate box

Circuit A	
Circuit B	
Circuit C	

Why have you made this choice? _____

_____

_____

_____

Second choice — type of wire used for system connections

Have you chosen to use single-strand or multi-strand wire?

Place a tick in appropriate box

single strand wire	
multi-strand wire	

Why have you made this choice?

_____

_____

Name of Candidate

Circuit chosen	

Candidate instructions: Complete this section by drawing in the connections between the blocks of this planning sheet <u>for your circuit only.</u>

<u>System Block Diagram – for Circuit A and B</u>

Flasher unit on PCB

Timer circuit and logic board including battery supply on stripboard.

Display unit on stripboard.

<u>System Block Diagram – for Circuit C</u>

Flasher unit on PCB

Switch unit

Timer circuit and logic board including battery supply on stripboard.

Display unit on stripboard.

Name of Candidate		Circuit chosen	

Candidate instructions: Complete the missing parts of this connection list. You may not need to use all the connections shown, depending upon your design choices.

CABLE LOOM CONNECTION LIST – WIRING SCHEDULE

Signal name	**From**	**To**	**Wire type and colour or identification**
+ 9 V	Battery snap	Circuit board Pin 1	Multi-strand red (1)
0 V	Battery snap	Circuit board Pin 9	
Vcc input to flash unit	Circuit board Pin	Vcc	
Flash unit output	O/P	Circuit board Pin 3	
0V input to flash unit	Circuit board Pin	GND	
To LED 1	Circuit board Pin 5		
To LED 2	Circuit board Pin 6		
To LED 3	Display Pin		

Name of Candidate		Circuit chosen	

Candidate instructions: Complete the missing parts of this connection list. You may not need to use all the connections shown, depending upon your design choices.

CABLE LOOM CONNECTION LIST – WIRING SCHEDULE (CONTINUED)

Signal name	**From**	**To**	**Wire type and colour or identification**

Name of Candidate

Parts /components list

Description of part	Quantity

Name of Candidate

Parts /components list (continued)

Description of part	Quantity

Name of Candidate		Circuit chosen	**A**

Candidate instructions: Complete all sections of this test results sheet

CYCLE LIGHTS – SYSTEM TESTING

- First set your multimeter to the 200 mA dc range.
- Then connect between the battery and battery snaps.
- Complete the circuit between battery and circuit.
- Turn on SW1 and SW2.
- Adjust the variable resistor until the multimeter reads 12 mA.
- You are now ready to complete the readings below.

Power off system tests		
Connection to be measured	**Expected measurement**	**Actual measurement**
Resistance between +Vcc and 0 V on circuit board with SW1 and SW2 closed (ON)	11 kΩ	
Power on system tests		
Test conditions - voltage and current	**Expected measurement**	**Actual measurement**
Voltage between +Vcc and 0 V on circuit board	9 V	
Voltage across non flashing LED when lit	2 V	

Name of Candidate		Circuit chosen	**B** or **C**

Candidate instructions: Complete all sections of this test results sheet

CYCLE LIGHTS – SYSTEM TESTING (CONTINUED)

- First set your multimeter to the 200 mA dc range.
- Then connect between the battery and battery snaps.
- Complete the circuit between battery and circuit.
- Turn on SW1 and SW2.
- Adjust the variable resistor until the multimeter reads 7 mA.
- You are now ready to complete the readings below.

Power off system tests		
Connection to be measured	**Expected measurement**	**Actual measurement**
Resistance between +Vcc and 0 V on circuit board with SW1 and SW2 closed (ON)	7 kΩ	
Power on system tests		
Test conditions - voltage and current	**Expected measurement**	**Actual measurement**
Voltage between +Vcc and 0 V on circuit board	+9 V	
Voltage across non flashing LED when lit	1·7 V	

Name of Candidate

Candidate instructions: Complete only the section of this test results sheet which applies to your circuit.

CYCLE LIGHTS – SYSTEM TESTING (CONTINUED)

Expected results for **Circuit A**

SW1	SW2	LED 1	LED 2	LED 3 and 4
OFF	OFF	OFF	OFF	OFF
OFF	ON	OFF	OFF	OFF
ON	OFF	OFF	ON	OFF
ON	ON	ON flashing	ON	ON flashing at same time

Actual results for **Circuit A**

SW1	SW2	LED 1	LED 2	LED 3 and 4
OFF	OFF			
OFF	ON			
ON	OFF			
ON	ON			

Expected results for **Circuit B or C**

SW1	SW2	Left hand LED	Mid LED	Right hand LED
OFF	OFF	OFF	OFF	OFF
OFF	ON	OFF	OFF	OFF
ON	OFF	OFF	ON	OFF
ON	ON	ON flashing	ON	ON flashing

Actual results for **Circuit B or C**

SW1	SW2	Left hand LED	Mid LED	Right hand LED
OFF	OFF			
OFF	ON			
ON	OFF			
ON	ON			

Name of Candidate

Date

Candidate instructions: Complete all sections of this evaluation sheet

CYCLE LIGHTS – EVALUATION SHEET

1. Did your Project work as expected? _____

   If your Project did not work as expected explain below what was different and why did the circuit work that way.

