basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

ELECTRICAL TECHNOLOGY (POWER SYSTEMS)

GUIDELINES FOR PRACTICAL ASSESSMENT TASKS (PAT)

GRADE 12

2024

These guidelines consist of 50 pages.

TABLE OF CONTENTS

1. INTRODUCTION

The 18 Curriculum and Assessment Policy Statements subjects which contain a practical component all include a practical assessment task (PAT). These subjects are:

- AGRICULTURE: Agricultural Management Practices, Agricultural Technology
- ARTS: Dance Studies, Design, Dramatic Arts, Music, Visual Arts
- SCIENCES: Computer Applications Technology, Information Technology, Technical Sciences; Technical Mathematics
- SERVICES: Consumer Studies, Hospitality Studies, Tourism
- TECHNOLOGY: Civil Technology, Electrical Technology, Mechanical Technology and Engineering Graphics and Design

A practical assessment task (PAT) mark is a compulsory component of the final promotion mark for all candidates offering subjects that have a practical component and counts 25% (100 marks) of the end-of-the-year examination mark. The PAT is implemented across the first three terms of the school year. This is broken down into different phases or a series of smaller activities that make up the PAT. The PAT allows for learners to be assessed on a regular basis during the school year and it also allows for the assessment of skills that cannot be assessed in a written format, e.g. test or examination. It is therefore important that schools ensure that all learners complete the practical assessment tasks within the stipulated period to ensure that learners are resulted at the end of the school year. The planning and execution of the PAT differs from subject to subject.

Practical assessment tasks are designed to develop and demonstrate a learner's ability to integrate a variety of skills to solve a problem. The PAT also makes use of a technological process to inform the learner what steps need to be followed to derive a solution for the problem.

The PAT consists of four simulations and a practical project. The teacher may choose any ONE of the practical projects and any TWO simulations available for POWER SYSTEMS. For the first simulation to be completed in term 1, the teacher must choose between Simulation 1 and Simulation 2. For the second Simulation to be completed in term 2, the teacher must choose between Simulation 3 and Simulation 4.

The teacher must apply assessment on an ongoing basis at the same time that the learner is developing the required skills. TWO simulations should be completed by the learners, in addition to the manufacturing of a practical project.

The PAT incorporates all the skills the learner has developed throughout the year. The PAT ensures that all the different skills will be acquired by learners on completion of practical work, as well as the correct use of tools and instruments.

Requirements for presentation

A learner must present the following:

- PAT file with all the evidence of simulations, design and prototyping. A copy of the PAT 2024 cover page. The relevant simulations and assessment sheets should be copied and handed to each learner to include in the file.
- Practical project with:
  - Enclosure:
    - The file must include a design.
    - The enclosure and the design must match.
    - No cardboard boxes are allowed.
    - Plastic wooden and metal enclosures are acceptable.
    - Enclosures that are manufactured and/or assembled by the learners are preferred.
    - The enclosure should be accessible for scrutiny inside.
    - Lids that are secured are preferred.
  - Circuit board:
    - The file should include the PCB design.
    - The PCB must be mounted inside the enclosure in such a manner that it can be removed for scrutiny. Alternatively, inspection can be made from the bottom in cases where translucent (see-through) enclosures are used.
    - Switches, potentiometers, connectors and other items must be mounted.
    - Wiring must be neat and bound/wrapped.
    - Wiring must be long enough to allow for the PCB to be removed and inspected with ease.
  - Logo and name:
    - The file should contain the logo and name design and specification plate.
    - Logo, specification plate and name must be prominent on the enclosure.
    - The logo/specification plate must be affixed in a permanent manner – painted, glued or stuck on with vinyl.

The PAT will have a financial impact on the school's budget and school management teams are required to make provision to accommodate this particular expense.

PAT components and other items must be acquired timeously, for use by the learners, before the end of the first term at the start of the academic year.

It is the responsibility of the HOD to ensure that the teacher is progressing with the PAT from the start of the school year.

Provincial departments are responsible for setting up moderation timetables and consequently PATs should be completed in time for moderation.

2. TEACHER GUIDELINES

2.1 How to administer PATs

Teachers must ensure that learners complete the simulations required for each term. The project should be started in January in order to ensure its completion by August. In instances where formal assessments take place, the teacher has to assume the responsibility thereof.

The PAT should be completed during the FIRST THREE TERMS and must be ready at the start of PAT moderation. Teachers must make copies of the relevant simulations and hand them to learners at the beginning of each term.

The PAT must NOT be allowed to leave the workshop and must be kept in a safe place at all times when learners are not working on them.

The weightings of the PAT must be adhered to and teachers are not allowed to change weightings for the different sections.

2.2 How to mark/assess the PATs

The PAT for Grade 12 will be set and assessed internally, but moderated externally. All formal assessment will be done by the teacher.

The teacher is required to produce a working model and model answer file that sets the baseline for assessment at a Highly Competent Level for every project choice exercised by the learners. This file must include all the simulations with answers the teacher has done him/herself. The teacher will use the model answers and project to assess the simulations and projects of the learners.

Once a facet sheet has been completed by the teacher, assessment will be deemed to be complete. No re-assessment will be done once the facet sheets have been completed and captured by the teacher. Learners must ensure that the work is done to the required standard before the teacher finally assesses the PAT during each stage of completion.

2.3 PAT Programme of Assessment (PAT PoA)

The programme of assessment (PoA) of the PAT is as follows:

TIME FRAME	ACTIVITY	RESPONSIBILITY
	Preparation for PAT 2024	Teacher – Builds the models and works out the model answers for the simulations. Identifies shortages in tools, equipment and consumable items for simulations that must be procured. SMT – Receives procurement requests from teachers and processes payments for the acquisition of required items
January–March 2024	Simulation 1	Teacher – Copies and hands out simulations Learners – Complete simulations Teacher – Assesses simulations HOD – Checks if tasks have been completed and marked by the teacher before the holidays
January 2024	PAT project – procurement	Teacher – Obtains quotations for PAT projects Principal – Approves PAT procurement for PAT projects Teacher – Ensures that PAT projects are ordered and delivered HOD – Checks in on teacher to see if the process is adhered to
February 2024	PAT project – learners commence with project	Teacher – Ensures that there is secure storage for PAT projects Teacher – Hands out and takes in PAT projects Teacher – Includes practical sessions for learners to complete the PAT project every week Learners – Commence with completion of the PAT project HOD – Checks in on teacher to ensure that practical workshop sessions take place on a weekly basis
April–June 2024	Simulation 2	Teacher – Copies and hands out simulations Learners – Complete simulations Teacher – Assesses simulations HOD – Checks if tasks have been completed and marked by the teacher before the holidays
April–June 2024	Moderation of Simulation 1	District subject facilitator/subject specialist will visit the school and moderate Simulation 1 10% of learners' work is moderated
April–June 2024	PAT project – learners continue with project	Teacher – Ensures that there is secure storage for PAT projects Teacher – Hands out and takes in PAT projects Teacher – Includes practical sessions every week for learners to complete the PAT project Learners – Continue with completion of the PAT project HOD – Checks in on teacher to ensure that practical workshop sessions take place on a weekly basis
July holidays 2024	PAT intervention	Learners that are behind on the PAT are required to complete the project during these holidays.
July–August 2024	Moderation of Simulation 2	District subject facilitator/subject specialist will visit the school and moderate Simulation 2 – different learners from the previous term 10% of learners' work is moderated
July–August 2024	PAT project – completion	Teacher – Ensures that there is secure storage for PAT projects Teacher – Hands out and takes in PAT projects Teacher – Completes the PAT project with learners and compiles the PAT file Learners – Complete the PAT project and file HOD – Checks to see that 100% of the PAT files and projects are completed and assessed
September–October 2024	PAT moderation	PAT projects are moderated by subject facilitators/subject specialists from the province and learners are available to demonstrate skills 10% of learners are moderated randomly

2.4 Moderation of PATs

Provincial moderation of each term's simulations will start as early as the following term. Simulation 1 should be moderated as soon as the second term starts. Similarly, Simulation 2 will be moderated in July. The project will, however, only be moderated on completion.

During moderation of the PAT, the learner's file and project must be presented to the moderator.

The moderation process is as follows:

- During moderation, learners are randomly selected to demonstrate the different simulations. All four simulations will be moderated.
- The teacher is required to build an exemplar model of each project type chosen for the school.
- This model must be on display during moderation.
- The teacher's model forms the standard of the moderation at Level 4 (Highly Competent).
- Level 5 assessments must exceed the model of the teacher in skill and finishing.
- Learners who are moderated will have access to their files during moderation and may refer to the simulations they completed earlier in the year.
- Learners may NOT ask assistance from other learners during moderation.
- All projects and files must be on display for the moderator.
- If a learner is unable to repeat the simulation or cannot produce a working circuit during moderation, marks will be deducted and circuits assessed as not being operational.
- The moderator will randomly select no fewer than two projects (not simulations) and the learners involved will have to explain how the project was manufactured.
- Where required, the moderator should be able to call on the learner to explain the function and principles of operation, and request the learner to exhibit the skills acquired through the simulations for moderation purposes.
- On completion the moderator will, if needed, adjust the marks of the group upwards or downwards, depending on the outcome of moderation.
- Normal examination protocols for appeals will be adhered to, if a dispute arises from adjustments made.

2.5 Absence/Non-submission of tasks

The absence of a PAT mark in Electrical Technology without a valid reason: The learner will be given three weeks before the commencement of the final end-of-year examination to submit the outstanding task. Should the learner fail to fulfil the outstanding PAT requirement, such a learner will be awarded a zero (0) for that PAT component.

2.6 Simulations

Simulations are circuits, experiments and tests/tasks which the learner will have to build, test and measure and practically do as part of the development of practical skills. These skills have to be illustrated to the external moderator that visits the school at intervals during the school year.

Teachers who make use of simulation programs on a computer may use them for the learners to practise on. However, it is required that the circuit be built using real components and that measurements be made with actual instruments for the purposes of assessment and moderation.

The correct procedure for completing simulations is outlined below for teachers and school management teams who are responsible for the implementation of the PAT in Electrical Technology.

STEP 1: The teacher will choose simulations from simulations that are provided.
STEP 2: Compile a list of the components needed for every simulation. Add extra components as these items are very small and you will need extras, as these items get lost/damaged very easily when learners work on them.
STEP 3: Contact three different electronics component suppliers for comparative quotations.
STEP 4: Submit the quotations to the SMT for approval and procurement of the items.
STEP 5: Place the components in storage. Collate items for each simulation, thus making it easier to distribute and use during practical sessions. Ensure that different values of components do not mix, as this would lead to components being used incorrectly and this could damage the component and in extreme cases, the equipment used.
STEP 6: Copy the relevant simulations and hand them out to learners at the start of the term.

Teachers are allowed to adjust circuits and component values to suit their environment/resource availability.

Teachers are required to develop a set of model answers in the teacher's file. Moderators will use the teacher's model answers and artefacts when moderating.

2.7 Projects

The projects are construction projects teachers can choose for their learners. These projects are based on proven circuits provided by schools and subject advisors. The projects are based on working prototypes and require careful construction in order for it to operate correctly.

Projects vary in cost and teachers must ensure that the projects chosen fall within the scope of the school's budget.

Once the teacher has decided on a circuit, he/she must construct the prototype. Thereafter, copies of the provided circuit can be made and distributed to learners. They MUST redraw these circuits in their files correctly.

The description of the operation of the circuits is NOT complete. Learners are required to interrogate the function of the components in the provided circuit. Learners should elaborate on the purpose of components in the circuit. It is recommended that learners investigate similar circuits available on the internet and in the school library or workshop reference books.

2.8 Working mark sheet

(A working Excel file is provided with this PAT.)

PAT mark sheet		Term 1	Term 2	Project		Total = Term 1 + Term 2 + Project	Mark out of 100	Moderated Mark
		Simulation 1	Simulation 2	Design and Make Part 1	Design and Make Part 2			
No.	Name of Learner	50	50	120	30	250		
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								
13.								
14.								
15.								
	Total							
	Average							

Teacher Name: ____________________ Principal Name: ____________________ Moderator Name: __________________

Signature: ________________________ Signature: ________________________ Signature: ________________________

Date: ____________________________ Date:____________________________ Date:____________________________

3. LEARNER GUIDELINES

3.1 PAT 2024 COVER PAGE

(Place this page at the front of the PAT.)

