QUALIFICATION SPECIFICATION SECTION A							
QUALIFICATION DEVELOPER	**Construction Industry Trust Fund**						
TITLE	**Certificate V in Industrial Mechatronics**					**NCQF LEVEL**	
FIELD	**Manufacturing, Engineering and Technology**			**SUB-FIELD**		**Industrial Mechatronics**	
New qualification	√		Review of existing qualification				
SUB-FRAMEWORK	General Education		TVET	√		Higher Education	
QUALIFICATION TYPE	Certificate	√	Diploma			Bachelor	
	Bachelor Honours		Master			Doctorate/ PhD	
CREDIT VALUE						132	

RATIONALE AND PURPOSE OF THE QUALIFICATION

Rationale

According to the Human Resource Development Council (HRDC) report titled "*Top Occupations in Demand*" (2016), Industrial Mechatronics, a multidisciplinary field that combines several types of engineering disciplines such as electrical, computer, and mechanical to create smarter systems for automation, is one of the occupations identified by employers as being in high demand. Prioritization of occupations in demand is informed by national policies as outlined in the VISION 2036, National Development Plan (NDP 11) and long-term strategies of the different sectors of the economy.

Industrial Mechatronics has a high potential for employment uptake, as it is applicable to most engineering disciplines, which include manufacturing, mining, automotive, mechanised agriculture as well as Energy and Water Resources sectors. Botswana, having no industrial base to manufacture heavy industrial machinery, imports all its machinery and equipment used in all industries from abroad, and as a result spends large amounts of money in flying in experts to repair and maintain this machinery and equipment. The introduction of mechatronics would plug in this identified gap.

In the quest to be more efficient, most industries are going the automation route, and most of the machinery employed are electromechanical, which are going to require mechatronics artisans.

Purpose

Industrial Mechatronics is a combination of mechanical, electrical and control engineering. Modern plants and machinery require the ability to integrate electronics, control, software and mechanical engineering into a range of innovative products and systems.

The Certificate V in Industrial Mechatronics takes on a number of tasks from the areas of mechanical, electrical and information technology. Candidates will develop skills to build and set up complex mechatronics systems. The qualification will develop learners' knowledge and understanding of electronics, electrical engineering, computer technology, control engineering, and mechanical engineering.

Technicians working in the Mechatronics field are required to install, maintain and repair, commission and generally see to the effective running of the various aspects of the system; while applying safety, health, environment and quality systems that govern their workplace.

The industry would greatly benefit from this qualification as it would provide it with the necessary skilled manpower with the requisite competencies to keep their plant and equipment in good working condition, thus contributing to the efficient and effective use of machinery. Large sums of money would be saved as the industry would no longer have to rely on foreign expertise which is both expensive and leads to long turnaround time of stoppage time.

ENTRY REQUIREMENTS (including access and inclusion)

Entry Requirements:

- Certificate IV in General Education (BGCSE) or equivalent
- Certificate IV in Industrial Mechatronics or equivalent qualification – Candidates with a Certificate IV in Industrial Mechatronics or equivalent qualification would be exempted from all Level IV modules
- Recognition of Prior Learning (RPL) – Two (2) years or more industrial experience in industrial mechatronics.
- To promote life-long learning, mature entry candidates would also be considered

