Republic of Rwanda
Ministry of Education

RTB | RWANDA TVET BOARD

CSAES401

EMBEDDED SYSTEM HARDWARE DEVELOPMENT

Develop Embedded System Hardware

Competence

RQF Level: 4

Learning Hours 120

Credits: 12

Sector: ICT and Multimedia

Trade: Computer System and Architecture

Module Type: Specific

Curriculum: ICTCSA4001 TVET Certificate IV in Computer System and Architecture

1200

Issue Date: September 2023

<table>
<tr><td>Purpose statement</td><td colspan="6">This module describes the skills, knowledge and attitude required to Develop Embedded System Hardware. This module is intended to prepare learners pursuing TVET Level 4 in Computer System and Architecture. At the end of this module the learners will be able to Setup workplace, Build and Integrate Embedded system Hardware.</td></tr>
<tr><td>Learning assumed to be in place</td><td colspan="6">▪ Digital Electronics
▪ Electronic Circuit Implementation
▪ PCB and Computer System Assembling
▪ Basics of Technical Drawing
▪ Electronic Fundamentals
▪ Basics of Electricity
▪ Applied Chemistry</td></tr>
<tr><td rowspan="6">Delivery modality</td><td colspan="2">Training delivery</td><td>100%</td><td colspan="2">Assessment</td><td>Total 100%</td></tr>
<tr><td colspan="2">Theoretical content</td><td>30%</td><td rowspan="4">Formative assessment</td><td>30%</td><td rowspan="4">50%</td></tr>
<tr><td colspan="2">Practical work:</td><td rowspan="3">70%</td><td rowspan="3">70%</td></tr>
<tr><td>Group project and presentation</td><td>30%</td></tr>
<tr><td>Individual project /Work</td><td>40%</td></tr>
<tr><td colspan="2"></td><td colspan="3">Summative Assessment</td><td>50%</td></tr>
</table>

Elements of Competence and Performance Criteria	
Elements of competence	**Performance criteria**
1. Setup workplace	1.1 Embedded system requirements are properly identified based on customer needs
	1.2 Tools, materials and equipment are properly identified according to the work to be done.
	1.3 The workplace is correctly organized based on standard operation procedures (SOP) document
2. Build Embedded system hardware	2.1 PCB Electronic Design software (CAD software) is appropriately selected in accordance with design requirements
	2.2. Circuits schematic diagrams are accurately designed based on Hardware requirements
	2.3. Circuit simulation and optimization are properly executed according to desired system functionality.
	2.4. PCB Layout is systematically designed with respect to the Circuit schematic diagram.
	2.5. PCB is correctly printed and Assembled according to circuit design
3. Integrate Embedded System Hardware	3.1. Hardware parts and peripherals specifications are properly assessed based on systems designs.
	3.2. Hardware system parts are correctly interconnected according to the system design.
	3.3. Required Peripherals are appropriately installed based on hardware design.
	3.4. Embedded system hardware is systematically tested in accordance with its functionality.

	3.5. Embedded system hardware is correctly documented based on the work done.

Intended knowledge, skills and attitude

knowledge	Skills	Attitude
✓ Describe Embedded System Fundamentals ✓ Define Hardware Integration concepts ✓ Identify Simulation software ✓ Describe Electronic fundamentals ✓ Define Principles of computer-aided design ✓ Describe applications of Microcontroller and Microprocessor ✓ Describe soldering/Desoldering	✓ Design PCB ✓ Interpret Technical drawing ✓ Solder /desolder electronic components ✓ Test embedded system hardware ✓ Troubleshoot embedded system hardware ✓ Apply electronic measurements ✓ Elaborate technical report	✓ Time management ✓ Passion ✓ Creativity ✓ Integrity ✓ Reliability ✓ Honesty ✓ Adaptability ✓ Team work ✓ Confidence ✓ Persistence ✓ Safety Consciousness ✓ Attention to Detail

Course content

Learning outcomes	**At the end of the module the learner will be able to:** 1. Setup workplace 2. Design Embedded system hardware 3. Integrate Embedded system Hardware