Department of Basic Education Grade 12
CAPS for Technical High Schools Practical Assessment Task – Electrical Technology

Time allowed: Terms 1–3 (2024)

Learner Name: ______________________________________

Class: ______________________________________

School: ______________________________________

Specialisation: POWER SYSTEMS

Complete Simulation 1 or 2 in the first term and Simulation 3 or 4 in the second term.

Project (Write the name of the project): ______________________________

Evidence of moderation:

NOTE:
When the learner evidence selected has been moderated at school level, the table will contain evidence of moderation. Provincial moderators will sign the provincial moderation and only sign if re-moderation is needed.

Moderation	Signature	Date	Signature	Date
School-based				
District moderation				
Provincial moderation			Re-moderation	

Mark allocation

PAT Component	Maximum Mark	Learner Mark	Moderated Mark
Simulation 1	50		
Simulation 2	50		
Design and Make Project – Circuit	120		
Design and Make Project – Enclosure	30		
Total	**250**		

3.2 Instructions to the learner

- The practical assessment task counts 25% of your final promotion mark.
- All work produced by you must be your own effort. Group work and co-operative work are NOT allowed.
- The practical assessment task must be completed over three terms.
- The PAT file must contain TWO simulations and a practical project.
- Calculations should be clear and include units. Calculations should be rounded off to TWO decimals. SI units should be used.
- Circuit diagrams can be hand-drawn or drawn on CAD. NO photocopies or scanned files are allowed.
- Photos are allowed and may be in colour or greyscale. Scanned photos and photocopies are allowed.
- This document must be placed inside your PAT file together with the other evidence.
- Learners with identical photos will be penalised and receive zero for that section.

3.3 Declaration of Authenticity (COMPULSORY)

Declaration:

I ________________________________ (name) herewith declare that the work represented in this evidence is entirely my own effort. I understand that if proven otherwise, my final results may be withheld.

________________________________ ____________
Signature of learner Date

4. SIMULATIONS

4.1 Simulation 1: RLC parallel circuit

Name of learner: ___________________________________	Mark ______ / **50**
Class: _______ Date completed: _________________	
Date Assessed: _________________	Assessor Signature: ____________________
Date Moderated: _________________	Moderator Signature: _________________________

4.1.1 **Purpose:**

- To build an RLC parallel circuit using discrete components and to compare the measured and calculated values of the RLC parallel circuit
- To observe the effect of changing the frequency in the circuit

4.1.2 **Required resources:**

COMPONENTS	TOOLS AND EQUIPMENT
R_1 = 22 Ω resistor C_1 = 10 µF capacitor 220- 6- 0- 6 V transformer OR L_1 = 30-45 mH Inductor	Multimeter Function generator Leads Breadboard Side cutters Pair of pliers Oscilloscope

4.1.3 **Procedure:**

Build the RLC parallel circuit in FIGURE 4.1.4 on the breadboard using the components provided.
Connect the circuit to a function generator.
Set the input signal voltage of the function generator to 2,5 V with a frequency of 50 Hz.

4.1.4 **Circuit diagram:**

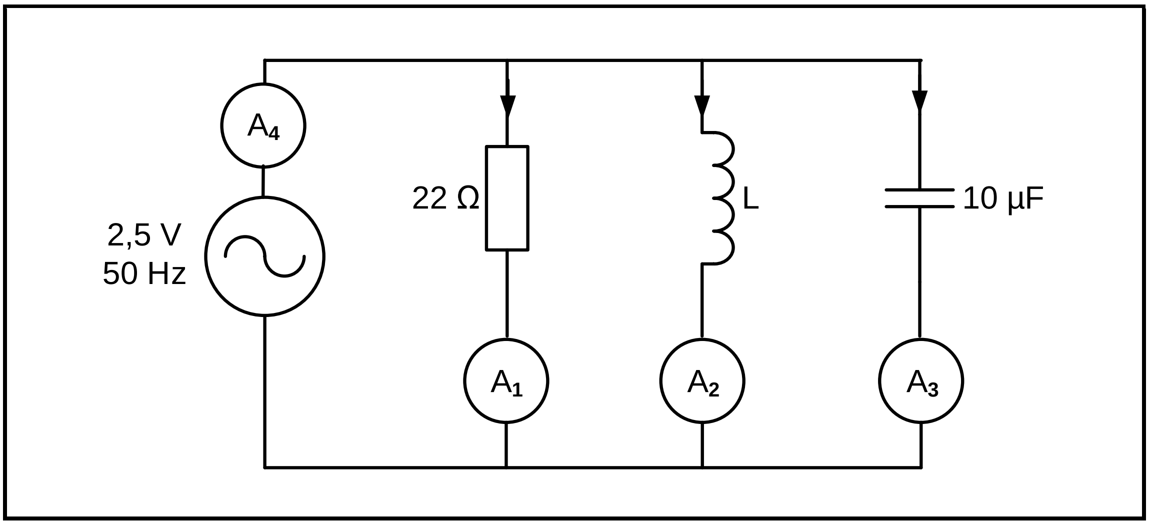


FIGURE 4.1.4: RLC PARALLEL CIRCUIT DIAGRAM

4.1.5 Measure the current through the:

(a) Resistor____________ (Ammeter 1) (1)

(b) Inductor_____________ (Ammeter 2) (1)

(c) Capacitor _____________ (Ammeter 3) (1)

(d) Circuit _____________ (Ammeter 4) (1)

4.1.6 Calculate the total current through the circuit using the measured values.

____

____

________________________ (3)

4.1.7 Calculate the following, using the appropriate formulae, when the frequency is 50 Hz.

(a) Capacitive current (I_c)

____

____

________________________ (3)

(b) Inductive current (I_L)

____

____

________________________ (3)

(c) Current through the resistor (I_R)

____

____

________________________ (3)

(d) Power factor

____

____

________________________ (3)

4.1.8 Draw the phasor diagram of the circuit in FIGURE 4.1.4. Use the space provided below. (5)

4.1.9 Increase the frequency of the signal generator and measure the values of I_R, I_L and I_C as shown in the table below.

F(Hz)	I_R	I_L	I_C
700			
900			
1 100			
1 300			

(12)

4.1.10 Write your observation when the frequency is increased. (2)

4.1.11 Is the circuit capacitive or inductive? ______________________
Motivate your answer.

____
____ (2)

Theory Simulation 1: [40]

NOTE: Learner competency in this context will mean the following:
(This is done for easy assessment when using a rubric.)

Not yet competent	Have not met the requirements and will be given another opportunity for reassessment. • Be precise about what they did wrong, or the areas they need to improve in. • Clearly explain the level of skill they need to achieve to be assessed as 'competent'. • Indicate whether part or all of the assessment events will need to be repeated.
Competent	Have the necessary ability, knowledge or skill to complete the task successfully. • Acceptable and satisfactory, though not outstanding.
Outstanding	Went beyond expectation (neatness, proficiency – high degree of skills, expertise)

FACET SHEET FOR SIMULATION 1

Task description	Mark allocation (tick the appropriate level next to the task indicated)				Allocation of marks
	Not yet competent after reassessment of certain/ all parts of the task	**Competent after reassessment of certain parts of the task**	**Competent**	**Outstanding (Highly competent)**	
Building the RLC circuit	The learner was given opportunities to rebuild the circuit after the teacher intervened in identifying and rectifying mistakes. **(1)**	The learner was given opportunities to rebuild part of the circuit after the teacher intervened in identifying and rectifying a few mistakes. **(2–3)**	The learner correctly built the circuit without the guidance of the teacher. **(4–5)**	The learner correctly built the circuit without the guidance of the teacher and went beyond expectations and with high proficiency. **(6)**	$\overline{6}$
Safety aspects	The learner was timeously reminded to apply safety rules, regulation and correct procedure when using tools and instruments. **(0)**	The learner was sometimes reminded to apply safety rules, regulation and correct procedure when using tools and instruments. **(1)**	The learner applied safety rules, regulation and correct procedure when using tools and instruments to wire the circuits without being reminded by the teacher. **(2)**		$\overline{2}$
Attitude/ Behaviour/ Conduct	The learner was reluctant to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice even after being cautioned/reprimanded. **(0)**	The learner was reluctant to a certain degree to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice. **(1)**	The learner demonstrated willingness to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice. **(2)**		$\overline{2}$
				Rubric **Theory** **Total Simulation 1**	10 $+ \quad /40$ $= \quad /50$

4.2 Simulation 2: Three-phase motor test

Name of learner: ______________________________	Mark	______ / **50**
Class: ______ Date completed: ______________		
Date Assessed: ______________	Assessor Signature: ________________	
Date Moderated: ______________	Moderator Signature: ______________________	

4.2.1 **Purpose:**

To conduct a visual, mechanical and electrical inspection/test on a three-phase motor using measuring instruments

4.2.2 **Required resources:**

TOOLS/INSTRUMENTS	MATERIALS
Three-phase AC electrical motor Multimeter Insulation tester (megger)	

4.2.3 **Procedure:**

Use the list below to conduct an inspection/test on an AC three-phase electrical motor.

Then complete the results in the table below.

ACTIVITY A

Complete the details on the nameplate of the motor that is tested. The information must be written as it appears on the nameplate of the motor, i.e., write the values of the voltage and the current as is on the nameplate.

Phase: ___________________________ Voltage:_______________

Pole pairs:_________________________ Speed:________________

Efficiency:_________________________ Current:_______________

Power rating:_______________________ Frequency:______________

(8)

ACTIVITY B

Perform the inspection/test in the table below on the motor and complete the table.

NOTE: These testing procedures are conducted when the motor is electrically isolated from the supply.

DESCRIPTION	ELECTRICAL INSPECTION/ TESTING AND READINGS TAKEN	MARKS ALLOCATED
Condition of windings: Measurements taken		
TEST 1: Continuity of windings (Write the reading shown on the multimeter in ohms.) (3 marks)		
U1 – U2		
V1 – V2		
W1 – W2		
TEST 2: Insulation resistance between windings (Write the reading shown on the insulation resistance tester in mega-ohms.) (3 marks)		
U1 – V1		
U1 – W1		
V1 – W1		
TEST 3: Insulation resistance to earth (Write the reading shown on the insulation resistance tester.) (3 marks)		
U1 – Earth		
V1 – Earth		
W1 – Earth		
TEST 4: Visual and mechanical inspection Note all errors (brief description). (3 marks)		
Test if the rotor is free to rotate.		
Check if the motor interior is free from dust, water and oil.		
Test the play in the bearings.		
Condition of motor frame (brief description) (6 marks)		
Condition of terminal box		
Flange/Foot mount		
Front/Back-end shield		
Stator/Field housing		
Mounting bolts and nuts/screws		
Condition of cooling fan, fan cover and cooling fins		

(18)

4.2.4 Draw the terminal box showing the coils and terminals of the tested three-phase motor.

NOTE: Correct labelling of the terminals of the motor and earth (4)
Correct layout of the internal coils of the motor you tested (3) (7)

4.2.5 According to the regulation, state the minimum acceptable resistance between the windings when an insulation resistance test is conducted.

____
______________________ (1)

4.2.6

Conducted test	**Acceptable/Not acceptable (Motivate your answer.)**	
Winding resistance		(2)
Insulation resistance		(2)
Insulation resistance to earth		(2)
State, with a reason, whether the motor can be used or not.		(2)
	Total	(8)
	Theory Simulation 2:	**[42]**

NOTE: Learner competency in this context will mean the following:
(This is done for easy assessment when using a rubric.)