QUALIFICATION SPECIFICATION	SECTION B
GRADUATE PROFILE (LEARNING OUTCOMES) **Upon completion of this qualification Candidates will:**	**ASSESSMENT CRITERIA**
• Interpret circuit diagrams, technical drawing and operating instructions.	• Fundamentals of technical communication are explained • Technical drawings are interpreted and drawn according to industry standards • Symbols in hydraulic, pneumatic and electrical circuit diagrams are interpreted according to industry standards • Components of electric hydraulic and pneumatic circuits are identified, and functions explained • Circuits diagrams of electro-hydraulic and electro -pneumatic circuits are interpreted according to industry standards • Working principles of electric, hydraulic and pneumatic circuits are explained • Preparation, compilation and use of technical documentation are carried out according to industry
• Apply principles of mechanical electronics, electrical, control engineering and computer technology.	• Fundamentals of mechanical, electronics, electrical engineering, control engineering and computer technology are explained and applied • Power supplies are identified, and various configurations and circuits are described • Advanced electrics principles and functions of components explained and applied • Principles of power electronics technology are applied • Principles of digital electronics, digital, logic and integrated circuits are distinguished and applied • Electronic components and sensors are identified, and their functions explained • Principles of interfacing electronics are applied • Display devices are identified, and their functions explained • Printed circuit boards are produced according to specified industry standards
• Apply principles of mechatronics systems to provide technological solutions	• Evolution of mechatronics technology is explained, and different applications are identified • Mechatronics system components are identified and their functions are explained. • Constructions and operations of mechatronic systems elements are identified and their functions explained

	• Components of mechanical systems are differentiated, and their functions explained. • Different types of signals and conditioning devices are identified, and their operation and functions are explained • Various digital logic system used to control overall system operation are identified and their functions are explained • Various software is used to control the acquisition of data and data acquisition systems signals and conditioning devices are identified, and their functions are explained • Computers and display devices are identified, and their functions explained.
• Integrate mechanical, electrical and electronics components	• Constructions, operations and functions of mechanical, electrical and electronics components are identified • Constructions and operations of electro- pneumatic and electro- hydraulics systems are explained • Different components of the mechanical systems and electro-mechanical are assembled, tested and maintained according to procedure and specifications • Various components of the electrical and electronic systems are assembled, tested and maintained according to procedure and specifications • Computers and display devices are assembled, tested and maintained according to procedure • Various sensors are positioned to detect the state of the system parameters, inputs and outputs • Hydraulic and pneumatic actuators are installed, tested and maintained according to industry standards • Electro -pneumatic and electro -hydraulic systems are installed, tested and maintained according to procedure and specifications. • Faults are identified and rectified during assembling, testing and maintenance actives • Information technology, digital control systems and control electronics are used to control mechatronics systems

• Apply industrial software and applications	• History Evolution of Industry 1.0 to 4.0 are explained • Principles of computers, system software and application software are explained and applied • Hardware and software are installed, used, configured, tested and maintained according to industry standards • Local area network (LAN) are installed, configured and maintained according to industry standards • Input and Output signal conditioning devices are configured and programmed to receive and send signals via interfacing devices and sensors. • Various display devices are installed and used to give visual feedback. • Various digital logic systems are configured and programmed to control overall system operation according to specifications. • Various software are programmed to control the acquisition of data according to specifications. • Manual and software driven variable speed control drives and BUS systems are installed tested and configured • Computers are used and maintained to store and process data according to industry standards.
• Test and Commission mechatronic systems	• Electric installations are inspected before controllers are commissioned. • Commissioning of individual devices and functional groups are conducted before the entire system is commissioned. • Procedure for commissioning of mechanical, electrical components is described and performed according industry standard • Procedure for commissioning of electro-pneumatic and electro-hydraulics elements is described and carried out according industry standard • Subsystems are operated according to industry standards under trial conditions • Mechatronic systems components are inspected and tested conducted before the entire system is commissioned • Installation and programming errors are correctly eliminated at the end of commissioning. • The entire mechatronics system is commissioned according correct procedure • The commissioning report, individual components report and handover report are documented according industry standard.
• Apply power electrical systems principles	• Principles of Electrical Safety is identified and applied • Various types of transformers are identified, working principles, functions and features explained

	• Elements and types of Electrical Drives are identified, selected, and principles applied • Types, construction and operating principles of AC/DC motors are identified and explained • EMC/EMI effects, design techniques, and standards, and principles are applied • EMI/EMC Compliance and Testing Services are identified and applied according industry standard • Three phase AC/DC machines, control and switch geared installed, commissioned, tested and maintained, according industry standard
• Perform machining operations and other workshop practices	• Bench work and measurement techniques are applied to perform metal work tasks and assemble components according industry standard • Tool Organizer Board are Manufactured according industry standard • Components are produced by machining using lathes, milling machines, and grinders of different types. • Machine tools are used to perform drilling, thread cutting and reaming operations • Fundamentals of CNC Machining and practices are explained and applied. • CNC Tools are identified and used according industry standard • Various Coordinate Systems are identified and described • CNC Programming Language structure, editor, and various codes are described and applied. • CNC Turning fundamentals are identified and applied • CNC Milling setups, fixture components, work coordinate systems, machine and tool offsets are identified and applied according industry standard