Learning outcome 1: Setup workplace	Learning hours: 30
Indicative content	

- **Identification of Embedded system requirements**
  - ✓ Description of embedded system
    - Definition
    - Types
    - Characteristics
    - Applications
  - ✓ Microcontrollers and Microprocessors
  - ✓ Memory (ROM and RAM)
  - ✓ Input/Output (I/O) Interfaces
    - Digital Input/Output (GPIO)
    - Analog Input/Output (ADC/DAC)
    - Serial Communication Interfaces (UART, SPI, I2C, CAN,…..)
    - Networking Interfaces (Ethernet, Wi-Fi, Bluetooth,.)
  - ✓ Peripherals requirement
    - Timers (Real-Time Clock (RTC)
    - Counters
    - PWM controllers
    - DMA Controllers
    - Watchdog timers
    - Drivers
  - ✓ Power Supply
  - ✓ Real-Time Operating System (RTOS)
    - Interrupt Handling
    - Error Handling
    - Scheduling
  - ✓ Determination of the Application Scope
    - Gather information about the application
    - Functional Requirements
    - Performance
    - Environmental Constraints
    - Power Requirements

- Communication Requirements
- Safety and Regulatory standards
- User Interface Requirements
- Scalability and Future Expansion constraints
- Cost and Budget Constraints

✓ Conduct Risk Analysis
✓ Enclosure and Physical Interface
✓ Workplace safety measures

- **Identification of tools, materials and equipment**

✓ Types of tools
✓ Types of materials
✓ Types of equipment

- **Organising the work place**

✓ Apply safety measures
✓ Arrange tools, materials and equipment

Resources required for the learning outcome	
Equipment	▪ Microcontroller Development Kits (with debugger and programmer) ▪ 3D Printer ▪ CNC machine ▪ Pick-and-Place Machine ▪ Reflow Oven ▪ Wave Soldering Machine ▪ PCB Milling Machine ▪ ESD-Safe Workstations and Benches ▪ Environmental Chambers (temperature and humidity testing) ▪ EMI Test Equipment ▪ Thermal Imaging Camera ▪ Automated Test Equipment (ATE) ▪ In-Circuit Test (ICT) Systems ▪ PCB Inspection System (AOI, Automated Optical Inspection) ▪ IC Programmers (EEPROM Programmers) ▪ Multimeters ▪ Oscilloscopes ▪ Soldering Station ▪ Hot Air Rework Station ▪ Function Generators ▪ Network Analyzers ▪ Spectrum Analyzers ▪ Power Analyzer

	▪ Logic Analyzers ▪ Signal Generators ▪ Power Supplies ▪ Heat Gun ▪ Hot Glue Gun
Materials	▪ PCB Copper Clad. ▪ Passive Components ▪ Sensors ▪ Actuators ▪ Active components ▪ Enclosure Materials ▪ Connectors ▪ Insulating Materials ▪ Thermal Interface Materials ▪ Adhesives and Sealants ▪ Heat Sink Materials ▪ Display Materials ▪ Wires ▪ Glue ▪ Soliderıng tin ▪ Soliderıng paste
Tools	▪ Soldering Iron ▪ Wire Cutters and Strippers ▪ Tweezers ▪ Screwdrivers (including precision screwdrivers) ▪ Pliers (including needle-nose pliers) ▪ Scissors ▪ Crimping Tools ▪ ESD-Safe Mats and Wrist Straps ▪ ESD-Safe Brushes ▪ Logic Probes and Test Leads ▪ Bench Vises ▪ PCB Holder and Third Hand Tool ▪ Magnifying Glass or Loupe ▪ Desoldering Pump or Solder Wick ▪ Breadboards and Prototyping Boards ▪ Wire Wrapping Tool ▪ PCB Design Software ▪ CAD Software for Mechanical Design ▪ Flying Probe Testers ▪ Vibration Testers ▪ Ultrasonic Cleaner

	▪ Boundary Scan Testers (JTAG Testers)
Facilitation techniques or Learning activity	▪ Group Discussion ▪ Demonstration ▪ Individualised work ▪ Practical exercise
Formative assessment methods /(CAT)	▪ Written Assessment ▪ Practical Assessment ▪ Performance Assessment ▪ Product based Assessment