Not yet competent	Have not met the requirements and will be given another opportunity for reassessment. • Be precise about what they did wrong, or the areas they need to improve in. • Clearly explain the level of skill they need to achieve to be assessed as 'competent'. • Indicate whether part or all of the assessment events will need to be repeated.
Competent	Have the necessary ability, knowledge or skill to complete the task successfully. • Acceptable and satisfactory, though not outstanding.
Outstanding	Went beyond expectation (neatness, proficiency – high degree of skills, expertise)

FACET SHEET FOR SIMULATION 2

Task description	Mark allocation (tick the appropriate level next to the task indicated)				Allocation of marks
	Not yet competent after reassessment of certain/ all parts of the task	**Competent after reassessment of certain parts of the task**	**Competent**	**Outstanding (Highly competent)**	
Continuity and insulation resistance tests	The learner was given opportunities to redo part of continuity and insulation resistance tests after the teacher intervened in identifying and rectifying mistakes. **(1)**	The learner was given opportunities to redo continuity and insulation resistance tests after the teacher intervened in identifying and rectifying a few mistakes. **(2)**	The learner correctly did continuity and insulation resistance tests on the motor without the guidance of the teacher. **(3)**	The learner correctly did continuity and insulation resistance tests on the motor without the guidance of the teacher and went beyond expectations and with high proficiency. **(4)**	$\frac{}{4}$
Safety aspects	The learner was timeously reminded to apply safety rules, regulation and correct procedure when using tools and instruments. **(0)**	The learner was sometimes reminded to apply safety rules, regulation and correct procedure when using tools and instruments. **(1)**	The learner applied safety rules, regulation and correct procedure when using tools and instruments to wire the circuits without being reminded by the teacher. **(2)**		$\frac{}{2}$
Attitude/ Behaviour/ Conduct	The learner was reluctant to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice even after being cautioned/reprimanded. **(0)**	The learner was reluctant to a certain degree to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice. **(1)**	The learner demonstrated willingness to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice. **(2)**		$\frac{}{2}$
				Rubric	8
				Motor Test	$+ \quad /42$
				Total Simulation 2	$= \quad /50$

4.3 Simulation 3: Automatic sequence starter with overload

Name of learner: ________________________________	Mark	______ **50**
Class: ______	Date completed: _______________	
Date Assessed: ________________	Assessor Signature: __________________	
Date Moderated: _______________	Moderator Signature: _______________________	

4.3.1 **Purpose:**

- Wiring a sequence motor starter to manually start motor 1 and after a pre-set time start motor 2 automatically using an ON-delay timer
- Adjusting the start delay time for motor 2
- Finding the fault inserted by the teacher

4.3.2 **Required resources:**

TOOLS/INSTRUMENTS	MATERIALS
2 x three-phase contactors with auxiliary contacts (for motor 1 and motor 2) 1 x three-phase main contactor 1 x three-phase overload relay 1 x timer relay (pneumatic or electronic) 1 x stop button 1x start button 2 x three-phase induction motors (alternatively, 1 three-phase and 1 single-phase induction motor) Correct wire size or plug-in leads Wire stripper Long-nose pliers Screwdriver Side cutters	Multimeter or continuity tester Multimeter or voltmeter Clamp-on ammeter Stopwatch

4.3.3 **Procedure A:**

Build the control circuit on the panels and let the teacher check it before switching on the supply.

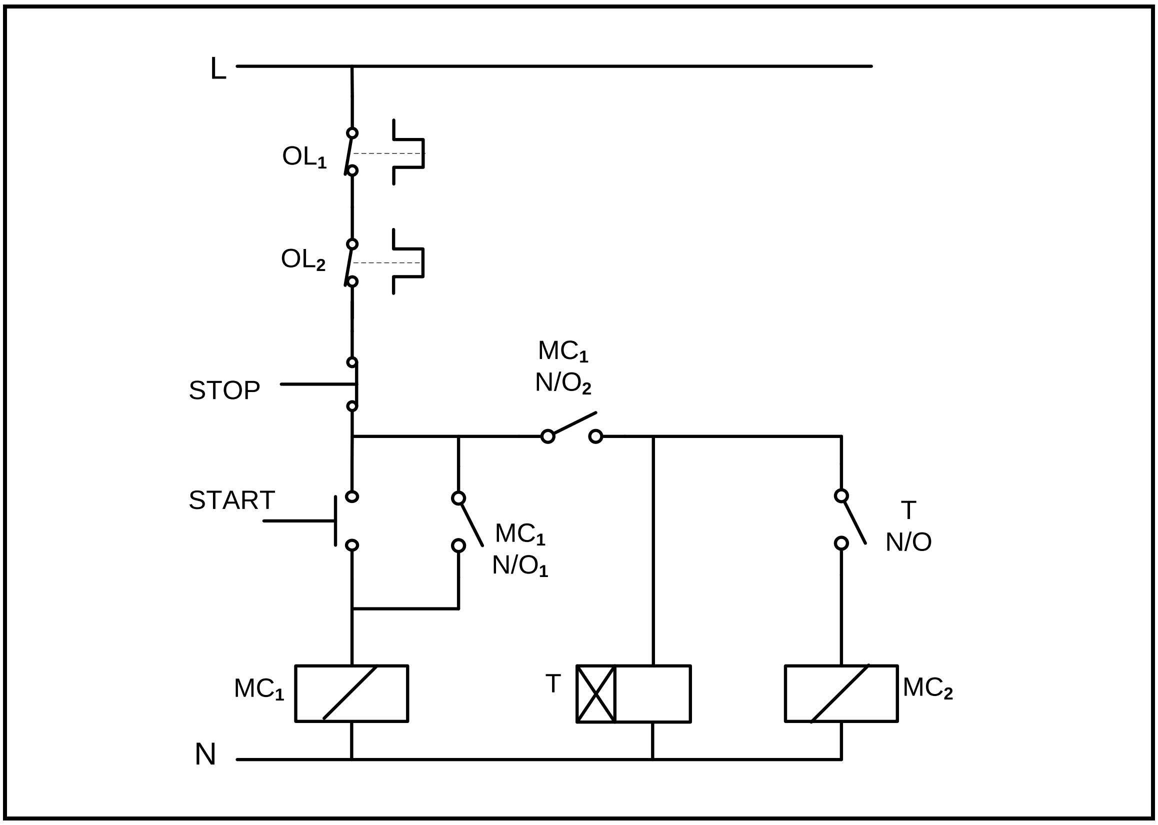


FIGURE 4.3.3(a): CONTROL CIRCUIT OF THREE-PHASE SEQUENCE MOTOR STARTER WITH OVERLOAD AND TIMER

Consider all safety aspects before and during the wiring process and be cautious until the circuit is operating.

Build the control circuit to test the operation.

Ask your teacher to check the control circuit before switching the supply on.

(a) Press the 'START' button and observe.
Did MC_1 energise? Yes/No _________ (1)

(b) Did the timer energise? Yes/No _________ (1)

(c) Did MC_2 energise? Yes/No _________

Write down the delay time: _____________ (2)

(d) Press the STOP button..

(e) Adjust the timer to a delay of _________ seconds.
(Time delay chosen by teacher.)
(Learner able (✓) or not able (X)) (1)

4.3.4 Set the overload for each motor. (Please use the nameplate in FIGURE 4.3.4 with motor 1Δ and motor 2Y if the motors on the panels you are using, do not have a nameplate.)

NOTE: S.F <1.15 Overload setting 115% of full load current and
S.F. $\geq$ 1.15 Overload setting 125% of full load current

(a) Inspect the nameplates of the motors you are using and complete the following table:

	Motor 1	**Motor 2**
Connection Y/Δ		
Full load current (I_{FL})		
Service factor (S.F.)		

(6)

TABLE 4.3.4

(b) Calculate the maximum overload current for each motor.

Motor 1	**Motor 2**

(6)

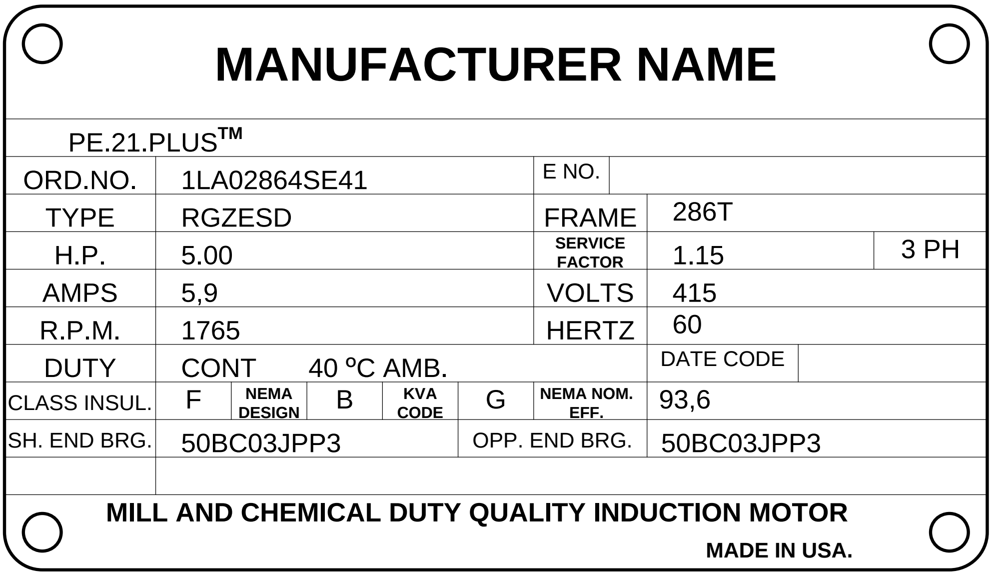


FIGURE 4.3.4: DELTA-CONNECTED MOTOR NAMEPLATE

(c) Set the overload correctly to the value calculated in (b) above.

Motor 1: __________ Motor 2: __________
(Learner able (✓) OR not able (X)) (2)

(d) Explain the operation of the control circuit.

(6)
[25]

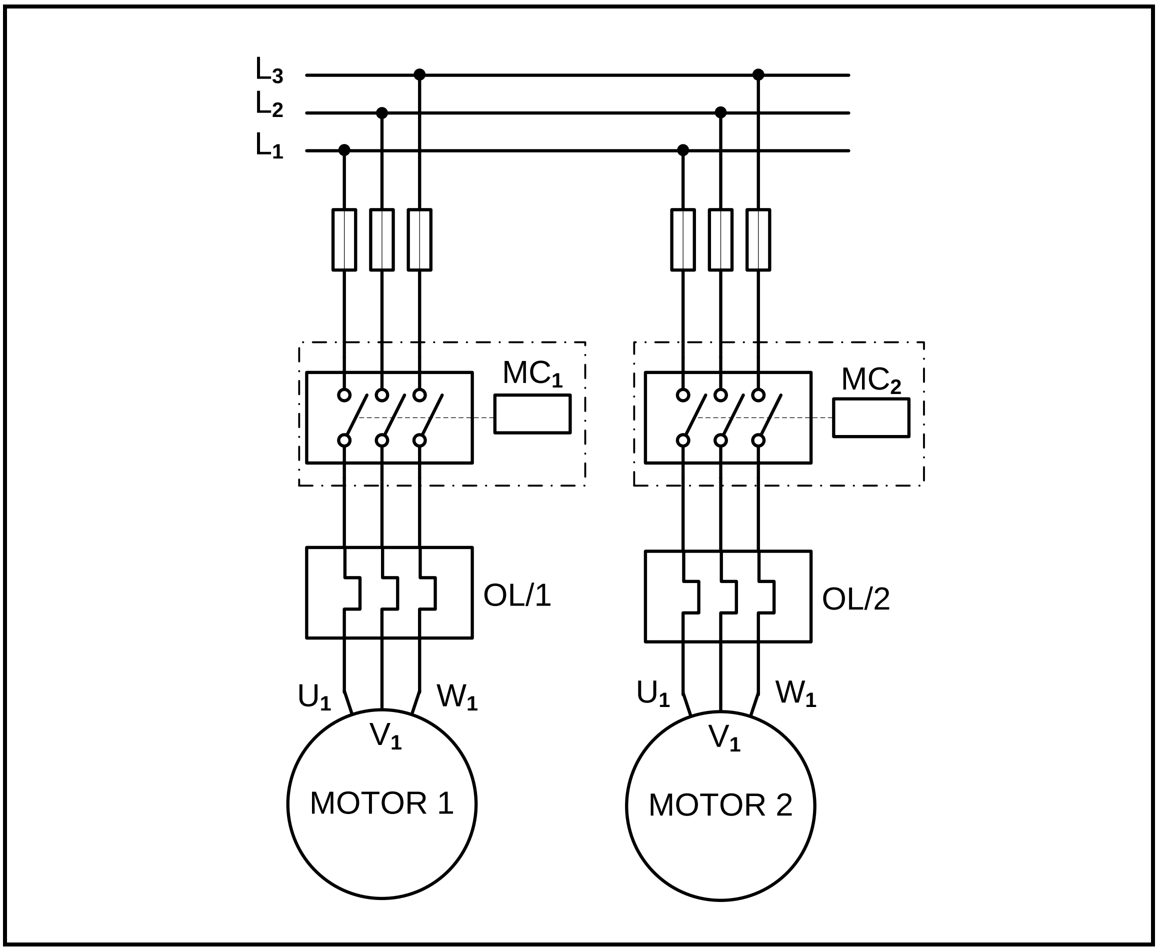


FIGURE 4.3.3(b): AUTOMATIC SEQUENCE POWER CIRCUIT DIAGRAM

4.3.4 **Procedure B:**

Consider all safety aspects before and during the wiring process and be cautious until the motor is operating.