   _____

   _____

   _____

   _____

2. If you were to do this Project again, would you make the same design choices?

   Yes ☐ No ☐

3. If you answered 'No' explain what you would do differently.

   _____

   _____

   _____

   _____

4. What was the most difficult part of the Project for you?

   _____

   _____

5. How could this difficult part have been made easier?

_____

_____

6. What have you learned from doing this Project?

_____

_____

A6. Staff guide – design notes

Project options

The candidate has a choice of circuit layout, the basic circuitry is similar but the number of logic gates used varies from 3 in Circuit A down to one in Circuit C. Correspondingly the marks available for each circuit in the categories **Complexity** and **Value** (refer to P24 Assessment of Project – Marking scheme and P16 Grading and Marking – detailed information) are determined by the circuit chosen eg

Assessable element	**Mark range**		
Complexity	11 – 15	9 – 10	7 – 9
Value	11 – 15	9 – 10	7 – 9
	Circuit A	Circuit B	Circuit C

Thus for these categories the marks are determined by the circuit chosen; this does not affect scoring in other categories.

For Circuit A the **total** marks available for the above assessable elements are (minimum and maximum) 22 – 30

For Circuit B the **total** marks available for the above assessable elements are (minimum and maximum) 18 – 20

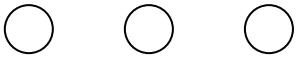
For Circuit C the **total** marks available for the above assessable elements are (minimum and maximum) 14 – 18

The teacher or lecturer should make this clear to the candidate prior to the project being started. However it should be noted that the variation in circuit **complexity**, and therefore **value**, does not affect the grading for the assessable element **system/circuit simulation and/or test simulation**.

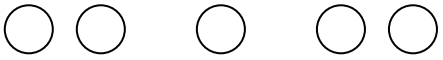
During the simulation phase, depending on the software package used, the flashing LEDs may only be shown at either on or off on the printout but can be viewed as flashing on the monitor screen. It is sufficient for the lecturer or teacher to write on the printout verifying that the LEDs were observed flashing.

The varied layouts allow for a greater range of candidate capabilities to be catered for in the sense that a circuit can be selected for all ability levels. However there is further scope for candidates to show genuine ingenuity within the scope of their abilities and teachers/lecturers can prompt students to amend the layout in Circuits B and C eg

3 led light unit Basic arrangement



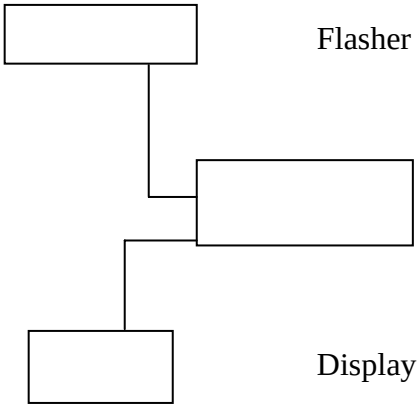
5 led light unit Complex arrangement



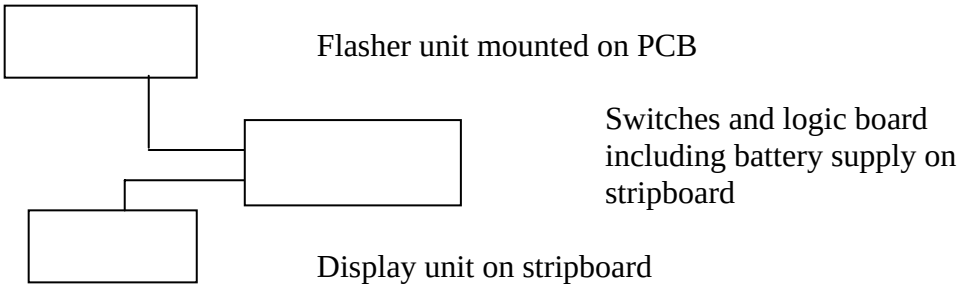
The candidate should choose the circuit from the layout diagrams provided in conjunction with the degree of difficulty indicated. The candidate can then make an informed decision which they should get confirmed by their teacher or lecturer before commencing construction. Clear step by step instructions have been incorporated alongside all the assessment pro formas so that supervising staff can spend more time supervising the actual work of the candidates rather than coping with multiple demands for guidance in relation to candidate documentation.

The circuit itself is very robust and by using a PP3 (9 V) battery rather than a low voltage power supply the risk of damaging the IC's and transistors is eliminated. By replacing the BC184L with the BFY51 transistor allows the less dexterous candidate more leeway during soldering before component damage is sustained (and being a physically larger component a heat sink can be attached to each leg prior to soldering). The circuit uses components already used in previous Units reducing the cost overheads associated with this course.