Learning outcome 2: Build Embedded system hardware	**Learning hours: 60**
Indicative content	

- **Selection of PCB Electronic Design software (CAD software)**
  - ✓ Description of CAD software
    - Types
    - Features
    - Application
  - ✓ Assessment of Designing Complexity
    - Consider Design Type (Analog, Digital, Mixed-Signal, etc.)
    - Available Libraries of Components and Symbols
    - Simulation and Analysis Capabilities (SPICE, SI, Thermal, EMI)
    - PCB Design and Layout Features
    - Ease of Use and Learning Curve
    - Integration with Other Tools and Formats
  - ✓ Vendor Support and Updates
    - Frequency of software updates

- Cost and Licensing
- Community and User Feedbacks
- Industry Standards Compliance
- Trial and Evaluation

- **Designing circuits schematic diagrams**
  - ✓ Creation of block diagrams
  - ✓ Selection of components and footprint assignment
  - ✓ Determine the connectivity and schematic software
  - ✓ Follow design guide lines
  - ✓ Label components and signals
  - ✓ Annotate Components
  - ✓ Validate and review
  - ✓ Update iteratively
- **Circuit simulation and optimization**
  - ✓ Circuit Simulation
    - Select a Simulation Tool
    - Specify Simulation Settings
    - Run the Simulation
    - Analyse Results
  - ✓ Circuit Optimization
    - Identify Goals and Constraints
    - Choose an Optimization Tool
    - Specify Optimization Parameters
    - Run the Optimization
    - Evaluate Results

- ✓ Refine the Circuit Design

- **Systematic designing of PCB Layout**
  - ✓ Interpret the schematic diagram
  - ✓ PCB Layer stackup design
  - ✓ PCB Prototype
  - ✓ Export file

- **Print and Assemble PCB**
  - ✓ Printing using CNC
    - Prepare materials and tools
    - CNC Machine Setup
    - Upload gerber file
    - CNC Milling and Drilling
    - PCB Inspection and Cleaning
    - Silkscreen Placement
    - Component placement
    - Test the circuit
  - ✓ Printing using Chemicals
    - Preparing the Copper Board
    - Transferring the PCB Design
    - Removing the Paper
    - Etching
    - Cleaning and Finishing
    - Drilling and Assembling
    - Circuit testing
  - ✓ Documentation

- Schematic Drawings
- Bill Of Material
- PCB Specification information

Resources required for the indicative content	
Equipment	▪ Drilling machine ▪ Flat Iron ▪ Heat Gun ▪ LaserJet printer ▪ Glass container ▪ CNC machine ▪ Pick-and-Place Machine ▪ Reflow Oven ▪ Wave Soldering Machine ▪ PCB Milling Machine ▪ Automated Test Equipment (ATE) ▪ In-Circuit Test (ICT) Systems ▪ PCB Inspection System (AOI, Automated Optical Inspection) ▪ IC Programmers (EEPROM Programmers) ▪ Multimeters ▪ Logic Analyzers ▪ Signal Generators ▪ Power Supplies ▪ Oscilloscopes ▪ Soldering Station ▪ Hot Air Rework Station ▪ Function Generators ▪ Network Analyzers ▪ Spectrum Analyzers

	▪ Power Analyzer
Materials	▪ Copper Clad ▪ film or paper ▪ Ferric chloride or ammonium persulfate ▪ Plastic or glass container for etching ▪ Rubber gloves ▪ Masking tape ▪ Water source ▪ Active components ▪ Drilling bit ▪ Fine sandpaper or abrasive pad ▪ Acetone or nail polish remover ▪ Soldering wire(Solidering tin) ▪ Soft brush or sponge ▪ Passive Components ▪ Enclosure Materials ▪ Connectors ▪ Insulating Materials ▪ Thermal Interface Materials ▪ Adhesives and Sealants ▪ Heat Sink Materials ▪ Display Materials ▪ Wires ▪ Glue ▪ Printed Circuit Board (PCB) Materials ▪ Semiconductor ▪ Sensors and actuators ▪ Soldering paste
Tools	▪ Soldering Iron