(a) Build and test the power circuit.

Ask your teacher to check the power circuit before switching the supply on.

(b) Start the motor and observe.

(c) Record all your findings.

(d) Press the stop button.

FACET SHEET FOR SIMULATION 3

Task description	Mark allocation (tick the appropriate level next to the task indicated)				Allocation of marks
	Not yet competent after reassessment of certain/ all parts of the task	**Competent after reassessment of certain parts of the task**	**Competent**	**Outstanding (Highly competent)**	
Wiring the control circuit on the panel	The learner was given opportunities to rewire the circuit on the panel after the teacher intervened in identifying and rectifying more mistakes. **(1–2)**	The learner was given an opportunity to rewire the control circuit on the panel after the teacher intervened in identifying and rectifying a few mistakes. **(3–4)**	The learner correctly wired the control circuit on the panel without guidance of the teacher. **(5–6)**	The learner correctly wired the control circuit on the panel without guidance of the teacher and went beyond expectations and with high proficiency. **(7–8)**	$\overline{8}$
Wiring the power circuit on the panel	The learner was given opportunities to rewire the circuit on the panel after the teacher intervened in identifying and rectifying more mistakes. **(1–2)**	The learner was given an opportunity to rewire the power circuit on the panel after the teacher intervened in identifying and rectifying few mistakes. **(3–4)**	The learner correctly wired the power circuit on the panel without guidance of the teacher. **(5–6)**	The learner correctly wired the power circuit on the panel without guidance of the teacher and went beyond expectations and with high proficiency. **(7–8)**	$\overline{8}$
Fault finding	The learners were given opportunities to re-identify and correct the fault after more interventions of the teacher. **(1–2)**	The learners were given an opportunity to re-identify and correct the fault after a few interventions of the teacher. **(3–4)**	The learners were able to identify/find the fault inserted by the teacher and corrected it. **(5)**		$\overline{5}$
Safety aspects	The learner was timeously reminded to apply safety rules, regulation and correct procedure when using tools and instruments. **(0)**	The learner was sometimes reminded to apply safety rules, regulation and correct procedure when using tools and instruments. **(1)**	The learner applied safety rules, regulation and correct procedure when using tools and instruments to wire the circuits without being reminded by the teacher. **(2)**		$\overline{2}$
Attitude/ Behaviour/ Conduct	The learner was reluctant to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice even after being cautioned/reprimanded. **(0)**	The learner was reluctant to a certain degree to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice. **(1)**	The learner demonstrated willingness to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice. **(2)**		$\overline{2}$
				Rubric	$/25$
				Simulation 3	$+ \quad /25$
				Total Simulation 3	$= \quad /50$

4.4 Simulation 4: Three-phase automatic direct-on-line motor starter with overload and off-delay timer using PLC

Name of learner: ______________________________	Mark	________ 50
Class: _______ Date completed: _______________		
Date Assessed: _______________	Assessor Signature: __________________	
Date Moderated: _______________	Moderator Signature: ______________________	

4.4.1 **Purpose:**

- To convert a direct-on-line motor starter control circuit with overload and off-delay timer and indication lights to a ladder logic diagram
- To operate a three-phase induction motor through the PLC after programming and loading the program to the PLC

Control circuit

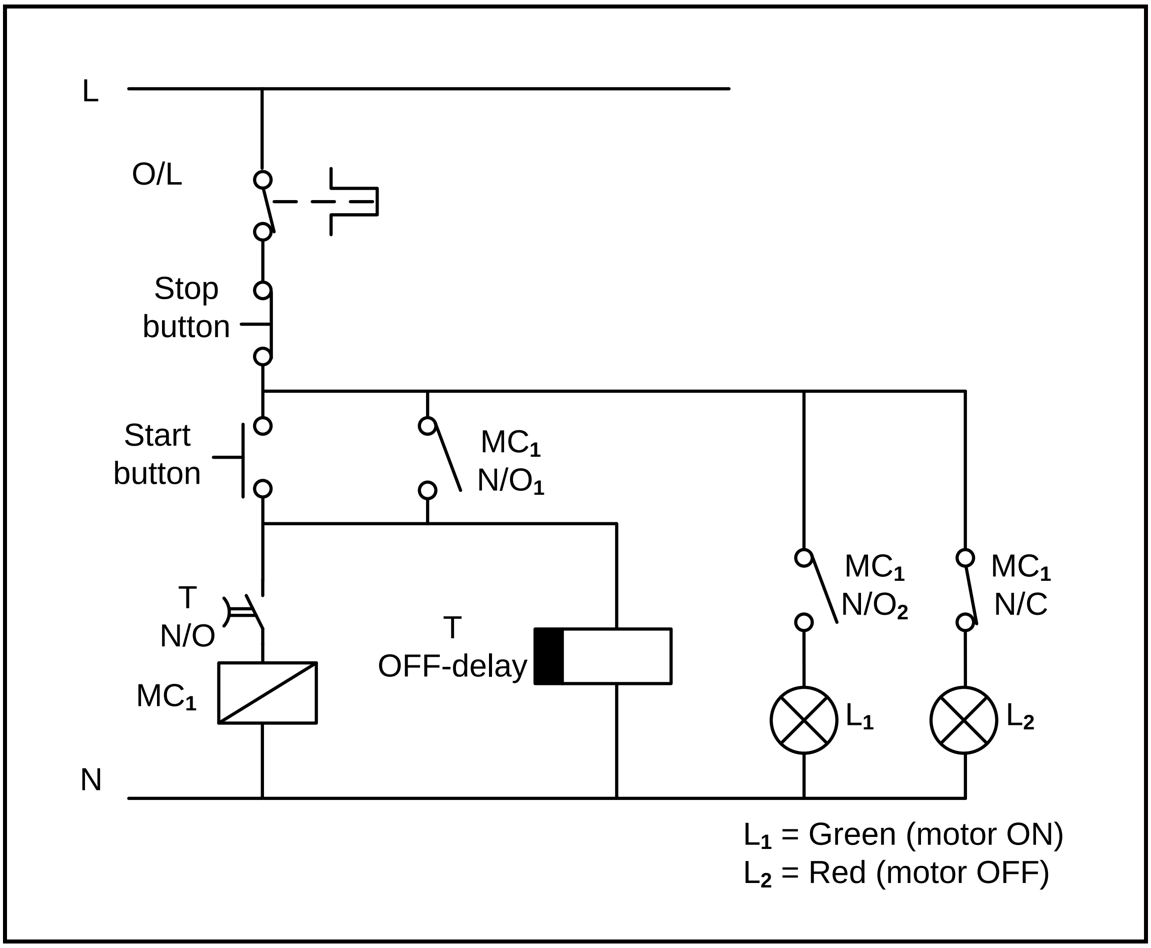


FIGURE 4.4.1(a): CONTROL CIRCUIT

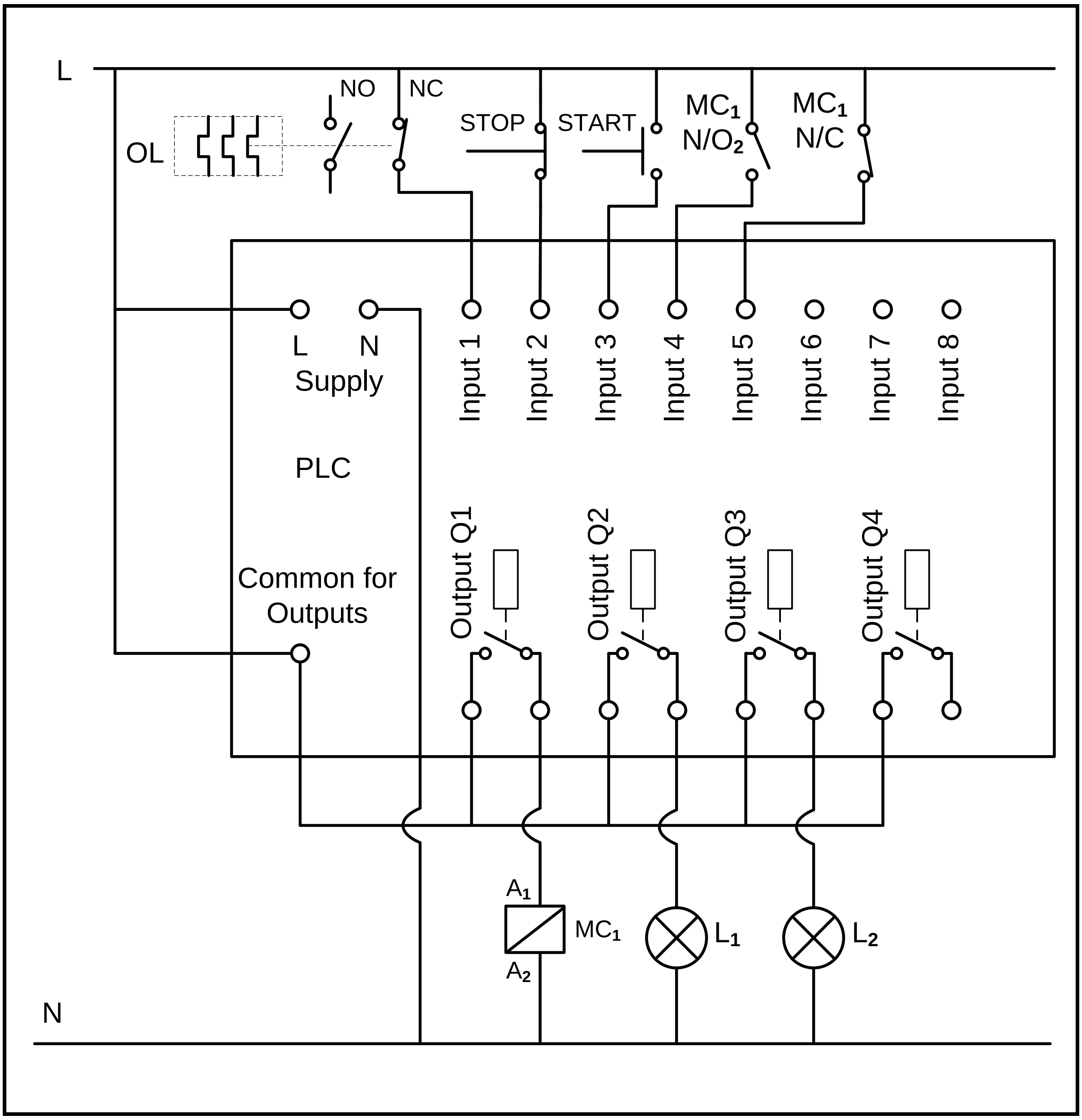


FIGURE 4.4.1(b): PLC UNIT CONNECTED TO THE CONTROL CIRCUIT

Inputs:

X1/I01 = O/L
X2/I02 = Stop button
X3/I03 = Start button
X4/I04 = MC_1N/O_2
X5/I05 = MC_1N/C

Outputs:

