Unit 132: Industrial Robot Technology

Unit code: Y/602/5130

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will develop learners' understanding of the operation and control of industrial robots and will give them the knowledge and skills needed to work safely when producing programs for robots or robot work cells.

Unit introduction

This unit will give learners an understanding of the principles and operation of industrial robots used in modern manufacturing. The unit will cover robot control systems, the different types of sensors used and their application within an industrial robot.

Learners will gain an understanding of the programming methods used and will be required to produce a working program for an industrial robot or robot work cell. The unit will also give learners an understanding of the health and safety and maintenance requirements associated with modern industrial robots.

Learning outcomes

On completion of this unit a learner should:

1 Understand the operating, design and control principles of modern industrial robots and typical robot work cells

2 Understand the operating principles of industrial robot sensors and end effectors

3 Be able to produce a working program for an industrial robot or robot work cell

4 Know the hazards and health, safety and maintenance requirements associated with industrial robots and robot work cells.

Unit content

1 **Understand the operating, design and control principles of modern industrial robots and robot work cells**

Principles of operation: operational characteristics and specifications; types of controller, manipulator, end effector/tooling eg pneumatic suction cup, hydraulic, electrical and mechanical grippers; work space organisation eg feed of work, robot-to-robot work, material flow and logistics

Design principles: manipulator coordinate systems eg cylindrical spherical, jointed, spherical, Cartesian and Selective Compliant Assembly Robot Arm (SCARA) with associated working envelope; wrist articulations eg yaw, pitch and roll, degrees of freedom in terms of translations and rotations; drive mechanisms eg mechanical (ball screws, chain/belt, gears), pneumatic, hydraulic, electrical; speed reducers/gearheads eg harmonic, cycloidal, parallel shaft spur gear, planetary

Control systems: on/off and programmable-integral-derivative (PID) control; closed-loop servo controlled systems eg for driving one axis of a robot; input, output and feedback signals eg the sequence which takes place in order to perform a task; control of three axes of a robot

2 **Understand the operating principles of industrial robot sensors and end effectors**

Sensors: sensor types eg tactile (microswitches/piezoelectric/strain gauge/pressure), non-tactile (capacitive/inductive/light/laser), vision (inspection, identification and navigation); sensor applications eg safety, work-cell control, component/part inspection

End effectors: grippers and tools eg parts handling/transfer, assembly, welding, paint spraying, testing

3 **Be able to produce a working program for an industrial robot or robot work cell**

Operating program: program selection, start-up, test, alterations and operation; types of programming eg manual, walk through, teach pendant methods; off-line programming; planning robot efficient routes; writing programs using flowcharts; work-cell commands eg wait/signal/delay

4 **Know the hazards and health, safety and maintenance requirements associated with industrial robots and robot work cells**

Health and safety requirements: relevant regulations eg Health and Safety at Work Act, Electricity at Work Regulations, Health and Safety Executive publications, Machine Tool Technologies Association Codes of Practice (MTA Safeguarding Codes of Practice – Industrial Robots parts 1–3); human dangers eg during programming, maintenance and as a result of system faults; safety barriers eg 'dead man's handle', hold and emergency stop buttons, pressure pads/matting surrounding robot, infra red curtains and electromagnetic field barriers

Maintenance: inspection routines eg mechanical condition of all parts, environmental conditions (particulate matter, temperature, ventilation, shock, vibration, electrical noise); spare parts required to sustain continuous operation; relevant maintenance tools and test equipment; set-up and maintenance schedules

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 explain the operating principles of a given industrial robot or robot work cell	M1 compare the benefits and limitations of mechanical, pneumatic, hydraulic and electrical drive systems	D1 evaluate an industrial robot or robot work cell installation in terms of its design, operation and control
P2 explain the design principles of a given industrial robot or robot work cell	M2 justify the use of a specific sensor/end effector for a given industrial robot or robot work cell application	D2 test that an industrial robot or robot work cell conforms to specification and performs the programmed tasks correctly and safely.
P3 describe the control systems, including input, output and feedback signals, used to control the operation of an industrial robot or robot work cell to perform a specific task	M3 justify the choice of a safety barrier for a given industrial robot or robot work cell operation	
P4 explain the operating principles of three different types of sensors and their application within an industrial robot or robot work cell	M4 compare two different methods used to program an industrial robot or robot work cell for a specific operation and justify the choice of one over the other.	
P5 explain the operating principles of two different industrial robot or robot work cell end effectors being used to perform a specific task		