	▪ Clean cloth or paper towels ▪ Sink or basin ▪ Wire Cutters and Strippers ▪ Tweezers ▪ Screwdrivers (including precision screwdrivers) ▪ Pliers (including needle-nose pliers) ▪ Scissors ▪ Crimping Tools ▪ ESD-Safe Mats and Wrist Straps ▪ ESD-Safe Brushes ▪ Logic Probes and Test Leads ▪ Bench Vises ▪ PCB Holder and Third Hand Tool ▪ Magnifying Glass or Loupe ▪ Desoldering Pump or Solder Wick ▪ Breadboards and Prototyping Boards ▪ Wire Wrapping Tool ▪ Hot Glue Gun ▪ Software Tools(Autodesk EAGLE, KiCad, Mentor Graphics PADS, easy EDA, Proteus PCB Design, NI multisim, LT pspice) ▪ CAD Software for Mechanical Design(freeCAD, Solidworks) ▪ Flying Probe Testers ▪ Vibration Testers ▪ Ultrasonic Cleaner ▪ Boundary Scan Testers (JTAG Testers)
Facilitation techniques or Learning activity	▪ Demonstration ▪ Simulation ▪ Individual work ▪ Practical exercise

Formative assessment methods /(CAT)	▪ Written Assessment ▪ Practical Assessment ▪ Performance Assessment ▪ Product based Assessment

Learning outcome 3: Integrate Embedded system Hardware	**Learning hours: 30**
Indicative content	

- **Assessing hardware parts and peripherals specifications**
  - ✓ Microcontroller or Microprocessor
  - ✓ External Storage interfaces
  - ✓ Connectivity Options
  - ✓ Form Factor and Mechanical Considerations
  - ✓ Display and User Interface
  - ✓ Power Supply
  - ✓ Sensors and Actuators
  - ✓ Security Features
- **Interconnection of hardware system parts**
  - ✓ Prepare the Hardware Components
  - ✓ Perform Connector and Header Placement
  - ✓ Perform Wiring and Cabling (if applicable)
  - ✓ Perform Enclosure and Mounting
- **Installation of required peripherals**
  - ✓ Identify Required Peripherals
  - ✓ Verify Compatibility
  - ✓ Flashing the .hex file to microcontroller

- **Testing of embedded system hardware**
  - ✓ Functional test
  - ✓ Performance test
  - ✓ Power consumption and efficiency test
  - ✓ Security test
- **Documentation of embedded system hardware**
  - ✓ Hardware Specifications
  - ✓ System Architecture and Design
  - ✓ Components and Materials
  - ✓ Power and Communication
  - ✓ Connectivity and Pinout
  - ✓ Operation Instruction
  - ✓ Troubleshooting instruction
  - ✓ Assembly instructions

Resources required for the indicative content	
Equipment	▪ Computer
Materials	▪ .hex file ▪ .cpp file ▪ .c file ▪ .a file ▪ .ino file

Tools	▪ AVR programmer ▪ AVR studio ▪ USBASP AVR Programmer ▪ PICPgm ▪ STLink V2 - STM32 programmer ▪ STM32CubeIDE ▪ Pic Programmer ▪ AVRDUDESS ▪ ArduinoIDE ▪ ST-LINK/V2 - In-circuit debugger
Facilitation techniques or Learning activity	▪ Demonstration ▪ Simulation ▪ Individual work ▪ Groupwork ▪ Practical exercise
Formative assessment methods /(CAT)	▪ Written Assessment ▪ Practical Assessment ▪ Performance Assessment ▪ Product based Assessment

Integrated/Summative assessment

Integrated situation

XYZ company ltd located in western province Nyamasheke district is a manufacturing company that produces steel products. The company uses security guards to secure High risk areas during the manufacturing process to avoid unauthorized access in such area .This method has become inefficient and ineffective security measure because some security guards cooperate with their friends in illegal access. The company has decided to hire an embedded system hardware technician to develop a

computerized system with a door access control system using finger print, so that if unrecognized user tries to access the restricted area automatically an alarm will be generated.