Q1 = MC_1
Q2 = L_1
Q3 = L_2

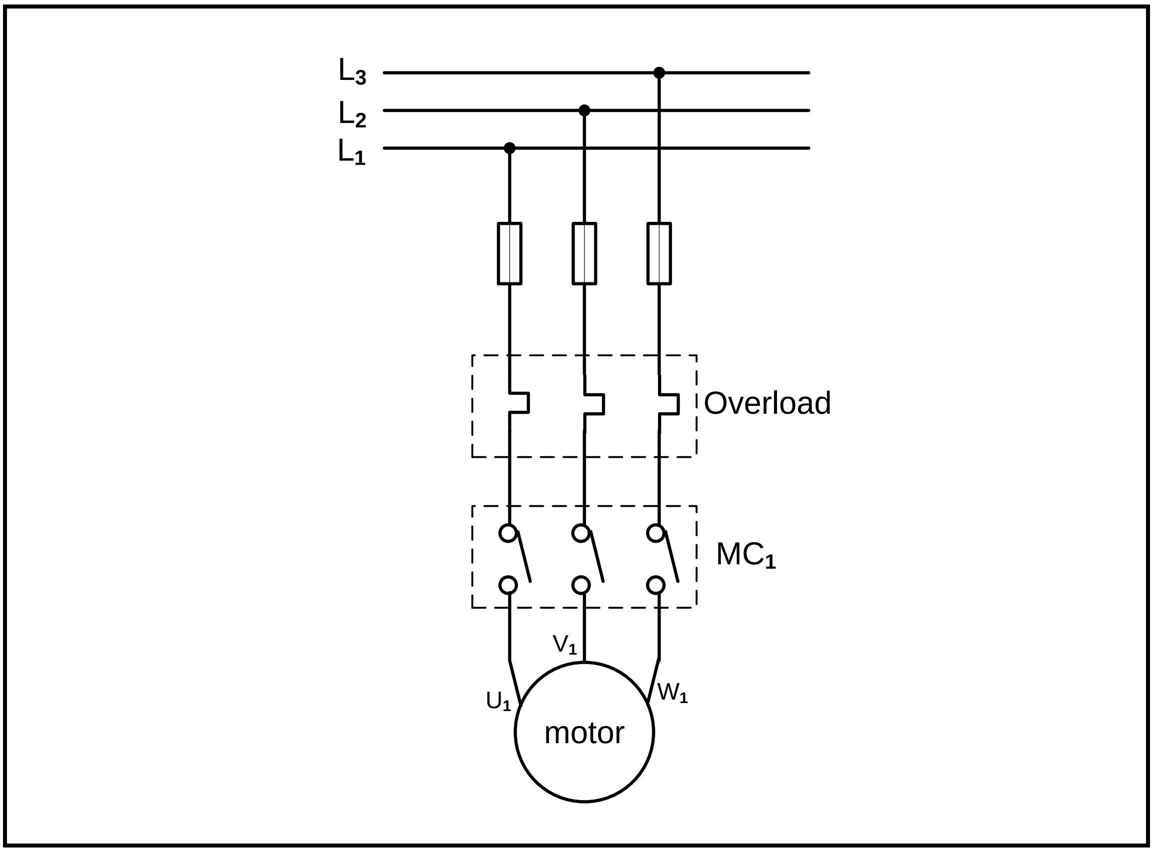


FIGURE 4.4.1(c): POWER CIRCUIT DIAGRAM

4.4.2 **Required resources:**

TOOLS/INSTRUMENTS	MATERIALS
Multimeter/Clamp meter or continuity tester Computer/Programmer Programming cable Wire stripper Long-nose pliers Screwdriver Side cutters	Connecting wires PLC unit 1 x three-phase induction motor (star or delta) 1 x three-phase overload relay 1 x stop button 1 x start button 1 x three-phase contactor 1 x green indicator light (230 V) 1 x red indicator light (230 V)

4.4.3 **Procedure**

- Convert the relay logic circuit in FIGURE 4.4.1(a) into a ladder logic program.
- Program the ladder logic diagram through a computer.
- Set the time delay to 5 seconds.
- Run the PLC program in the computer and simulate the operation.
- Load the program from a computer to a PLC.
- Ensure the PLC is in run mode.
- Disconnect the programming cable.
- Switch off the supply.
- Connect the PLC to the control of the circuit.
- Only switch ON the supply after your teacher has checked the circuit and confirmed it as correct.
- If the program and control circuit are working, switch OFF the power supply.
- Wire the power circuit to the motor.
- Ask your teacher to check the wiring of the power circuit before switching it ON.
- The teacher will insert faults on the PLC and the learner must identify and correct them.
- Ask your teacher to inspect the circuit and ensure that all faults are corrected.

4.4.4 (a) Take a snapshot (screenshot) of the programmed ladder logic diagram. Save, print and paste it on the blank space below. Ensure that your name and the circuit name appear on the title block of the circuit.

(15)

4.4.5 Name TWO components of the control circuit that are soft-wired and not hard-wired in the system.

______________________ ______________________

______________________ ______________________ (2)

4.4.6 Explain the operation of the ladder program after the stop button is pressed.

(3)
[20]

FACET SHEET FOR SIMULATION 4

Task description	Mark allocation (tick the appropriate level next to the task indicated)				Allocation of marks
	Not yet competent after reassessment of certain/ all parts of the task	**Competent after reassessment of certain parts of the task**	**Competent**	**Outstanding (Highly competent)**	
Loading the program to the PLC	The learner was given opportunities to reload the program after the teacher intervened in identifying and rectifying several mistakes. **(1)**	The learner was given an opportunity to reload the program after the teacher intervened in identifying and rectifying few mistakes. **(2–3)**	The learner correctly loaded the program to the PLC without the guidance of the teacher. **(4–5)**	The learner correctly loaded the program to the PLC without the guidance of the teacher and went beyond expectations and with high proficiency. **(6)**	$\overline{6}$
Wiring the control circuit to the PLC	The learner was given opportunities to rewire the circuit on the panel after the teacher intervened in identifying and rectifying more mistakes. **(1–2)**	The learner was given an opportunity to rewire the control circuit on the panel after the teacher intervened in identifying and rectifying a few mistakes. **(3–4)**	The learner correctly wired the control circuit on the panel without the guidance of the teacher. **(5–6)**	The learner correctly wired the control circuit on the panel without the guidance of the teacher and went beyond expectations and with high proficiency. **(7–8)**	$\overline{8}$
Wiring the power circuit on the panel	The learner was given opportunities to rewire the circuit on the panel after the teacher intervened in identifying and rectifying more mistakes. **(1–2)**	The learner was given an opportunity to rewire the power circuit on the panel after the teacher intervened in identifying and rectifying a few mistakes. **(3–4)**	The learner correctly wired the power circuit on the panel without the guidance of the teacher. **(5–6)**	The learner correctly wired the power circuit on the panel without the guidance of the teacher and went beyond expectations and with high proficiency. **(7)**	$\overline{7}$
Fault finding	The learner was given opportunities to re-identify and correct the fault after more interventions of the teacher. **(1–2)**	The learner was given an opportunity to re-identify and correct the fault after few interventions of the teacher. **(3–4)**	The learner was able to identify/find the fault inserted by the teacher and corrected it. **(5)**		$\overline{5}$
Safety aspects	The learner was timeously reminded to apply safety rules, regulation and correct procedure when using tools and instruments. **(0)**	The learner was sometimes reminded to apply safety rules, regulation and correct procedure when using tools and instruments. **(1)**	The learner applied safety rules, regulation and correct procedure when using tools and instruments to wire the circuits without being reminded by the teacher. **(2)**		$\overline{2}$
Attitude/ Behaviour/ Conduct	The learner was reluctant to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and work-shop practice even after being cautioned/ reprimanded. **(0)**	The learner was reluctant to a certain degree to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice. **(1)**	The learner demonstrated willingness to work, cooperate, take responsibility of their own conduct and follow instructional, regulation and workshop practice. **(2)**		$\overline{2}$
				Rubric	$/30$
				Simulation 4	$+ \quad /20$
				Total Simulation 4	$= \quad /50$

5. SECTION B: DESIGN AND MAKE

Design and Make Project

Time: January to August 2024

Learner Name: ______________________________

School: ______________________________

Class: ______________________________

Title/Type of Project: ______________________________

INSTRUCTIONS

- This section is COMPULSORY for all learners.
- The teacher will choose a circuit for the project.
- Any project constructed must include at least (but is not limited to):
  - Seven components
  - A variety of components (both active and passive)
  - PCB making in some form
  - Soldering
  - An enclosure with a switch and protection
- The checklist below must be used to ensure that all the required tasks for the PAT have been completed.

PAT CHECKLIST

The learner MUST fill in this checklist BEFORE marking of the section takes place.

NO.	DESCRIPTION	TICK (☑)	
		NO	YES
Design and Make: Part 1			
1.	Circuit diagram drawn	☐	☐
2.	Circuit description filled in	☐	☐
3.	Component list completed	☐	☐
4.	Tools list for circuitry populated	☐	☐
5.	Measuring instrument list filled in	☐	☐
Design and Make: Part 2			
1.	Enclosure design completed and included in the file	☐	☐
2.	Unique name written down and on the enclosure	☐	☐
3.	Logo designed and on the enclosure	☐	☐
Miscellaneous			
1.	Enclosure included in the project	☐	☐
2.	Enclosure prepared and drilled according to the design	☐	☐
3.	Enclosure finished off and completed with name and logo	☐	☐
4.	PCB securely mounted in the enclosure using acceptable techniques	☐	☐
5.	Circuit inside the enclosure accessible	☐	☐
6.	Internal wiring neat and ready for inspection	☐	☐
7.	File and project completed and ready for moderation at the workshop/room	☐	☐

5.1 Design and Make: Part 1

5.1.1 Circuit diagram

Draw a circuit diagram of the project chosen and paste it on the next page.

5.1.2 Project: Description of operation

Use the space below to describe how the project operates. Do research and use your own words.

5.1.3 **Component list**

List the components you will need for the circuit diagram.

LABEL	DESCRIPTION AND VALUE	QUANTITY

5.1.4 **Tools/Instrument list**

List the tools needed to complete the project.

DESCRIPTION	PURPOSE

5.2 Assessment of the Design and Make Phase: Part 1

NO.	FACET DESCRIPTION	Mark	Achieved mark
Circuit Diagram			
1.	The circuit diagram was drawn using • EGD equipment (4) • CAD/Any electronic design software (6)	6	
2.	The circuit diagram was drawn using correct symbols.	3	
3.	The circuit diagram has all labels, e.g. R1, C1, Tr1	3	
4.	The circuit diagram has all component values, e.g. 100 Ω, 220 μF	4	
5.	The circuit diagram has a name/title.	2	
6.	The circuit diagram has a frame and title block.	2	
	Circuit Diagram Subtotal:	**20**	
Component List			
7.	Labels correlate with circuit diagram.	2	
8.	Description and values correlate with circuit diagram.	2	
9.	Quantities are correct.	1	
	Component List Subtotal:	**5**	
Description of Operation			
10.	Basic function of the circuit is described correctly. The purpose/role/function of each component is described.	11	
11.	All subcircuits in the circuit diagram and component list are included in the description.	4	
12.	Purposes of subcircuits in the circuit diagram are described correctly.	5	
13.	Learner used own interpretation and did not copy from another source verbatim.	3	
14.	Sources are acknowledged.	2	
	Description of Operation Subtotal:	**25**	
Tools/Instrument List			
15.	The tools/instrument list has been completed.	4	
16.	The tools/instruments listed all have a purpose for being used.	1	
	Tools/Instrument List Subtotal:	**5**	

NO.	FACET DESCRIPTION	Mark	Achieved mark
Circuit Board Manufacturing			
17.	Transfer of the PCB design onto the blank board is correct. Not over-exposed or under-exposed.	5	
18.	Circuit board is etched neatly according to the PCB design.	10	
19.	The learner's name is etched onto the circuit design.	4	
20.	All burrs are removed.	2	
21.	Axial and radial components are placed neatly and flush with the board.	5	
22.	Component orientation are aligned between similar components (e.g. the gold band of all resistors are placed on the same side).	2	
23.	Soldered components – leads are cut off, flush and neat on the solder side.	5	
24.	More than 60% of the solder joints are shiny (not dry joints).	5	
25.	Wire insulation is stripped to the correct length (no extra copper showing).	3	
26.	Wiring is long enough to allow for dismantling and inspection.	2	
27.	Wiring is wrapped neatly.	2	
28.	A power switch is included and fitted to the enclosure.	2	
29.	A fuse/protection is included and fitted correctly where applicable.	2	
30.	Wiring entering/exiting the enclosure is provided with a grommet/applicable fittings/sockets where applicable.	2	
31.	Batteries/Transformer is mounted using a battery housing/ mounting bracket and battery clip (NO double-sided tape).	2	
32.	The project has a pilot light/LED installed in the enclosure showing when the circuit is operational. LED is mounted with a grommet or applicable fitting. (Switch is on – must go out when fuse is blown.)	2	
33.	The project is fully operational and commissioned/installed in the enclosure.	10	
	Circuit Board Manufacturing Subtotal:	**65**	
	Circuit Diagram Subtotal:	**20**	
	Component List Subtotal:	**5**	
	Description of Operation Subtotal:	**25**	
	Tools/Instrument List Subtotal:	**5**	
	Circuit Board Manufacturing Subtotal:	**65**	

TOTAL (PART 1 = 120 marks)	

NOTE: In projects where facets are not applicable, the projects should be marked and the totals adjusted accordingly.

5.3 Design and Make: Part 2

5.3.1 **Enclosure design**

- Design an enclosure for your project.
- NO FREEHAND DRAWINGS.
- Draw using EGD equipment **OR** use a CAD program.
- Draw in first-angle orthographic projection.
- Add your drawings after this page.
- Use colour to enhance your drawing.