QUALIFICATION STRUCTURE SECTION C			
	Title	**Level**	**Credits**
FUNDAMENTAL COMPONENT Subjects / Units / Modules /Courses	Occupational Health & Safety	4	2
	Entrepreneurial principles	4	2
	Technical Mathematics	4	3
	Physics	5	3
	Information and Communication Technology Basics	5	2
	Technical Communication	4	3
	Planned Maintenance	4	2
	Measurement Techniques	5	3
	Manufacturing technology	5	2
			22
CORE COMPONENT Subjects / Units / Modules /Courses	Engineering Material Processes	5	3
	Mechanical Workshop Processes	5	5
	Computer Aided Draughting for Engineers	5	5
	Electrical Engineering Systems	5	8
	Pneumatics and Hydraulics	4	4
	Analogue & Digital Electronics	5	8
	Mechatronic Application Systems	5	8
	Programmable Logic Controllers	5	4
	Software Programming	5	5
	Control Engineering Systems	5	8
	Heating Ventilation and Cooling (HVAC)	5	4
	Electro-Mechanical Components Repairs	5	8
	Installations Testing & Commissioning Systems	5	5
	Mechatronics Systems Maintenance	5	4
	Electrical Tools Operations	4	4
	CNC Machine Tooling	5	5
	Fourth Industrial Revolution	4	2
	Industrial Attachment	5	**10**

			100
ELECTIVE COMPONENT Subjects / Units / Modules /Courses	Computer Program Design	**5**	**5**
	Risk management	**5**	**5**
	Project Management	5	5
	Quality Management System (QMS)	5	5
	Mechatronics Systems Design	5	5
	Leadership management and communication	5	5
	Advanced Industrial Programmable Logic Controllers	5	5
			10
	Total		**132**

Rules of combinations, Credit distribution(where applicable):

The qualification consists of Fundamental, Core and elective Components.

To be awarded the Qualification learners are required to obtain a minimum of 132 credits as detailed below.

Fundamental Components:
The Fundamental components consist of foundational knowledge in Industrial Mechatronics to the value of 22 credits all of which are compulsory

Core Components:
The core components consist of modules containing applied knowledge and practical skills to the value of 100 credits which are compulsory.

Elective Components:
Learners are to choose two (2) electives to the value of 10 credits so as to attain a minimum of 132 credits for the qualification.

Modules	Fundamental	Core	Electives	Sub total
LEVEL 4	**12**	**6**	**0**	**18**
LEVEL 5	**10**	**94**	**10**	**114**
Total Credit	**22**	**102**	**10**	**132**
Total Credit Value			**132**	

ASSESSMENT AND MODERATION ARRANGEMENTS

All assessments leading to the award of credits or a qualification shall be based on learning outcomes and/or sub-outcomes. Consistent to the TVET Sub-framework right hand rule, more weighting shall be given to performance tasks as opposed to knowledge and theory.

The qualification shall be assessed through a combination of both Continuous Assessment (Formative) and Final Examination (Summative).

In line with the Modularized Competency Based Assessment, learners are required to successfully complete one module before proceeding to the next progressive module.

1. Formative assessment

- Formative assessment will be conducted to inform learning, remedial training and establish the learner's level of readiness for progression to the next learning unit or module. This shall include knowledge-based assignments, self-assessments and tests, projects, and practical work.
- Formative shall constitute 60% of the Final grade

2. Summative assessment

- Summative assessment will be conducted per module and shall constitute 40% of the Final grade. It shall be in the form of an examination comprising theory and practical for each module completed.