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P6 produce and test an operating program for an industrial robot or robot work cell to enable it to carry out a specific function [SM3]		
P7 describe the health and safety requirements for the safe operation of a given industrial robot or robot work cell		
P8 describe maintenance procedures on a given industrial robot or robot work cell.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers CT – creative thinkers RL – reflective learners TW – team workers SM – self-managers EP – effective participators

Essential guidance for tutors

Delivery

There are strong links between the learning outcomes (especially outcomes 1, 2 and 4) and the delivery strategy used should ensure that these links are maintained. The unit could be delivered through a range of lectures, tutor-led demonstrations, assignments, case studies and practical activities and/or industrial visits to see robots in use. Industrial visits would be particularly useful for developing learners' understanding of robotic cells and relevant health and safety.

Delivery of this unit should avoid a wholly theoretical approach and learners should be given an opportunity to carry out practical investigations on robotic systems. However learners should be given support in the early stages of the unit in order to relate theory to practice. For learning outcome 3 the programs should be based around appropriate tasks that are industrially relevant.

Where possible, learners should have access to a complex robotic system either through an industrial robot or training robots. Software which simulates the robotic cell to allow planning and integration of it into the manufacturing operation would be advantageous. Learners should be encouraged to use the working programs that are produced and make adjustments to them, or incorporate other sub-routines to carry out specific functions. These functions should be related to typical and realistic industrial scenarios. Learners are expected to produce flow diagrams for programs and sequences and have an understanding of the advantages and limitations of robotic systems for undertaking operations.

Learners should also be aware of maintenance and health and safety issues and how commissioning, maintaining, upgrading and personnel training, relates to these for robotic systems.

Evidence should include knowledge and understanding of how robots function, their control and design philosophy, the reasons for the choice of end effectors/tools and sensors, the maintenance procedures employed with robots.

The use of computer-based software packages is helpful for learning and for the assimilation of modern-day techniques. Assignments, case studies and project work should, where appropriate, focus on current industrial applications. Industrial visits or work experience would be of real value in supporting learning activities.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: - introduction to unit content, scheme of work and assessment strategy - explain the operational characteristics and specifications of industrial robots and robot work cells - describe types of controllers, manipulators and tooling - explain the need for and methods of work space organisation - explain robot design principles including manipulator coordinate systems, wrist articulations, drive mechanisms and speed reducers/gearheads - explain robot control systems - industrial visit to view industrial robots and robot work cells in operation *Individual learner activities:* - research and investigation of robot design, control and operation
Prepare for and complete Assignment 1: Robot Operation, Design and Control Principles (P1, P2, P3, M1, D1)
Whole-class teaching: - explain the reasons for the choice of end effectors/tools and sensors - explain the operation of different types of robot sensors and end effectors in different applications *Individual learner activities:* - investigation of applications of robot system sensors and end effectors
Prepare for and complete Assignment 2: Sensors and End Effectors (P4, P5, M2)
Whole-class teaching: - explain the health and safety requirements and regulations that need to be followed when working with industrial robots and robot work cells - explain industrial robot and robot work cell maintenance requirements
Whole-class teaching: - explain and demonstrate process for program selection, start-up, test, alteration and operation - explain types of programming and off-line programming - explain planning robot efficient routes, writing programs using flowcharts and use of work-cell commands *Individual learner activities:* - producing working programs for robots or robot work cells
Prepare for and complete Assignment 3: Producing and Testing Operating Programs for Industrial Robots
Feedback to learners, unit evaluation and close

Assessment

Assessment evidence could be gathered from a variety of tests, assignments, case studies and practical activities involving industrial or training robots. Where possible assessment instruments should cover multiple assessment criteria when there are clear links between them, eg P6, M4 and D2.

