Control Systems Engineer

Alternate Titles: Controls Engineer, Process Control Engineer, Instrument & Controls Engineer, Systems Engineer, Automation Systems Engineer, Manufacturing Automation Engineer, Instrumentation & Electrical Engineer.

Description: Control Systems Engineers analyze user requirements and the design of process and/or mechanical equipment to design automation systems that will cause the equipment to function in the desired manner. They analyze user requirements, procedures, and problems to identify the system components and develop the design and functional specifications for the automation systems. They are responsible for the interface between the hardware and software development for the automation system.

Sources of Material: Certified Automation Professional (CAP) Body of Knowledge, Control Systems Engineer (CSE) Examination Specification, Automation Competency Model.

Performance Domains:

Domain I: Measurement and Control Element Devices; Device Signals, and Transmission Media
Domain II: System Design
Domain III: Development

Domain I: Measurement and Control Element Devices; Device Signals and Transmission Media	
Task 1: Select, specify, and design the installation of measurement devices to measure and analyze physical and chemical properties.	
Knowledge of:	Sensor technologies applicable to the desired type of measurement (e.g., flow, pressure, level, temperature, analytical, counters, position, motion, vision, etc.) Sensor characteristics (e.g., rangeability, accuracy and precision, temperature effects, response times, reliability, repeatability, etc.) Material compatibility Safety Instrumented System [SIS] model validation calculations (e.g., Safety Integrity Level [SIL], reliability, availability, etc.)
Skill in:	Calculations involved in: ▪ Pressure drop ▪ Flow element sizing ▪ Differential pressure ▪ Hydraulic head pressure

	▪ Velocity, area, volumetric, density, and mass relationships ▪ Velocity, acceleration, mass, work energy ▪ Unit conversions ▪ Linearization
Task 2: Select, specify, and design the installation of control element devices to manipulate flows, energy, positions, speeds, and other variables.	
Knowledge of:	Control Element devices ▪ Pressure Relieving Devices ▪ Types (e.g., conventional spring, balanced bellows, pilot operated, etc.) ▪ Characteristics (e.g., modulating, pop action, etc.) ▪ Calculations (e.g., sizing considering inlet pressure drop, back pressure, multiple valves, etc.) ▪ Material selection based on process characteristics ▪ Installation practices (e.g., linking valves, sparing the valves, accessibility for testing, car sealing inlet valves, piping installation, etc.) ▪ Rupture discs (types, characteristics, application, calculations, etc.) ▪ Control Valves ▪ Types (e.g., globe, ball, butterfly, etc.) ▪ Characteristics (e.g., pneumatic or electric actuation, on/off, modulating, linear, low noise, equal percentage, shutoff class, etc.) ▪ Calculation (e.g., body and trim sizing, split range, noise, actuator sizing, speed, pressure drop, air/gas consumption, etc.) ▪ Applications of fluid dynamics (e.g., cavitation, flashing, choked flow, Joule-Thompson effects, two-phase flow, etc.) ▪ Material selection based on process characteristics (e.g., erosion, corrosion, plugged, extreme pressure, temperature, etc.) ▪ Accessories (e.g., limit switches, solenoid valves, positioners, transducers, air regulators, etc.) ▪ Environmental constraints (e.g., fugitive emissions, packing, special sealing, etc.) ▪ Installation practices (e.g., vertical, horizontal, bypasses, troubleshooting, etc.) ▪ Motor Driven Control Elements ▪ Types of Motors (e.g. Single and Polyphase Alternating Current (AC) Motors, Direct Current (DC) Motors, Stepper Motors, Servo Motors, linear, etc) ▪ Types of Motor Controllers or Drives (e.g. full voltage, reduced voltage, reversing, variable frequency, adjustable DC, servo, stepper, etc.)