5.3.2 Manufacture the enclosure neatly according to your design.

You may use pre-cut panels from metal, wood and/or Perspex/Plexiglas.
You must, however, construct/assemble these parts.
Injection moulded enclosures are also acceptable. It is important that your enclosure and the placement of the parts align with your design.

5.3.3 Choose a name for your device.

Write down the name of the device below.

____

5.3.4 Design a unique logo for your device, as well as a specification plate and attach it after this page.

5.4 Assessment of the Design and Make Phase: Part 2

NO.	FACET DESCRIPTION	Mark	Achieved mark
Enclosure Design			
1.	Enclosure design is included in first-angle orthographic projection.	2	
2.	Drawn design includes a title box and page border.	1	
3.	Isometric drawing included additionally.	2	
4.	Dimensions are included.	2	
5.	The name of the device is written in the PAT document.	1	
6.	The logo design and specification plate design is in the PAT document.	2	
	Enclosure Design Subtotal:	**10**	
Enclosure Manufacturing			
7.	Enclosure matches the design. Dimensions and placement correlate.	1	
8.	Name of the device is attached on the enclosure.	1	
9.	The logo design is attached on the enclosure.	2	
10.	The logo design on the enclosure is durable and not merely a paper pasted on the enclosure (painted/used decoupage/screen printed/sublimation printed).	2	
11.	The enclosure is manufactured from scratch/pre-cut parts. Does NOT include: cardboard, paper, margarine container Does include: sheet metal, Perspex, Plexiglas, wood, glass and other raw materials, injection-moulded plastic boxes	5	
12.	Holes/Cut-outs in the enclosure are made with the appropriate tools.	3	
13.	Specification plate with the learner's name, operating voltage, fuse rating and additional information on the project.	2	
14.	Enclosure is neatly prepared, painted and aesthetically pleasing.	2	
15.	The circuit board is mounted using appropriate methods inside the enclosure. (NO double-sided tape, Prestik, glue, chewing gum, masking tape, etc.)	2	
	Enclosure Manufacturing Subtotal:	**20**	

TOTAL (PART 2 = 30 marks)	

6. PROJECTS

6.1 Practical Project 6.1: Automatic Battery Charger with Battery-voltage Bar-graph Display

This automatic battery charger project is based on the National Semiconductor LM350 3 A adjustable regulator. It is designed to charge 12 V lead-acid batteries. When the switch SW1 is pushed, the output of the charger will go up to 14,5 V. The initial charging current is limited to 2 A. As the charge of the battery continues to rise, the charging current decreases to 150 mA and the output voltage is reduced to 12,5 V. At this stage the charging is terminated, and the light-emitting diode lights up to indicate that the charging process has been completed.

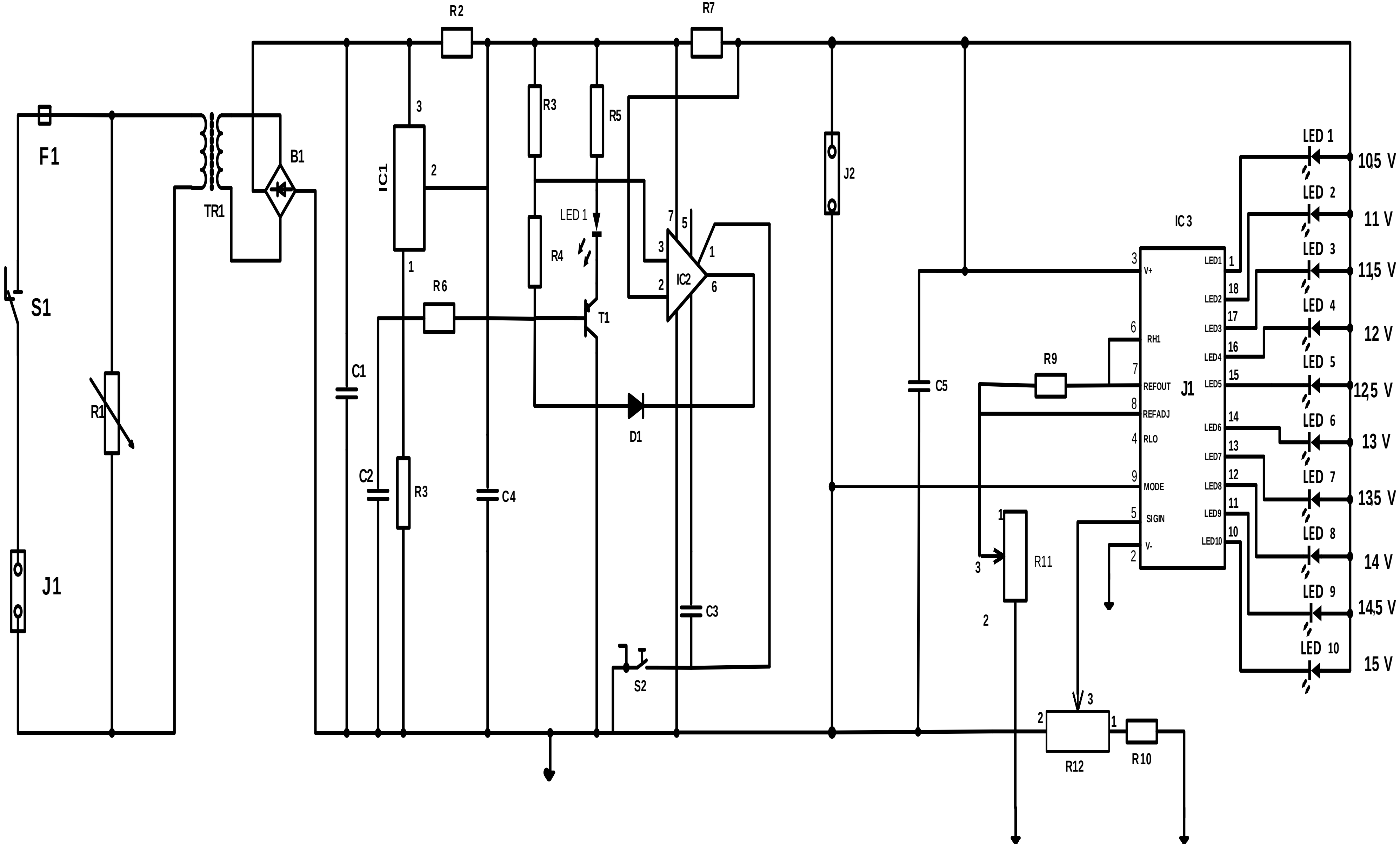
The schematic diagram below shows how the various components are connected. The first part of the diagram shows how the DC power supply to LM350 is achieved. The combined use of varistor V1 and fuse F1 is to protect the circuit from overcurrent and power surge of the mains supply.

Transformer T1 is used to step down the input voltage from the mains to 16 V AC. Diode bridge DB and electrolytic capacitor E1 are used to rectify the AC voltage to DC voltage. This rectified DC power supply is fed into the input of the second circuit where LM350 and operational amplifier LM301A are used to control the charging current and voltage of the lead-acid battery. Once the charge is full, transistor Q1 will turn ON and LED L1 will be ON to indicate that the charging has been completed. A heat sink is attached to LM350 to transfer the heat generated from the regulator to the ambient.

This bar-graph LED-battery-level-indicator project is based on the LM3914 monolithic IC of the National Semiconductor that senses the voltage levels of the battery and drives the 10 light-emitting diodes based on the voltage level that is detected. It provides a linear analogue display output and has a pin that can be configured to display the output in moving dot or bar graph. The current driving the LEDs is regulated and programmable, hence limiting resistors are not required.

The schematic diagram below shows how the various components are connected. Switch S1 is used to change the display type from moving dot to bar graph type. When S1 is ON, the display type is bar graph, but when it is OFF, the display changes to the moving dot type.

R3 is used to set the lower limit of the display. Use a variable DC power supply and set the VBAT to 10,5 V. Adjust VR1 until the LED L1 turns ON. Next, set the VBAT to 15 V; adjust VR2 until all the LEDs turn ON (when S1 is ON).


R2
R7
F1
S1
J1
R1
TR1
B1
IC1
R6
C1
C2
R3
C4
R5
R4
LED 1
T1
IC2
D1
C3
S2
J2
C5
R9
IC3
J1
V+
RH1
REFOUT
REFADJ
RLO
MODE
SIGIN
V-
LED1
LED2
LED3
LED4
LED5
LED6
LED7
LED8
LED9
LED10
R11
R12
R10
LED 1
LED 2
LED 3
LED 4
LED 5
LED 6
LED 7
LED 8
LED 9
LED 10
10,5 V
11 V
11,5 V
12 V
12,5 V
13 V
13,5 V
14 V
14,5 V
15 V

COMPONENT LIST			
R1	varistor 14 mm	B1	5 A diode bridge
R2	500 ohm, 5 W	C1	6 800 µF 35 V electrolytic capacitor (battery charger)
R3, R6	15 K ¼ W	C2	0,1 µF ceramic 104
R4	230 ohm ¼ W	C3	1 nF ceramic 102
R5	1k	C4	1 µF electrolytic 25 volt
R7	0,2 ohm, 5 W	D1	1N 4148 diode
R8	3k3 ¼ W	IC1	LM350 16 volt positive voltage regulator
J1	mains supply	IC2	LM301 H operational amplifier
J2	12 V connector for battery/battery clamps	S1	On/Off switch for mains voltage SPST toggle switch
F1	500 mA fast-blow fuse	S2	push-to-make switch
TR1	240 V–16 V transformer 3 A (+/-50 VA)	LED 1	red LED 5 mm
R9	1k2 ¼ W 5%	IC 3	LM3914 N bar-graph display driver
R10	4k7 ¼ W 5%	C5	10 µF 25 volt electrolytic capacitor (Bar-graph voltage indicator)
R11	5k potentiometer	T1	PN2907 alternative (BC527 or BC 528)
LED 1,10	red,		
LED 4,5,6,7	green		
LED 2,3,8,9	amber		
R12	5k potentiometer		

6.2 Practical Project 6.2: Sound-to-light Controller

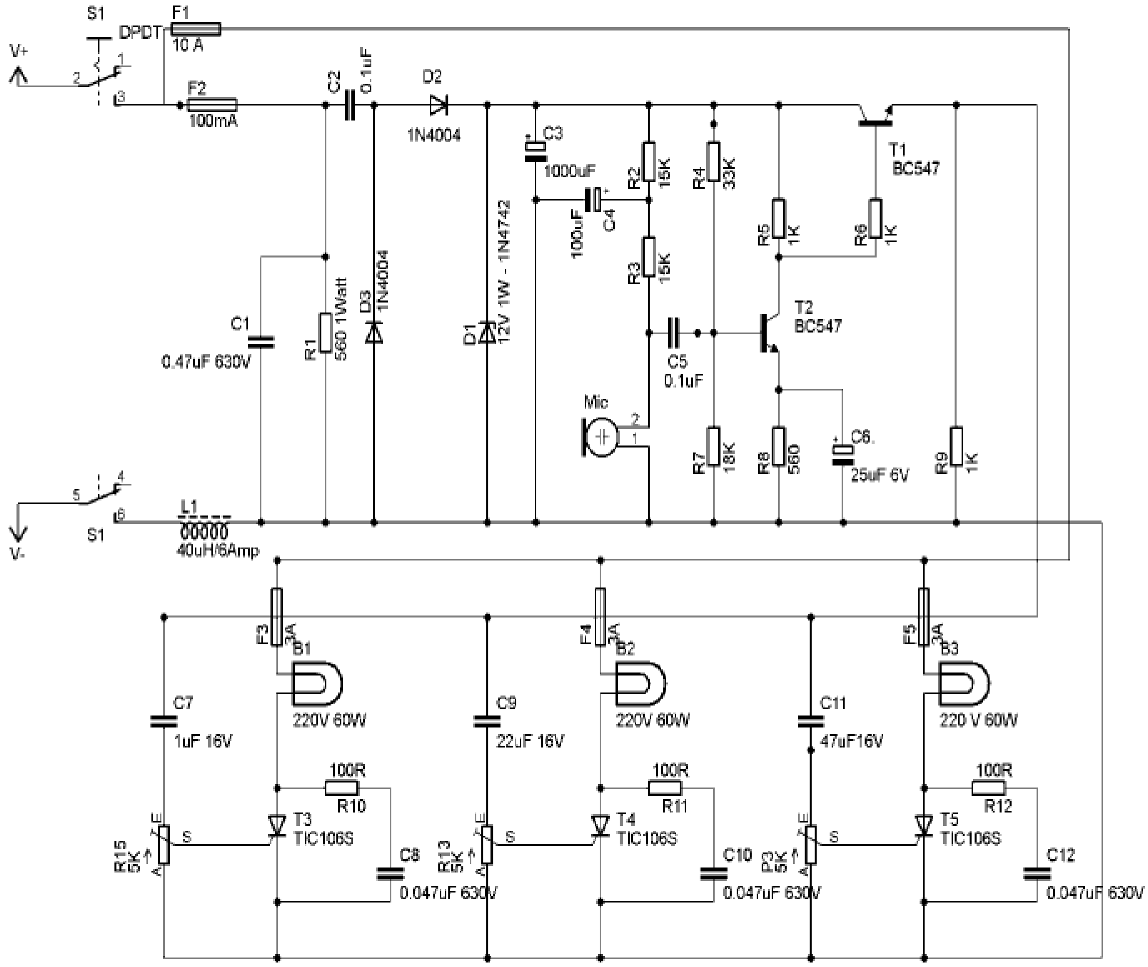
This sound-controlled light circuit design is used to control the brightness of the lights attached to it in sync with the sound that is being captured by its microphone. This electronic circuit design is very common in disco houses, bars, parties, etc.