3. Documentation

- All necessary documents including qualification document, alignment matrices, assessment instruments and Assessment criteria should be available.

4. Internal Moderation

There shall be a robust internal moderation system performed by BQA registered moderators. Amongst the activities of the internal moderation process, the following activities shall be carried out:

- Determining that the assessment strategy to be used is appropriate for the learning outcome to be assessed;
- Determining that the assessment instrument adequately captures the learning outcomes against which the assessment is to be carried out;
- Determining whether the assessment tasks or questions can enable the assessor to collect sufficient evidence that is typical of relevant exit level descriptors;
- Checking if the cover page contains all necessary information;
- Checking if the assessment instrument layout is appropriate and that wording of assessment tasks or questions is appropriate; and
- Checking if the assessment criterion is consistent with the learning outcomes against which the assessment is to be done.

5. External Moderation

External Moderators, consisting of BQA registered moderators from local TVET ETPs that are accredited would verify that the assessment has been done in compliance with assessment principles. This shall include:

- Checking if all scripts have been assessed using the same criteria;
- Verifying if assessment judgments and decisions have been done consistently and that principles such as validity, authenticity, currency and sufficiency have been considered;
- Checking if calculation of marks has been done correctly; and
- Checking if necessary, whether records and reports have been completed.

5.1 Sampling Procedure for Moderation

The total number of scripts to be sampled shall be dependent on the total number of candidates. For a small number of candidates, the moderator may go through all the papers, while for larger groups the percentage of scripts to be moderated shall increase such that the sample is representative of the population of candidates in relation to performance, gender, etc.

5.2 Moderation reports

A moderation report shall capture, but not limited to the following:

- Sample size and sampling procedures
- observations about the performance of candidates
- consistency of assessment judgments and decisions
- assessment instruments and alignment to learning outcomes
- recommendations for improvement

RECOGNITION OF PRIOR LEARNING (if applicable)

Candidates may submit evidence of prior learning and current competence and/or undergo appropriate forms of RPL assessment for the award of credits towards the qualification in accordance with applicable RPL policies and relevant national-level policy and legislative framework.

Implementation of RPL shall also be consistent with requirements, if any, prescribed for the field or sub-field of study by relevant national, regional or international professional bodies.

PROGRESSION PATHWAYS (LEARNING AND EMPLOYMENT)

Articulation and Education Pathways

Horizontal Articulation: Graduates of this qualification may consider pursuing to other qualifications on the same levels in the field of Electronics such as:

- Certificate V in Instrumentation
- Certificate V in Mechanical Engineering
- Certificate V in Electrical Engineering
- Certificate V in Electronics Engineering
- Certificate V in Control Engineering

Vertical Articulation: Learners may progress to higher level in the same field such as:

- Diploma in Instrumentation
- Diploma in Industrial Mechatronics
- Diploma in Automotive Mechatronics
- Diploma in Electrical Engineering
- Diploma in Electronics Engineering
- Diploma in Mechanical Engineering
- Diploma in Control Engineering

Diagonal Articulation: Learners may progress to the next upper level in a different Sub Framework such as:

- Diploma in Vocational Education and Training
- Diploma in Business Management
- Diploma in Project Management

Employment Pathways

Learners who attain this qualification will have competencies and attributes to work as:

- Mechatronic Technician
- Automation Technician
- Plant Maintenance Technician

QUALIFICATION AWARD AND CERTIFICATION

Minimum standards of achievement for the award of the qualification.

The candidate must have met the following requirements:

- All exit level outcomes
- Minimum 132 credit requirements
- All qualification requirements including modules.