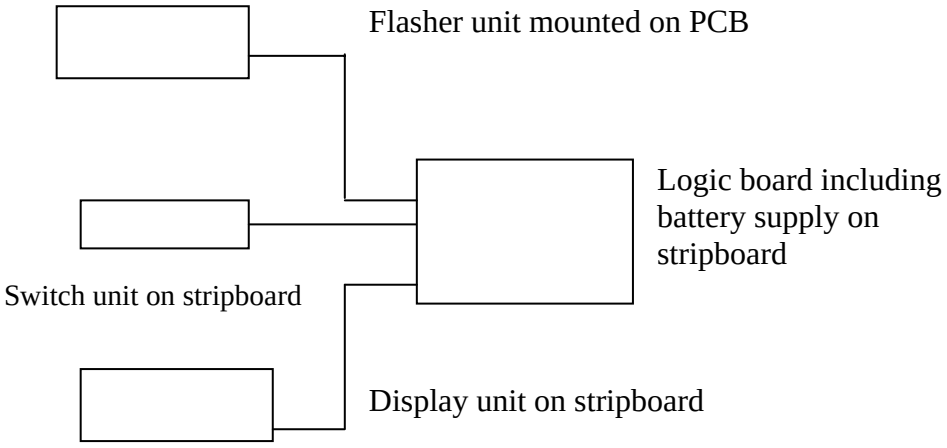
Block diagram – Circuit A



Block diagram – Circuit B

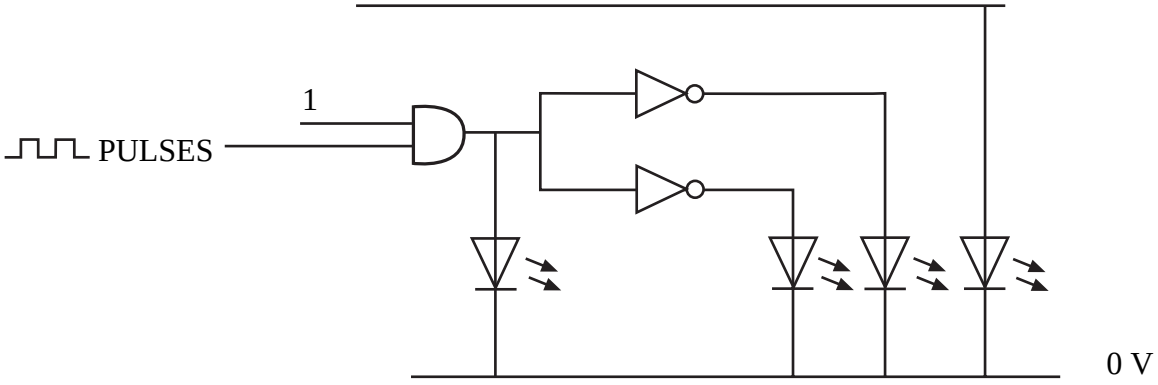


Block diagram – Circuit C

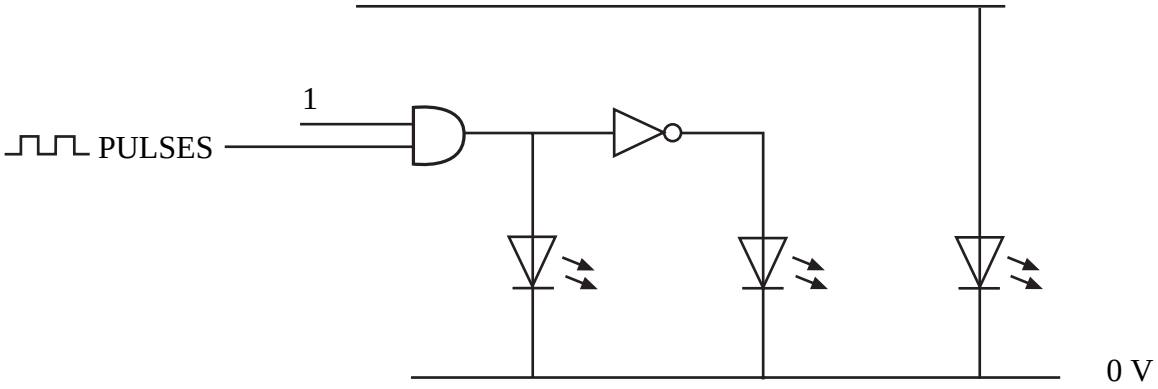


Logic diagrams

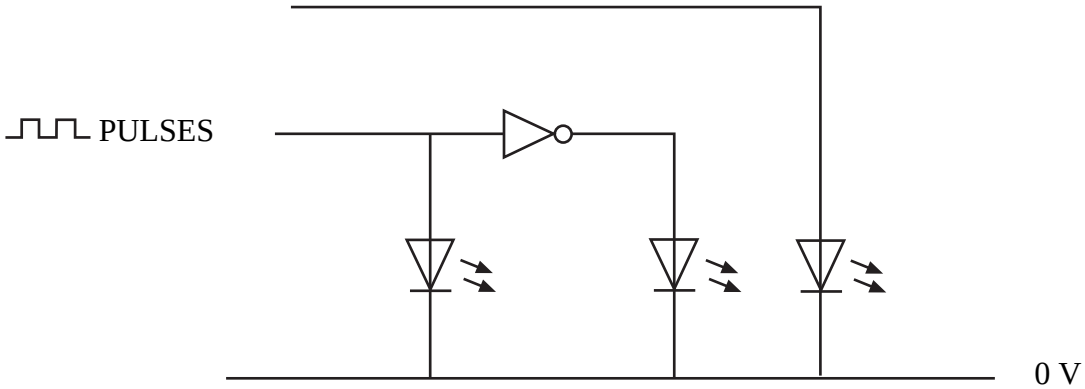
Circuit A



Circuit B



Circuit C



The parts of the project circuit ie flasher unit, logic unit, switch unit and lighting unit are to be constructed on stripboard. Each unit must be linked using labelled (at each end) and colour coded wires which are held together by some form of binding. Candidates can select the type of binding however it must be functional and not a random or irrational choice. There is considerable flexibility in how various boards are linked, two separate looms can be made up or a single loom with a break out at the discretion of the supervising lecturer or teacher. Candidates are strongly advised to mount the ICs on IC sockets and to use heat sinks when soldering the transistors to the stripboard.