Usually, sound-controlled lights are just connected in parallel with the loudspeakers. This configuration has two disadvantages: a very powerful amplifier can destroy the lights, or worse, a defective light can destroy the amp. This problem is avoided by the circuit by not connecting directly to the amp. Instead, it picks up the sound with its microphone.

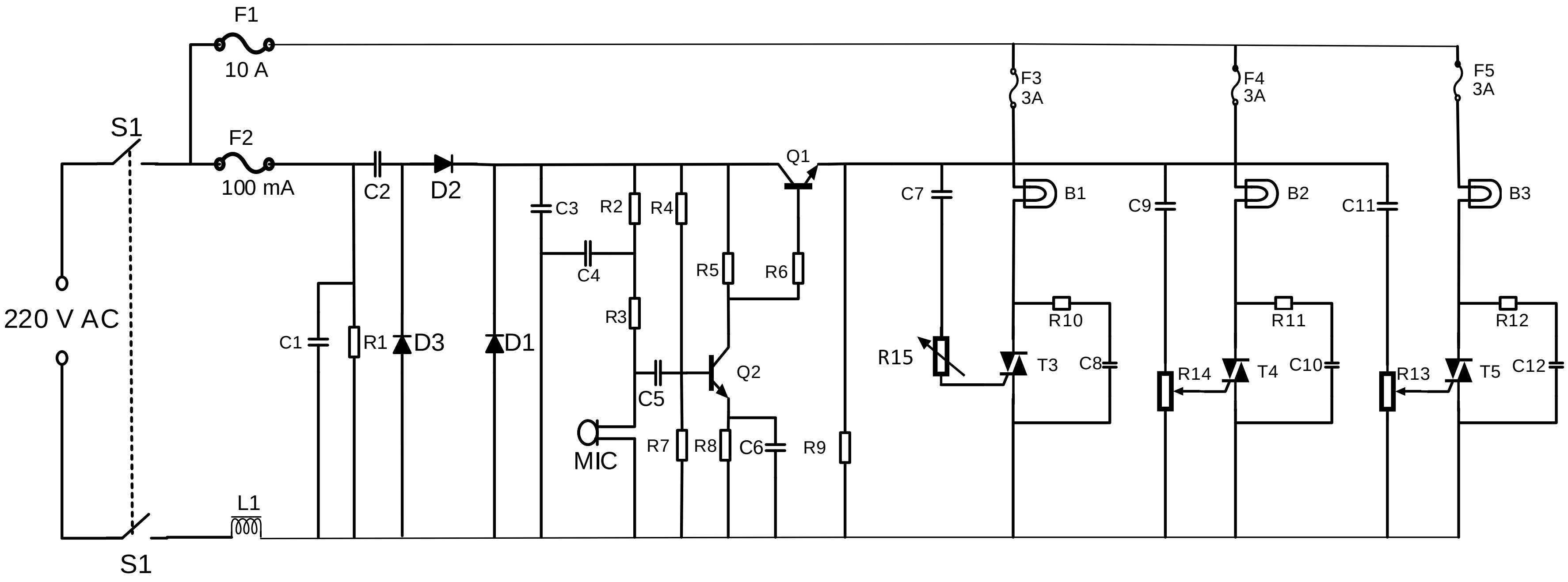
The power-supply part is on the left of the electret microphone amplifier and the light controller part is on the right. The capacitors C2 and C3 are the capacitive voltage divider and reduces the power supply level. Diodes D1 and D2 rectify the positive swing of the AC voltage. The network composed of L1 and C1 protects the power line from voltage surges. In this circuit design, an electret microphone is being used. Take note that there are two types of electret mics. The first type has three pins for power, ground and output. The second type has only two pins. The second type is used for this circuit.

WARNING: Some parts in the circuit board are subject to lethal potential because the device is connected to 230 V AC. When plugging in the project, place it in a plastic or wooden box to prevent the circuit from shocking you. Avoid connecting this circuit to other appliances (e.g. to the output of an amplifier by means of a cable) because of the absence of a mains transformer. Use only the microphone in the main case to pick up the sound.

COMPONENT LIST			
R1	560 kΩ/1 W	C8, C10,C12	0,047 µF
R2, R3	15 kΩ ¼ W	C9	22 µF 16 V
R4	33 kΩ/¼ W	C11	47 µF 16 V
R5, R6, R9	1 kΩ ¼ W	D1, D2	1N4004
R7	18 kΩ ¼ W	D3	1N4742 12v/1 W
R8	560 Ω ¼ W	F1	10 A fuse 220 V
R10, R11, R12	100 kΩ	F2	100 mA fuse 220 V
R13, R14, R15	5 kΩ Pot	F3, F4, F5	220 V 3 A fuse
C1	0,47 uF 630 V	L1	40 µH 6 A 10-15 turns on a ferrite core
C2, C5	0,1 µF/220 V	B1, B2, B3	60 W incandescent lamp
C3	1 000 µF/16 V electrolytic	mic	low-impedance microphone
C4	100 µF/16 V	S1A & S1B	Double-pole switch
C6	25 µF/6 V	T1,T2	BC 547
C7	1 µF 16 V	T3,T4,T5	TIC 106 or BT 136



SOUND-TO-LIGHT CONTROLLER



ALTERNATIVE CIRCUIT

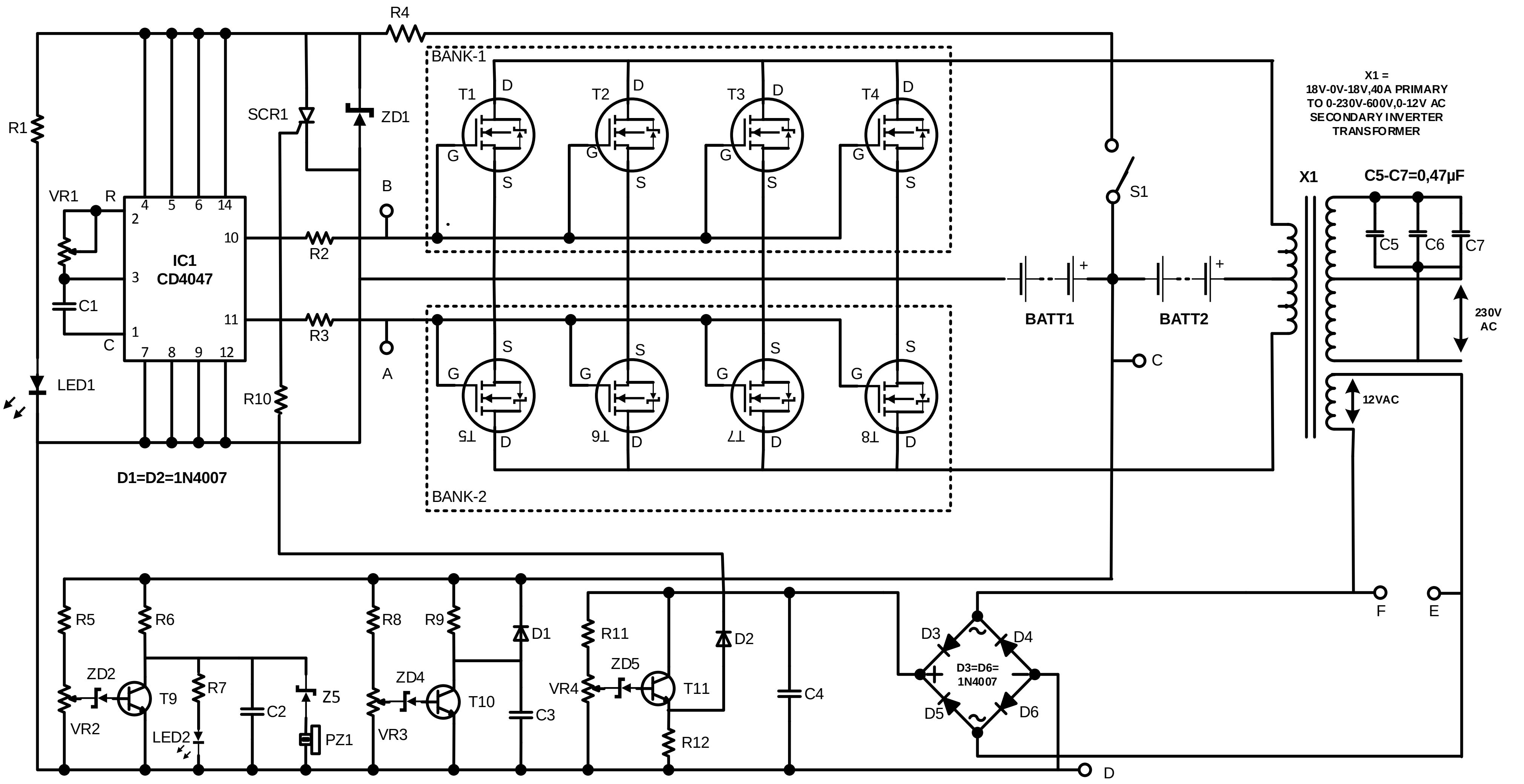
6.3 Practical Project 6.3: Sine Wave Inverter Circuit Diagram

PLEASE NOTE: The sine wave inverter has been included to keep up with the current load shedding trends. If this project is too expensive, the SQUARE WAVE INVERTER can be built. Schools can purchase one transformer and a set of batteries to demonstrate the workings of this project.

An inverter provides power backup for mains-based appliances in the event of a power failure. Most of the inverters available in the market have complicated circuit designs and are not very economical. Some of them produce a square-wave output, which is undesirable for inductive loads.

Here we designed a simple sine wave inverter circuit that produces 50Hz quasi-sine wave output using a single IC CD4047 and some discrete components, which makes it a very cost-effective solution.

COMPONENT LIST	
SEMICONDUCTORS	
IC1	CD4047 multivibrator
SCR1	2P4M SCR
T1 – T8	IRF 250 MOSFET
T9 – T11	BS548 NPN transistor
ZD1	5,1 V, 1W zener diode
ZD2 – ZD5	5,1 V zener diode
D1 – D6	1N4007 rectifier diode
LED1, LED2	5 mm LED
RESISTORS (all 0,25 W, ±% carbon)	
R1	560 Ω
R2, R3	1,2 kΩ
R4,R5,R6, R8, R9, R11	1 kΩ
R12	2,2 kΩ
R7	220 Ω
R10	5,6 kΩ
VR1	470 kΩ pre-set
VR2 – VR4	10 kΩ pre-set
CAPACITORS	
C1	0,2 µF, 100 V ceramic disk
C2,C3	100 µF, 35 V electrolytic
C4	1000 µF, 35 V electrolytic
C5-C7	0,47 µF, 600 V polyester
MISCELLANEOUS	
PZ1	Piezo Buzzer
S1	SPST switch
X1	18-0-18V, 40 A primary to 0-230V-600 V secondary inverter transformer
BATT1, BATT2	12 V (Ah determined by the size transformer)



SINE WAVE INVERTER CIRCUIT DIAGRAM

It comprises a CD4047 multivibrator (IC1), MOSFET, IRF250 MOSFETs (T1 through T8), transistors, and a few discrete components.