Certification

Upon completion of the qualification the candidate will be awarded a **CERTIFICATE V IN INDUSTRIAL MECHATRONICS**

REGIONAL AND INTERNATIONAL COMPARABILITY

Public and private training providers worldwide offer short courses in Mechatronics. Such short courses focus on the installation, assembly, and maintenance of various mechatronic systems. Comparable examples of Mechatronics qualifications at this level were not located in any of the SADC countries, except South Africa. However, Namibia and Zimbabwe (University of Chinhoyi) do offer mechatronics at bachelor's degree level. This certificate in Industrial Mechatronics NCQF level 5 has been compared with qualifications from the below countries:

South Africa:

1. BMW SA, in South Africa offers an NQF Level 5 called the **National Certificate in Mechatronics.** The qualification has 141 credits broken down as follows:
   - Fundamental – 5
   - Core - 116
   - Electives - 10
   - Offered at Level 5 on the NQF and titled **National Certificate in Mechatronics**
   - 141 credits broken down as follows: Fundamental – 15, Core – 116, Elective – 10

This qualification is skills based and emphasis is thus on performance outcomes as opposed to knowledge outcomes.

2. The Buffalo City TVET College in East London has a Mechatronics qualification at levels 2, 3, and 4 of the NQF. The national certificate Mechatronics is a full year programme at each of the NQF levels of study. A student is issued with a certificate on the successful completion of each level of study that is Level 2, Level 3 and Level 4.

In order to obtain a National Mechatronics Certificate, students are required to study a total of 7 subjects. These include 3 fundamental subjects and 4 vocational subjects, of which 3 are compulsory and 1 is optional.

The vocational subjects in Mechatronics are:

- Introduction to Computers
- Electro technology
- Manual Manufacturing
- Mechatronics Systems
- Stored Programme System
- Machine Manufacturing
- Computer- Integrated Manufacturing

These subjects are offered at each of the different NQF levels of study in the National Certificate Mechatronics qualification.

United Kingdom

Siemens in the United Kingdom offers a qualification called **Siemens Mechatronics System Certificate Programme,** is skilled based and covers domains that include Electrical Components, Mechanical Components and Electrical Drives, and Manufacturing Processes.

The qualification is designed to complement and enhance existing study pathways not replace them. Its goal is to prepare learners to be more effective, more quickly, in the intended working environment. Exit level outcomes are as follows:

- Efficiently operate complex mechatronic systems, troubleshooting and foreseeing problems
- Systems management, investigation, repair and troubleshooting
- Operate complex mechatronic systems at a professional level

United States of America

1. The Carnegie Mellon University, under its **Open Learning Initiative** has a 30 credit **NSC Mechatronics Technology Certificate** qualification mapped to the Siemens Mechatronic Systems Level 1 certification. The qualification has learning outcomes in the categories of Safety, Applied Mathematics, Foundational Principles, Critical Thinking/Problem-Solving, Equipment, Troubleshooting, Technical Literacy, Documentation, Communication, Interpersonal Interaction, and Cultural and Social Awareness. These outcomes are broad themes of the program, achieved in one or more of its courses: Learning Modules include:
    - Autonomous Robots
    - Engineering CAD and Drafting
    - Electrical Systems
    - Industrial Robots
    - High –Tech Manufacturing
    - Manufacturing Processes
    - Mechanical Systems
    - Mechatronic Capstone
    - PLCs
    - Pneumatics and Hydraulics
    - Welding

2. The Piedmont Technical College in the state of Georgia offers a 12 credit mechatronic qualification called **Introduction to Automation Certificate.** Its broad outcomes include the installation, assembly, and testing of automated systems.

    Domains covered include:
    - Robotics
    - Microprocessors
    - Programming Logic Control

    Assessment is integrated and includes both theory and practice.

3. The Monroe Community College, under the State University of New York has a **Mechatronics Certificate Program** running for two semesters and carrying a total of 30 credits. The qualification prepares graduates for entry-level positions that involve the operation and maintenance of electro-mechanical-computer controlled systems commonly found in automated manufacturing environments. Systems-level analysis, assembly, and troubleshooting techniques are stressed with hands-on laboratory experiences to complement classroom-based instruction.

4. Upon completion of the program, graduates will be qualified for the jobs such as Equipment Maintenance Technician and Industrial Equipment Maintenance Technician. They will have the knowledge required to assemble systems, troubleshoot, repair, and upgrade machinery and the associated control systems.