Course Project typical parts list

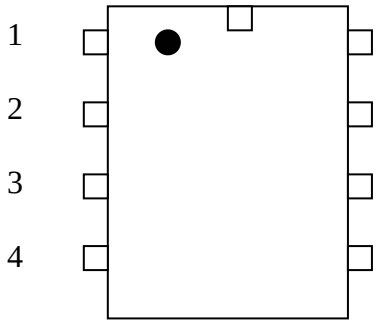
The following lists typical components and materials required for each candidate. The components are all readily available from a number of distributors and are normally purchased in bulk with components, terminals, pins, tie wraps and connectors in packs of various sizes, stripboard in small sheets and wire and sleeving on reels. Some components and materials may be reused after the external assessment verification process has been completed.

	Description of Part	**Quantity**
1.	Black insulated single strand, solid conductor wire 1/0.6 mm	as required
2.	Red insulated single strand, solid conductor wire 1/0.6 mm	as required
3.	Blue insulated single strand, solid conductor wire 1/0.6 mm	as required
4.	Orange insulated single strand, solid conductor wire 1/0.6 mm	as required
5.	16/0.2 mm black stranded wire	as required
6.	16/0.2 mm red stranded wire	as required
7.	Integrated circuit type 74HC04N	1
8.	Integrated circuit type 74HC08	1
9.	14 pin DIL I.C. socket (turned pin)	2
10.	9 volt PP3 battery	1
11.	Battery snaps – PP3	1
12	Cable markers 1, black	as required
13.	Cable markers 2, red	as required
14.	Cable markers 3, orange	as required
15.	Cable markers 4, yellow	as required
16.	Cable markers 5, green	as required
17.	Cable markers 6, blue	as required
18.	Cable markers 7, violet	as required
19.	Cable markers 8, white	as required
20.	Continuous sleeving, silicon rubber, 6 mm black	as required
21.	Cable ties (tie-wraps), white, 100 mm x 2.5 mm	as required
22.	Spiral cable wrap	as required
23.	PCB terminal pins, single sided, press fit, 1 mm hole	8 or 10
24.	Metal film resistor (0.25W) 560R	3
25.	Metal film resistor (0.25W) 270R	2
26.	Metal film resistor (0.25W) 1K0	1
27.	Variable resistor 50K	1
28.	Switch SPDT (may be PCB or panel mounting)	2
29.	Transistor BFY51	2 or 3
30.	Red LED, 5 mm standard diffused	3 or 4
31.	Stripboard, 0.1" pitch	as required

A7. Additional Information

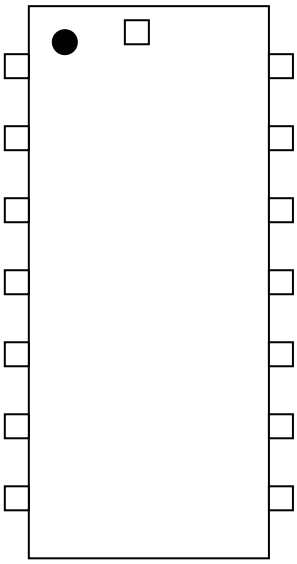
Pin out diagrams for the Integrated Circuits and transistors

NE 555



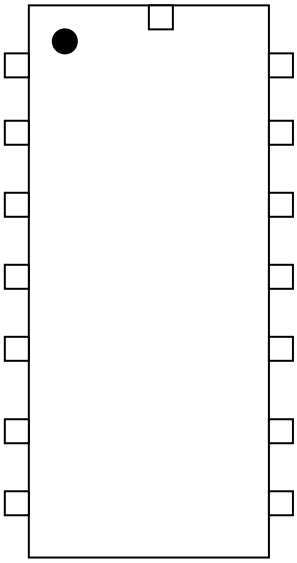
3 timer output

74HC04 hex inverter



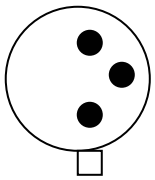
1 input to NOT gate
2 output from NOT gate
3 input to NOT gate
4 output from NOT gate
ground
Vcc
9 input to NOT gate
8 output from NOT gate

74HC08 AND gate



ground
Vcc
13 input to AND gate
12 input to AND gate
11 output from AND gate
10 input to AND gate
9 input to AND gate
8 output from AND gate

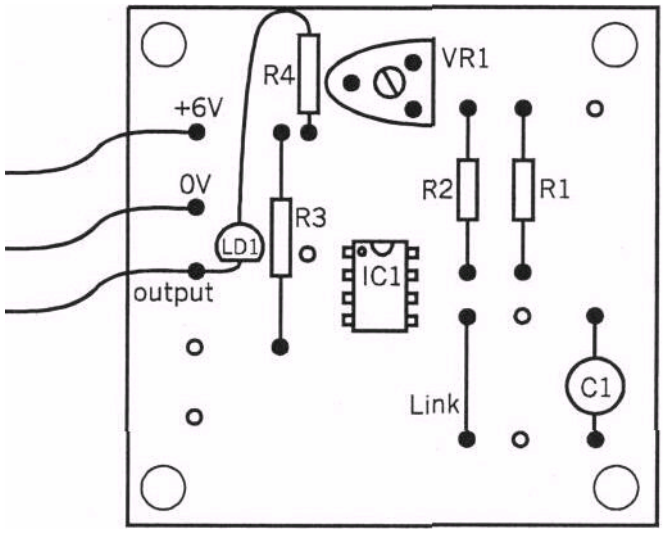
Pin out diagrams for the Integrated Circuits and transistors (continued)



Collector **BFY51**
Base
Emitter

TO18 casing Emitter tagged

Bottom view of **LED** – flat side leg connects to the 0 V side of circuit.