	▪ Drive and/or Motor Characteristics (e.g. solid state, constant torque AC, variable torque AC, vector AC, shunt wound DC, etc.) ▪ Calculations (e.g. horse power, torque, speed ranges, reduction ratios, etc.) ▪ Accessories (e.g. speed sensors, encoders, etc.) ▪ Fluid powered actuators ▪ Pneumatic pistons ▪ Hydraulic pistons ▪ Sizing actuators and control devices. ▪ Other Control Elements ▪ Solenoid valves ▪ On-off devices/relays ▪ Self-regulating devices Safety Instrumented System [SIS] model validation calculations (e.g., Safety Integrity Level [SIL], reliability, availability, etc.)
Skill in:	Installation Design (e.g., process, fluid power systems, electrical, etc.) Calculations for: ▪ Valve sizing ▪ Power requirements ▪ Heat load, cooling, heating and space conditioning. ▪ Horsepower and torque ▪ Linear actuation force ▪ Etc.
Task 3: Design and install wiring to reliably communicate information between measurement and control element devices and control equipment.	
Knowledge of:	Control Signals ▪ Pneumatic, hydraulic, electronic, optical, discrete voltage, analog, digital, digital bus, etc. ▪ Transducers (e.g., analog/digital [A/D], digital/analog [D/A], current/pneumatic [I/P] conversion, etc.) ▪ Electrical hazardous area classifications and required wiring and protection methods (e.g. Intrinsic Safety, explosion proof, non-incendive, etc.) ▪ Grounding, shielding, segregation, AC coupling ▪ Basic signal circuit design (e.g., two-wire, four-wire, isolated inputs/outputs, loop or external powering, etc.) Signal Transmission ▪ Signal communications system architecture physical layers (e.g., fiber optics, coaxial cable, wireless, paired conductors, fieldbus, industrial networks, etc.) ▪ Signal Communications protocols (e.g. foundation fieldbus, profibus, DeviceNet, ASi, Ethernet/IP, CAN, LonWorks, BACnet, etc.)

	▪ Physical installation considerations versus transmission medium type ▪ Media types and specifications ▪ Voltage drop or signal attenuation ▪ Signal distortion due to media length or network structure ▪ Active and passive network components (e.g. taps, splitters, repeaters/amplifiers, terminators, etc.) ▪ Grounding & shielding
Skill in:	Electrical Installations ▪ Use of design standards and practices ▪ Determination of applicable codes. Calculations: circuit (voltage, current, impedance) Calculations: unit conversions
Task 4: Calibrate, troubleshoot, test, repair, and improve sensing, measurement, and actuation devices.	
Knowledge of:	Installation requirements (e.g., grounding, shielding, constructability, input/output termination, environmental, heat load calculations, power load requirements, purging, etc.) Functionality and performance of measurement and control element devices
Skill in:	Commissioning (e.g., performance tuning, loop checkout, etc.) Troubleshooting (e.g., root cause failure analysis and correction)
Domain II: System Design - do the complete conceptual design of the control and information systems including specifications of the hardware and software to be used in the system (sometimes called "front end engineering" or "basic engineering"); and also do the "detail design" and procurement of the hardware systems including preparation of construction work packages.	
Task 1: Perform safety and/or hazard analyses, security analyses, and regulatory compliance assessments by identifying key issues and risks in order to comply with applicable standards, policies, and regulations.	
Knowledge of:	Additional Codes, Standards, and Regulations: ▪ American National Standards Institute (ANSI) ▪ Factory Mutual (FM) ▪ Institute of Electrical & Electronics Engineers (IEEE) ▪ International Society of Automation (ISA) ▪ National Electrical Code (NEC) ▪ National Electrical Manufacturers Association (NEMA) ▪ National Fire Protection Association (NFPA) ▪ Occupational Safety and Health Administration (OSHA) ▪ Underwriter Laboratory (UL) ▪ Equivalencies to international codes and standards Hazard analysis methodologies Risk analysis