    The Learning Outcomes are as follows:

    - Interpret electrical schematics to analyze the electrical operation of industrial equipment.
    - Interpret pneumatic and hydraulic schematics to determine the mechanical sequencing of industrial equipment.

- Explain the role of Programmable Logic Controllers (PLC) to monitor and control the production process.
- Demonstrate proper use of diagnostic tools to identify system malfunctions.
- Perform corrective and preventive maintenance procedures on industrial equipment.
- Identify common safe job practices associated with industrial equipment maintenance.
- Construct a function-sequence chart for industrial equipment.
- Develop a personalized troubleshooting process to diagnose and repair system failures.
- Work within a team environment to maintain production equipment.

Germany

The RWTH International Academy, which is part of the RWTH Aachen University, has a summer course in **Mechatronic Systems Engineering and Product Innovation.** The Summer School of mechatronic systems engineering and product innovation will introduce the learner to the fundamentals and challenges related to the engineering of mechatronic systems. Mechatronics is a dynamic, multidisciplinary subject combining three engineering fields: mechanical, electrical and software engineering. This complex intermeshing of disciplines requires profound technical expertise.

This highly integrated approach creates smart, inventive and evermore efficient solutions for a wide range of high-tech engineering problems. Learning Outcomes include:

- Fundamentals of Machine Elements in Mechanical Design
- Introduction to Mechatronic and Robotic
- Information Theory and Coding
- Introduction in Electrical Drives

An intensive practical part will provide great opportunities to apply all the gained knowledge. The subjects can obviously only be treated with a limited level of detail, but must be detailed enough to apply the concepts on a design project which the learners work on in competitive teams.

Comparability

This qualification compares very well with the qualifications it was benchmarked against in terms of content, exit level outcomes, and the number of credits that lead to an award. What however sets this qualification apart from the qualifications it was benchmarked is that it is a full trade, hence the number of 132 credits. The qualification also has both fundamental and elective module which add more value to it as a full qualification.

The qualification was adopted from a similar one in Germany contained in a qualification document called *Ordinance on Vocational Education and Training in the Occupation of Mechatronics Fitter.* In Germany, the qualification is completed in 4 years with a total of 1020 hours, which translates into 102 credits. The Summary of Learning Fields for the occupation of Mechatronic Fitter are as follows:

- Analysis of functional correlations in mechatronic systems
- Production of Mechanical sub-systems
- Installation of Electrical equipment in accordance with technical safety aspects
- Investigation of the energy and information flows in electrical, pneumatic and hydraulic sub-assemblies
- Communication through the assistance of data processing systems
- Planning and Organising work processes
- Creation of simple mechatronics components
- Design and development of mechatronics systems
- Investigation of information flows in complex mechatronics systems

- Planning of Assembly and Disassembly
- Commissioning, troubleshooting, and repair
- Preventative Maintenance
- Handover of mechatronics systems to customers

The proposed qualification compares well with the German qualification and they share similar features such as the number of credits and emphasis of performance outcomes as opposed to knowledge outcomes.
The qualification also has many similarities with the South African qualification which has its origins in Germany. This could be attributed to the fact that most of the equipment and machinery used in most industries both in South Africa and Botswana are from Germany.

REVIEW PERIOD

This qualification shall be reviewed after 5 years from the date of registration. Should there be a need for a review of the qualification before the elapse of the 5 year stated period, the review process shall be carried out, and all the concerned stakeholders shall be involved in the process.

Other information – please add any supplementary information to help the application for this qualification for NCQF Registration.

This qualification is institutional and the delivery methodology will follow the Competency Based Modular Training (CBMT) approach, an Outcomes Based delivery method best suited for a skills-based training programme.

The CBMT method is very flexible and also individualised. The foregoing therefore allows the learners to have the latitude of choosing the number of modules or units sufficient enough to be awarded a part qualification or taking all the required modules to be awarded a full qualification.

The above align very well with the principles of credits accumulation and lifelong learning.

To ensure a smooth adaptation to this learning method, there is a pre-requisite learning module called Orientation to CBMT, which the learner has to undertake before commencement of the training programme.