555 Timer PCB Circuit assembled as part of Practical Electronics Unit.

Remember to replace C1 47 μF resistor with a 100 μF capacitor.

Construction Schedule

1. Collect your 555 timer PCB circuit.

2. Replace the 47 µF resistor with a 100 µF capacitor.

3. Construct the main circuit board:

    i. solder the variable resistor
    ii. the 2 switches
    iii. position the two IC holders cut the tracks and solder into place
    iv. the non flashing LED and resistor
    v. the flashing LED from IC1
    vi. the flashing LED(s) from IC2.

4. Position the timer unit and the LEDs unit.

5. Fix all three units onto backing board.

6. Locate trunking or measure lengths for colour coded wiring looms.

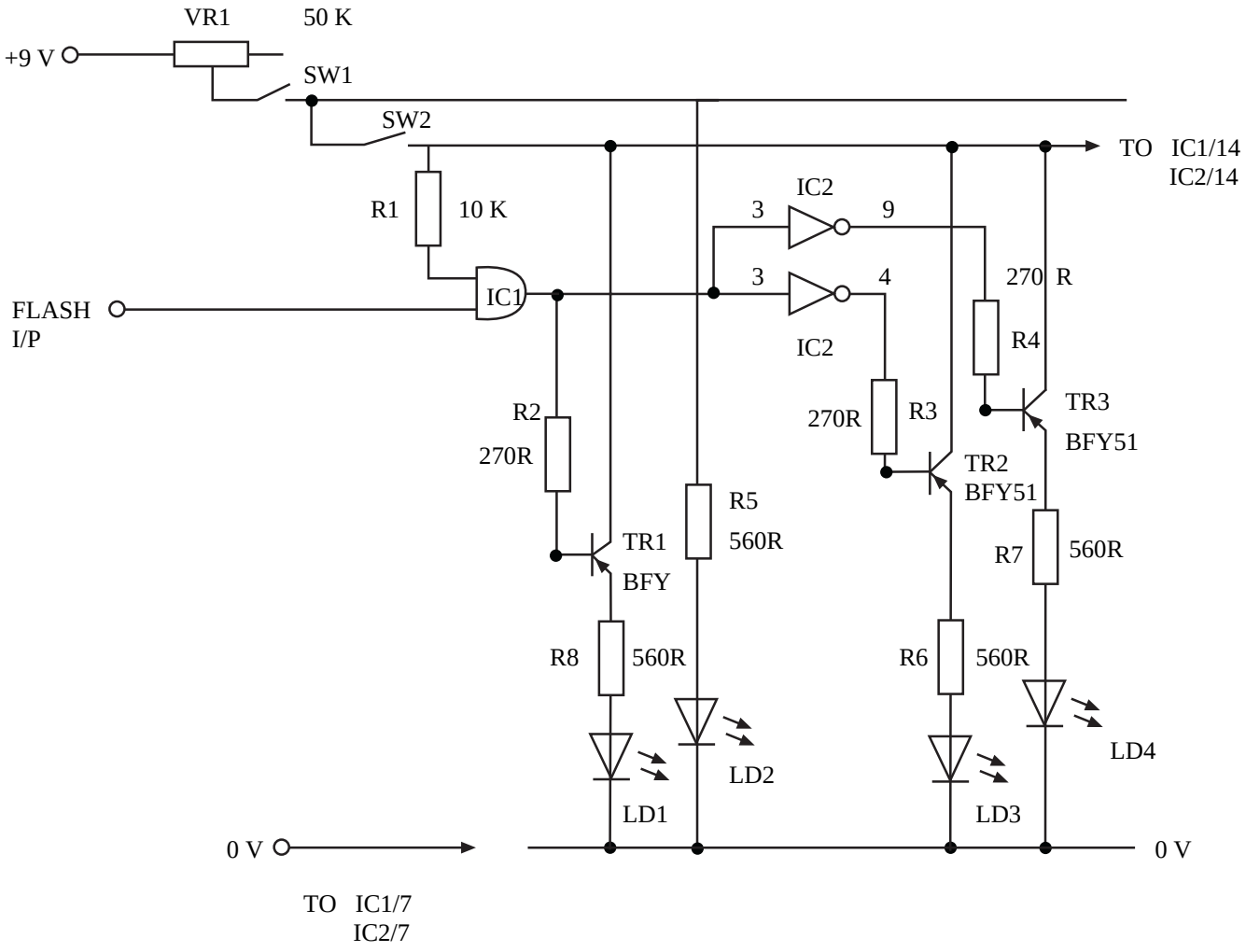
7. Connect the thee units but number the wires **before** connection.