For P1, learners will need to explain the principles of operation of robots, including types of controller, manipulator, end effector/tooler and work space organisation. This can be linked to P2, so that their explanation also includes robot design principles (manipulator coordinate systems, wrist articulations, drive mechanisms and speed reducers).

Learners will need to describe types and applications of control systems suitable for robots (P3). For P4, learners will need to explain the operation of three different sensors and their different applications. This can be linked to P5 where they will need to provide details of robot end effectors.

For P6, a robot must be programmed and the program produced should be tested. It is suggested that the program should be centred on industrially relevant tasks. A clear awareness of health and safety (P7) and maintenance issues (P8) associated with robots should be shown through the assessment tasks.

To achieve a merit, learners must be able to compare options in the design and actuation of robots and their safe operation and choose and justify choices of end effector in an industrially relevant situation. The ability to have used two programming methods and subsequently to evaluate and compare them is also necessary.

Learners must be able to select and interpret from a range of sources of information, such as manufacturers' literature, textbooks and the internet. Learners should require significantly less tutor help or guidance when carrying out assessable practical activities.

To achieve a distinction, learners must demonstrate the ability to evaluate an industrial robot or robot work cell installation in terms of its design, operation and control. They will also need to test that an industrial robot or robot work cell confirms to specification and performs the programmed tasks correctly and safely.

Learners must demonstrate good interpretation and in-depth use of widely researched sources of information to support and qualify evidence of activities. They will be able to consistently communicate to the highest standard and use a wide range of methods to effectively analyse results of research and investigations and reach well-reasoned conclusions. Learners should require little or no tutor help or guidance when carrying out practical activities for distinction criteria.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1, D1	Robot Operation, Design and Control Principles	A technician needs to evaluate the operation, design and control of a robot to see if improvements can be made	A written report
P4, P5, M2	Sensors and End Effectors	A technician needs to explain to a new apprentice the operating principles of robot sensors and end effectors	A written report
P6, P7, P8, M3, D2	Producing and Testing Operating Programs for Industrial Robots	A technician needs to produce and test an operating program for an industrial robot	A practical task supported by learners' written records and records of tutor observation

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with:

Level 1	Level 2	Level 3
		Health and Safety in the Engineering Workplace
		Selecting and Using Programmable Controllers

Essential resources

Centres delivering this unit should be equipped with, or have access to, an industrial standard robot or smaller educational-standard robots. Learners are expected to undertake programming exercises and be encouraged to set up robot controlled systems/processes.

Employer engagement and vocational contexts

Much of the work for this unit can be set in the context of learners' work placements or be based on case studies of local employers. Manufacturers are usually willing to supply robot details and specifications.

Further information on employer engagement is available from the organisations listed below:

- Work Experience / Workplace learning frameworks — Centre for Education and Industry (CEI -University of Warwick) — www.warwick.ac.uk/wie/cei/
- Learning and Skills Network — www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme — www.stemnet.org.uk
- National Education and Business Partnership Network — www.nebpn.org
- Local, regional Business links — www.businesslink.gov.uk
- Work-based learning guidance — www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbooks

Appin Knowledge Solutions — *Robotics* (Infinity Science Press, 2006) ISBN 9781934015025

Niku S — *Introduction to Robotics* (John Wiley and Sons, 2010) ISBN 9780470604465

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are …
Self-managers	organising time and resources and prioritising actions when producing and testing operating programs for industrial robots or robot work cell

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are …
Reflective learners	setting goals with success criteria for their development and work

Functional Skills — Level 2

Skill	When learners are …
ICT — Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	producing programs for industrial robots or robot work cells
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	reading relevant health and safety regulations
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining the operating and design principles and control systems of industrial robots and robot work cells explaining the operating principles of robot sensors and end effectors

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