	Safety system design (e.g., Safety Instrumented System [SIS], Safety Requirements Specification [SRS], application of OSHA 1910, etc.)
Skill in:	Participating in a Hazard Operability Review Analyzing safety integrity levels Analyzing hazards Analyzing risks Assessing security requirements or relevant security issues Applying regulations to design
Task 2: Establish standards, templates, and guidelines as applied to the automation system using the information gathered in the definition stage and considering human-factor effects in order to satisfy customer design criteria and preferences.	
Knowledge of:	Process Industry Practices (PIP) (Construction Industry Institute) IEC 61131 programming languages Customer standards Vendor standards Template development methodology Measurement and control element devices Electrical standards and codes Instrument selection and sizing tools ISA standards (e.g., S5, S88) Etc.
Skill in:	Developing programming standards Selecting and sizing instrument equipment Designing instrument installations. Designing low-voltage electrical systems Preparing drawing using AutoCAD software
Task 3: Create detailed equipment specifications and instrument data sheets based on vendor selection criteria, characteristics and conditions of the physical environment, regulations, and performance requirements in order to purchase equipment and support system design and development.	
Knowledge of:	Measurement and control element devices. Electrical standards and codes Instrument selection and sizing tools Vendors' offerings Motor and drive selection sizing tools Electronic control system hardware (e.g. controller, power supplies, input/output cards and chassis, communication hardware, etc.) Human Machine Interface (HMI) (e.g., graphics, alarm management, trending, historical data, etc.) Ergonomics (e.g., human factors engineering, physical control room arrangement, panel layout)
Skill in:	Selecting and sizing motors and drives

	Selecting and sizing instrument equipment Designing low-voltage electrical systems Selecting and sizing computers Selecting and sizing control equipment Evaluating vendor alternatives Selecting or sizing of input/output signal devices and/or conditioners
Task 4: Define the data structure layout and data flow model considering the volume and type of data involved in order to provide specifications for hardware selection and software development.	
Knowledge of:	Data requirements of system to be automated (e.g. data sampling frequency, storage duration, archival requirements, security, integrity, etc.) Data structures of control systems (e.g. distribution and access to data, storage redundancies, distribution, archiving, etc.) Data flow of controls systems (e.g. data buffering, time base stamp, location of active and archive data files) Data analysis tools Entity relationship diagrams
Skill in:	Modeling data Tuning and normalizing databases
Task 5: Select the physical communication media, network architecture, and protocols based on data requirements in order to complete system design and support system development.	
Knowledge of:	Vendor protocols Ethernet and other open networks Physical requirements for networks/media Physical topology rules/limitations Network design Security requirements Redundancies, failure modes, and disaster recovery. Grounding and shielding practices
Skill in:	Designing networks based on chosen media, architecture and protocols
Task 6: Develop a functional description of the automation solution (e.g., control scheme, alarms, HMI, reports) using rules established in the definition stage in order to guide development and programming.	
Knowledge of:	Control theory ▪ Basic processes (e.g., compression, combustion, distillation, hydraulics, motion control, etc.) ▪ Process dynamics (e.g., loop response, P-V-T relationships, simulations, cycle times, throughput, etc.) ▪ Basic control (e.g., regulatory control, feedback, feed forward, cascade, ratio, PID, split-range, etc.) ▪ Discrete control (e.g., relay logic, Boolean algebra, state logic,

	function block/combinational logic, etc.) ▪ Sequential control (e.g., batch, sequential function charts, logic sequences, etc.) Visualization, alarming, database/reporting techniques Documentation standards Vendors' capabilities for their hardware and software products General control strategies used within the industry Process/equipment to be automated Operating philosophy
Skill in:	Writing functional descriptions Interpreting design specifications and user requirements Communicating the functional description to stakeholders
Task 7: Design the test plan using chosen methodologies in order to execute appropriate testing relative to functional requirements.	
Knowledge of:	Relevant test standards Simulation tools Process Industry Practices (PIP) (Construction Industry Institute) General software testing procedures Functional description of the system/equipment to be automated
Skill in:	Writing test plans Developing tests that validate that the system works as specified
Task 8: Perform the detailed design for the project by converting the engineering and system design into purchase requisitions, drawings, panel designs, and installation details consistent with the specification and functional descriptions in order to provide detailed information for development and deployment.	
Knowledge of:	Field devices, control devices, visualization devices, computers, and networks Installation standards and recommended practices Electrical and wiring practices Specific customer requirements Functional requirements of the system/equipment to be automated Applicable construction codes and standards Documentation standards Productivity tools (e.g. InTools, AutoCAD, Microstation, etc.) Typical industry standard drawings (e.g., PFD, P&ID, Loop Diagrams, Ladder Diagrams, Logic Drawings, Cause & Effects Drawings, SAFE Charts, etc.)
Skill in:	Performing detailed design work Documenting the design
Task 9: Prepare comprehensive construction work packages by organizing the detailed design information and documents in order to release project for construction.	
Knowledge of:	Applicable construction practices Documentation standards