8. Connect battery snaps.

9. Connect timer circuit.

10. Connect LED unit.

CIRCUIT DIAGRAM A



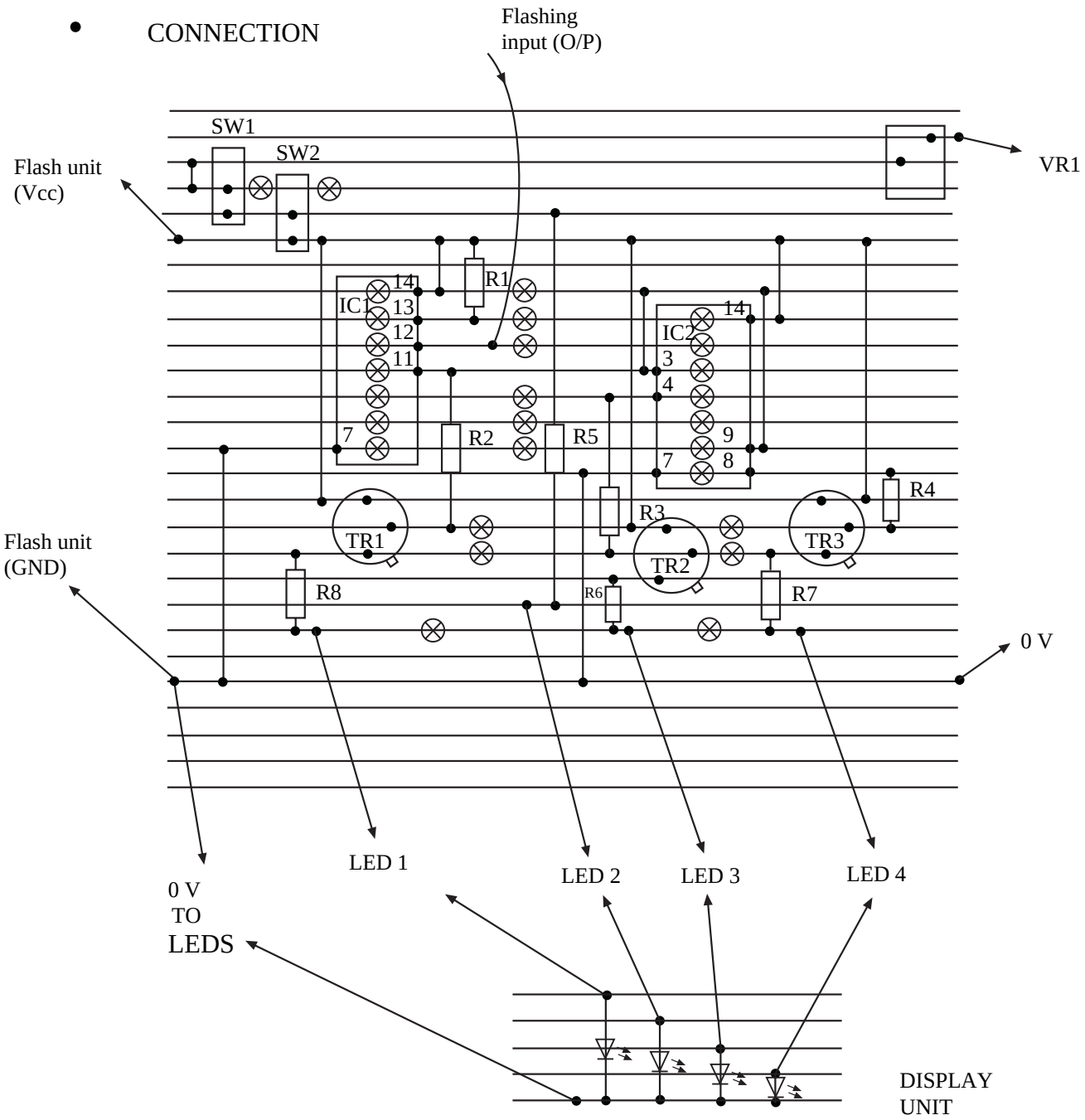