IC CD4047 has built-in facilities for a stable and bistable multivibrator. The inverter application requires two outputs that are 180 degrees out of phase. Therefore, IC1 is wired to produce two square-wave output signals at pins 10 and 11 with 50 Hz frequency, 50% duty cycle, and 180-degree phase shift. The oscillating frequency is decided by external pre-set VR1 and capacitor C1.

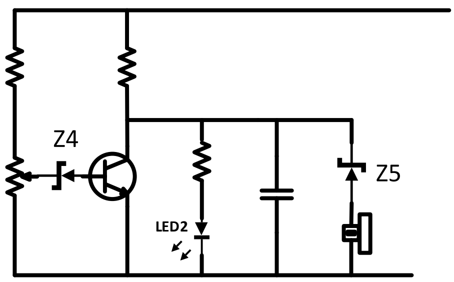
These two signals drive the two MOSFET banks (bank-1 and bank-2) alternatively. When pin 10 of IC1 is high and pin 11 low, MOSFETs of bank-1 (T1 through T4) conduct, while MOSFETs of bank-2 (T5 through T8) remain in the non-conducting state.

Therefore, a large swing of current flows through the first half of the primary winding of inverter transformer X1 and 230V AC develops across the secondary winding. During the next half cycle, the voltage at pin 10 of IC1 goes low, while the voltage at pin 11 is high. Thus, MOSFETs of bank-2 conduct, while the MOSFETs of bank-1 remain non-conducting. Therefore current flows through the other half of the primary winding and 230 V AC develops across the secondary winding. This way an alternating output voltage is obtained across the secondary winding.

The sine wave output is obtained by forming a tank circuit with the secondary winding of the inverter transformer in parallel with capacitors C5 through C7. Two 2,2 µF capacitors are connected to the gates of the MOSFETs in both banks with respect to the ground if a proper sine wave is not produced.

The natural frequency of the tank circuit is adjusted to 50 Hz. Current consumption with no load is only 500 mA due to the 50% duty cycle of the square-wave signal. As the load is increased, current consumption increases. The supply voltage to IC1 is limited to 5,1 volts by using Zener ZD1 and resistor R4 with the external battery.

LOW BATTERY INDICATOR CIRCUIT



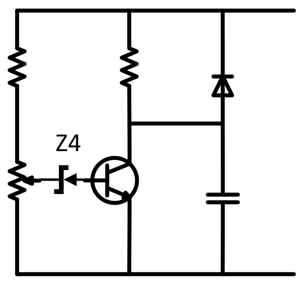
Low-battery indicator circuit diagram

The low-battery indication circuit consists of transistor T9, pre-set VR2, Zener diode ZD2, resistors R5,R6, and R7, LED2, and capacitor C2. The 12 V supply voltage from BATT.1 is applied to the low-battery indicator circuit with a full load (not more than 1 000 watts) connected to the inverter output.

The voltage across the load is 230 V AC. At this instant, adjust pre-set VR2 such that Zener diode ZD2 and transistor T9 conduct to drop the collector voltage to 0.7 volt keeping LED2 'off.' If the supply voltage goes below 10.5 volts, the voltage across the load decreases from 230 V AC to 210 V AC.

At this instant, Zener diode ZD2 and transistor T9 do not conduct, and hence the collector voltage increases to about 10.5 volts and LED2 glows to indicate the low voltage of the battery.

LOW-BATTERY CUT-OFF CIRCUIT



Low-battery Cut-off Circuit Diagram

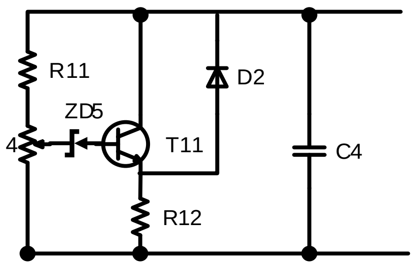
If the battery is discharged to zero volts repeatedly, the battery life will decrease. The low-battery cut-off circuit consists of transistor T10, pre-set VR3, Zener diode ZD4, resistors R8 and R9, capacitor C3, and diode D1.

Adjust pre-set VR3 such that when the voltage across the load is above 200 volts, Zener diode ZD4 and transistor T10 conduct. The collector voltage of T10 is about 0.7 volts in this case and hence the SCR (SCR1) will not conduct. However, if the voltage across the load goes below 200 volts, Zener diode ZD4 and transistor T10 will not conduct and the collector voltage of T10 will increase, causing the SCR to conduct. Once the SCR conducts, the supply voltage to IC1 (CD4047) will be 0.7 volts, due to which IC1 will be unable to produce the voltage pulses at output pins 10 and 11 and the inverter will turn off automatically. During this state, the SCR remains conducted.

The low cut-off of the inverter can be set at the load voltage of 170 volts for the tube light, fan, etc. So the tube light and fan will not be switched off until the voltage goes below 170 volts.

NO-LOAD CUT-OFF CIRCUIT

If there is no load connected to the output of the inverter, the output voltage is 270 to 290 volts. This voltage is sensed by the 0-12V tap at the secondary winding of inverter transformer X1, which is connected to the no-load cut-off circuit comprising Zener diode ZD5, transistor T11, pre-set VR4, resistors R12 and R11, and capacitor C4.



No-load cut-off circuit diagram

When no load is connected, the voltage at the 12 V tap will also increase. This voltage is rectified by the full-wave bridge rectifier comprising diodes D3 through D6, filtered by capacitor C4 and given to transistor T11.

Adjust pre-set VR4 such that if the inverter voltage goes above 250 volts, Zener diode ZD5 and transistor T11 conduct. This increases the emitter voltage; hence the SCR fires to switch the inverter ‘off.’ When a proper load is connected, the inverter will automatically turn on.

SINE-WAVE INVERTER PCB DESIGN

An actual size, single-side PCB for the pure sine wave inverter circuit is shown below.

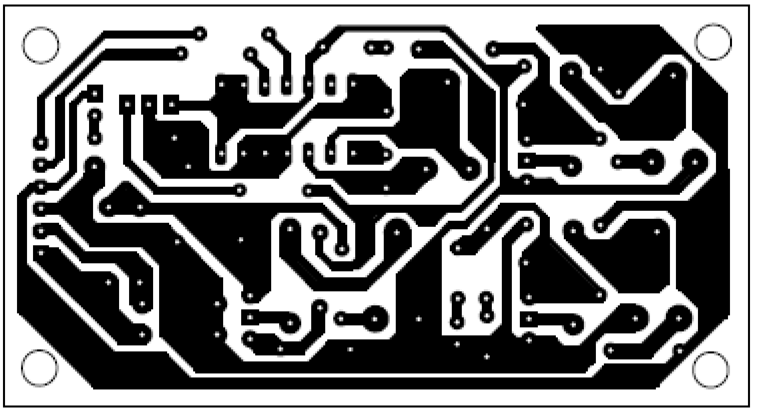


Fig. 2: An actual-size, single-side PCB for the sinewave inverter

A PCB for the sine-wave inverter circuit

A suitable connector CON1 is provided on the PCB to connect the MOSFET banks and the transformer externally. Connector CON1 pins A through F are also marked on the schematic. Assemble the circuit on a PCB as it saves time and minimizes assembly errors. Carefully assemble the components and double-check for any overlooked errors. MOSFETs should be mounted over heat sinks using mica spacers as the insulators between them.

SINE-WAVE INVERTER PCB LAYOUT

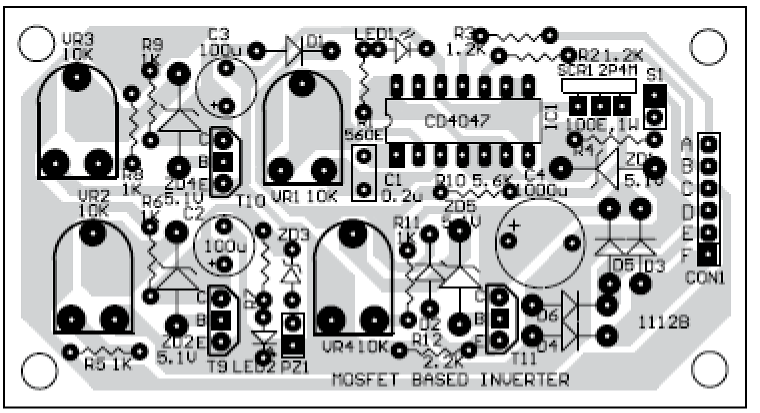


Fig. 3: Component layout for the PCB

Sine-wave inverter PCB layout

Connect the 24V supply terminal directly to the centre tap of the primary winding of the inverter transformer, which carries a maximum current of more than 50 amperes with 1 000 watts.

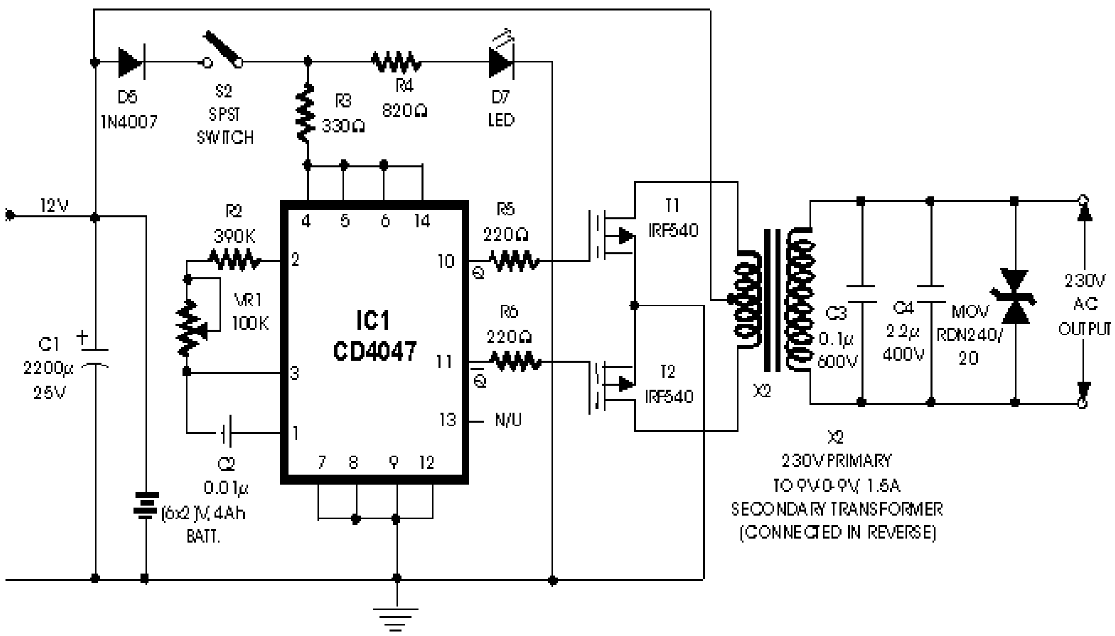
The current depends on the load applied. There is no need to add a switch in the high-current path to make the inverter turn on and off. The inverter can be switched on and off by low-current switch S1.

OR

6.4 Practical Project 6.4: SQUARE WAVE INVERTER 100 W 12 VDC TO 230 VAC BY IC 4047 – IRF540

A 100 W inverter circuit converts 12 VDC to 230 VAC with IRF540. The circuit applied IC 4047 to generate a continuous wave signal and IRF540 to amplify the signal to be stepped up by the transformer.

NOTE: You will need a 2–3 A centre-tapped transformer to handle/supply a 100 W load.



INVERTER 100 W 12 VDC TO 230 VAC BY IC 4047 – IRF540

COMPONENT LIST			
Diode	1N4007	VR1	100 KΩ
C1	2 200 µF	R2	390 KΩ
C2	0,01 µF	R3	330 Ω
C3	0,1 µF	R4	820 Ω
C4	2,2 µF	R5	220 Ω – 330 Ω
D5	1N4007	R6	220 Ω – 330 Ω
D7	LED		
MOV	RDN240/20		
IC 4047 – IRF540		2 x D MOSFET (T1) IRF540	
LED		S2 SPST switch	
Supply 12 V or 12 V DC supply for testing			
TRANSFORMER on circuit diagram optional; a smaller one can be used for testing.			

NOTE: All circuits MUST include an On/Off switch with an ON indicator and fuse protection.

7. CONCLUSION

On completion of the practical assessment task, learners should be able to demonstrate their understanding of the industry, enhance their knowledge, skills, values and reasoning abilities as well as establish connections to life outside the classroom and address real-world challenges. The PAT furthermore develops learners' life skills and provides opportunities for learners to engage in their own learning.