	Contracting and subcontracting of construction trades.
Skill in:	Assembling construction work packages
Domain III: Development - software development and coding. [domain IV of CAP]	
Task 1: Develop Human Machine Interface (HMI) in accordance with the design documents in order to meet the functional requirements.	
Knowledge of:	Specific HMI software products Tag definition schemes Programming structure techniques Network communications Alarming schemes Report configurations Presentation techniques Database fundamentals Computer operating systems Human factors/ergonomics HMI supplier options
Skill in:	Presenting data in a logical and aesthetic fashion Creating intuitive navigation menus Implementing connections to remote devices Documenting configuration and programming Programming configurations
Task 2: Develop database and reporting functions in accordance with the design documents in order to meet the functional requirements.	
Knowledge of:	Relational database theory Specific database software products Specific reporting products Programming/scripting structure techniques Network communications Structured Query language Report configurations Entity diagram techniques Computer operating systems Data mapping
Skill in:	Presenting data in a logical and aesthetic fashion Administrating databases Implementing connections to remote applications Writing queries Creating reports and formatting/printing specifications for report output Documenting database configuration Designing databases Interpreting functional description
Task 3: Develop control configuration or programming in accordance with the design	

documents in order to meet the functional requirements.	
Knowledge of:	Specific control software products Tag definition schemes Programming structure techniques Network communications Alarming schemes I/O structure Memory addressing schemes Hardware configuration Computer operating systems Processor capabilities Standard nomenclature (e.g., ISA) Process/equipment to be automated
Skill in:	Interpreting functional description Interpreting control strategies and logic drawings Programming and/or configuration capabilities Implementing connections to remote devices Documenting configuration and programs Interpreting P&IDs Interfacing systems
Task 4: Implement data transfer methodology that maximizes throughput and ensures data integrity using communication protocols and specifications in order to assure efficiency and reliability.	
Knowledge of:	Specific networking software products (e.g., I/O servers). Network topology Network protocols Physical media specifications (e.g., copper, fiber, RF, IR) Computer operating systems Interfacing and gateways Data mapping
Skill in:	Analyzing throughput Ensuring data integrity Troubleshooting Documenting configuration Configuring network products Interfacing systems Manipulating data
Task 5: Implement security methodology in accordance with stakeholder requirements in order to mitigate loss and risk.	
Knowledge of:	Basic system/network security techniques Customer security procedures Control user-level access privileges Regulatory expectations (e.g., 29 CFR Part 11)

	Industry standards (e.g., ISA)
Skill in:	Documenting security configuration Configuring/programming of security system Implementing security features
Task 6: Review configuration and programming using defined practices in order to establish compliance with functional requirements.	
Knowledge of:	Specific control software products Specific HMI software products Specific database software products Specific reporting products Programming structure techniques Network communication Alarming schemes I/O structure Memory addressing schemes Hardware configurations Computer operating systems Defined practices Functional requirements of system/equipment to be automated
Skill in:	Programming and/or configuration capabilities Documenting configuration and programs Reviewing programming/configuration for compliance with design Requirements
Task 7: Test the automation system using the test plan in order to determine compliance with functional requirements.	
Knowledge of:	Testing and simulation techniques Specific simulation products and software. Specific control software products Specific HMI software products Specific database software products Specific reporting products Network communications Alarming schemes I/O structure Memory addressing schemes Hardware configurations Computer operating systems Functional requirements of system/equipment to be automated
Skill in:	Writing test plans Executing test plans Documenting test results Programming and/or configuration capabilities Implementing connections to remote devices

	Interpreting functional requirements of system/equipment to be automated Interpreting P&IDs
Task 8: Assemble all required documentation and user manuals created during the development process in order to transfer essential knowledge to customers and end users.	
Knowledge of:	General understanding of automation systems Computer operating systems Documentation practices Operations procedures Functional requirements of system/equipment to be automated
Skill in:	Documenting technical information for non-technical audience Using documentation tools Organizing material for readability - field ins