LD1/2/3/4 5 mm STANDARD LED

LAYOUT DIAGRAM – CIRCUIT A

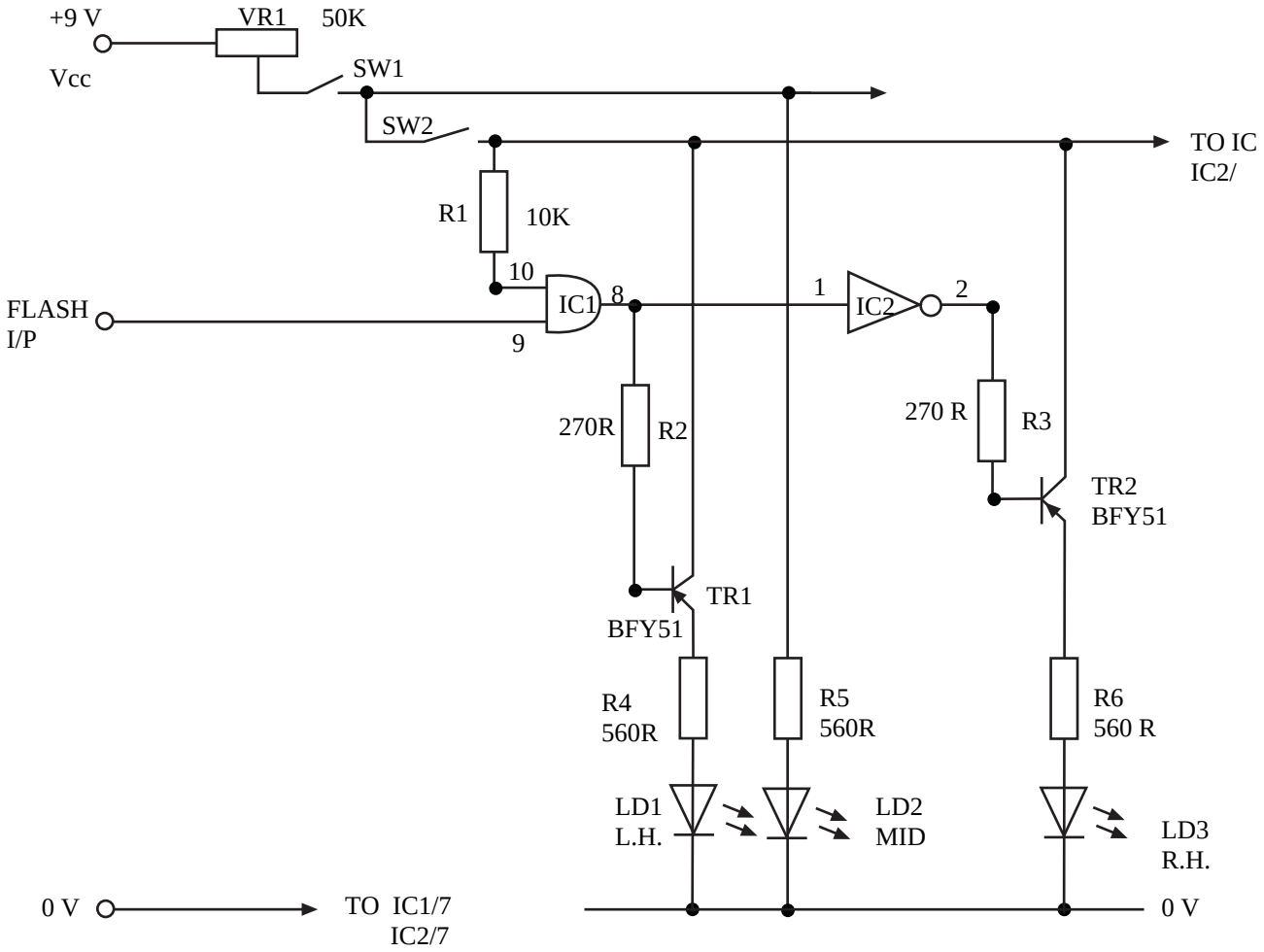
TOP VIEW (COMPONENT SIDE)