As an embedded system hardware technician, you are required to design and build an embedded system hardware with a finger print based door lock system and an automatic alarm system to control access in manufacturing area.

You have to refer to the given table that shows how different actuators and sensors should be connected to the microcontroller board:

Sensor/actuator Pin		**ESP 32 PIn**
Fingerprint Sensor	**TX**	**RX2**
	RX	**TX2**
OLED Display	**SDA**	**D21**
	SCL	**D22**
Buzzer	**(+)**	**D15**
Solenoid Lock (RELAY)	**(+)**	**D23**

Instructions:

1. The system should store not more than 10 persons locally in the device.

2.This work should be done in 12hours

Information:

1. A firmware is provided

Resources

Tools	▪ Hardware integration tools ▪ Software integration tools ▪ PCB simulation tools ▪ PCB design tools ▪ Testing tools

Equipment	▪ Computer ▪ Drilling machine ▪ Drilling bit ▪ CNC machine ▪ Oscilloscopes ▪ Multimeter ▪ Function generator
Materials/ Consumables	▪ Breadboard and prototyping boards ▪ Printed Circuit Board (PCB) Materials ▪ ESP32 Board ▪ Fingerprint Sensor ▪ Solenoid Lock ▪ OLED Display ▪ Relay 5V ▪ Voltage Regulator 7806 ▪ Diode 1N4007 ▪ Resistor 330-ohm ▪ Buzzer 5V ▪ BC547 Transistor ▪ DC Power Jack ▪ Power Supply 9V ▪ Female Headers ▪ Connecting Wires

Assessable outcomes	**Assessment criteria (Based on performance criteria)**	**Indicator**	**Observation**		**Marks allocation**
			Yes	**No**	
Learning outcome 1: Setup	1.1 Identifying Embedded system Hardware requirements	1. Project scope is identified			2
		2. Peripherals are identified			2
		3. Workplace is arranged			2

workplace (30%)	1.2 Identifying Tools, materials and equipment	1. Materials are selected			3
		2. Designing tools are selected			1
		3. Simulation tools are selected			1
		4. Optimization tools are selected			1
		5. Equipment are selected			2
Learning outcome 2: Build Embedded system hardware (40%)	2.1. Designing Circuits schematic diagrams	▪ 1. Block diagrams are drawn			3
		2. Component symbols and footprint assignment are selected			3
		3. Design guide lines are followed			2
		4. Components and signals are labelled			3
	2.2. Executing Circuit simulation and optimization	1. Simulation settings are specified			2
		2. Simulation results are analysed			3
		3. Goals and constraints are identified			2
		4. Optimization parameters are specified			3
		5. Optimisation results are evaluated			3
	2.3. Designing PCB	1.Schematic diagrams are			3

	Layout	interpreted			
		2. PCB Layer stackup design are chosen			2
		3.PCB Prototype is performed			2
		4. Files are exported			2
	2.4. Printing PCB	1. Copper Board is prepared			2
		2. PCB Design is transferred to copper board			2
		3. Paper is removed from the copper board			2
		4. Etching is performed			2
		5. Cleaning is performed			2
		6. Finishing is performed			2
		7. Drilling is performed			3
		8. Assembling is performed			2
		9. Circuit functionality testing is perform			2
Learning outcome 3: Integrate Embedded system Hardware (30%)	3.1. Interconnecting Hardware system parts	1. Hardware Components are interconnected			2
		2. Connectors are Placed to headers			2
		3. Wiring is performed			2
		4. Cabling is performed			3
		5. Enclosure is performed			2
		6. Mounting is performed			2
	3.2. Installing Required	1. Peripherals to connect are installed			2

	Peripherals	2. Firmware is flashed into hardware			2
	3.3.Testing Embedded system hardware	1. Door access requires finger print			2
		2. Recognized finger print opens the door			3
		3. Unrecognized finger print automatically actives alarm			3
		4. Door does not open when unrecognized finger print is inputted			3
		5. Power consumption is tested			2
		Security test is performed			2
	3.4. Documenting Embedded system hardware	1. Hardware system functionality is documented			2
Total marks					**100**
Percentage Weightage					**100%**
Minimum Passing line % (Aggregate): 70%					

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