⊗ TRACK CUT

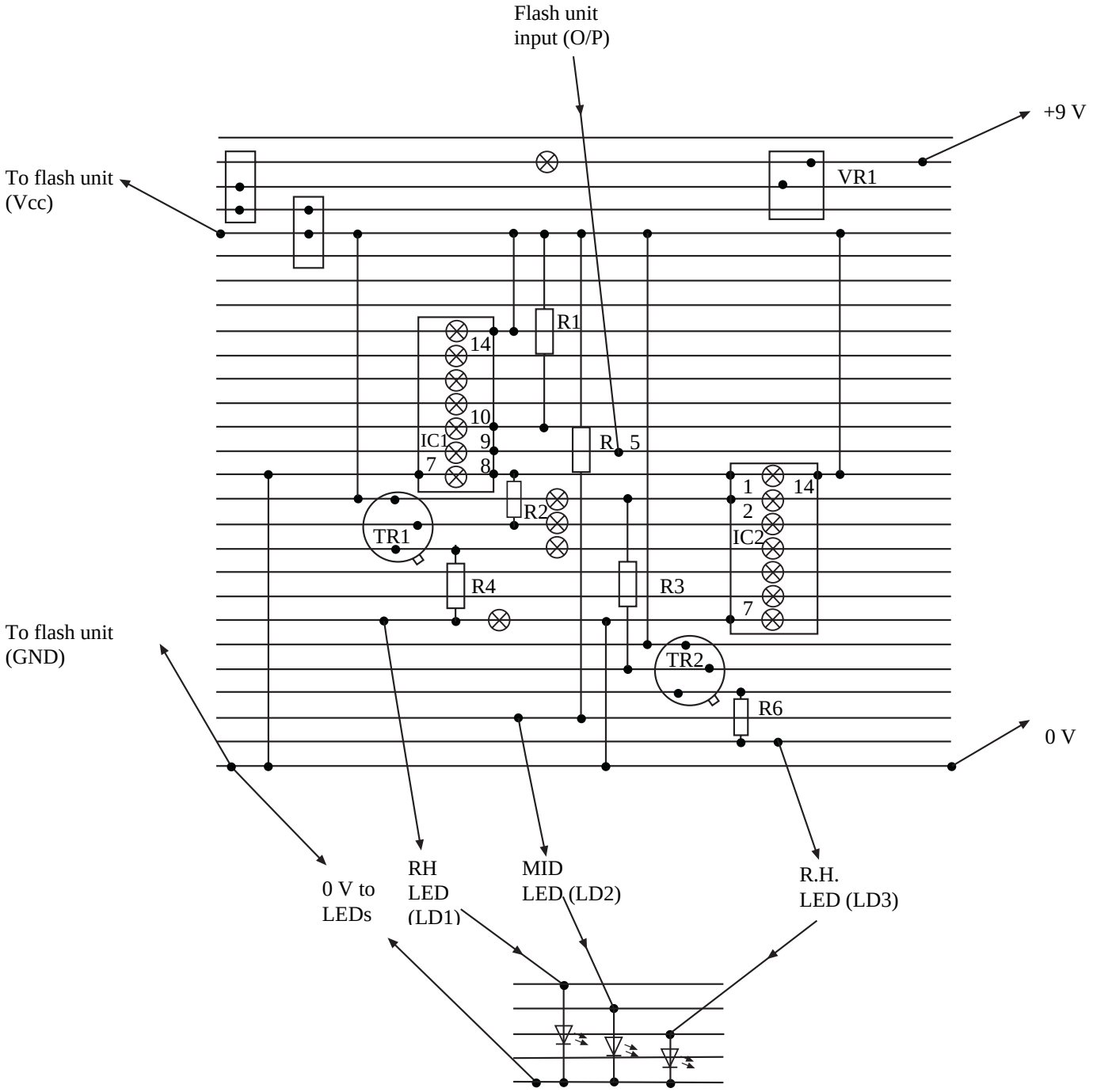
● CONNECTION



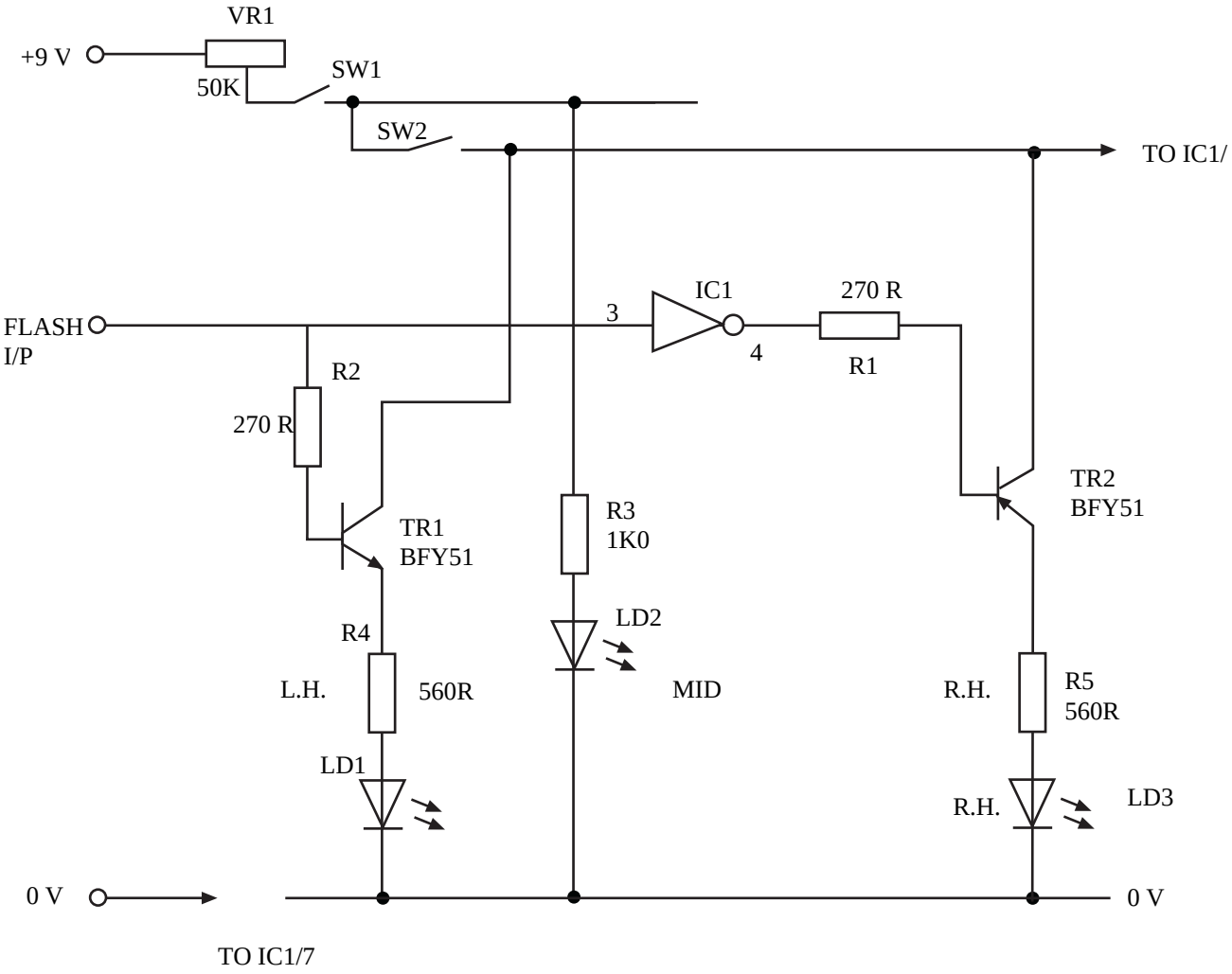
CIRCUIT DIAGRAM B



LAYOUT DIAGRAM – CIRCUIT B



CIRCUIT DIAGRAM C



LAYOUT DIAGRAM – CIRCUIT C