ISE 589-006: INTRODUCTION TO MODERN INDUSTRIAL AUTOMATION

LECTURE 004

Fred Livingston, PhD

Course Schedule

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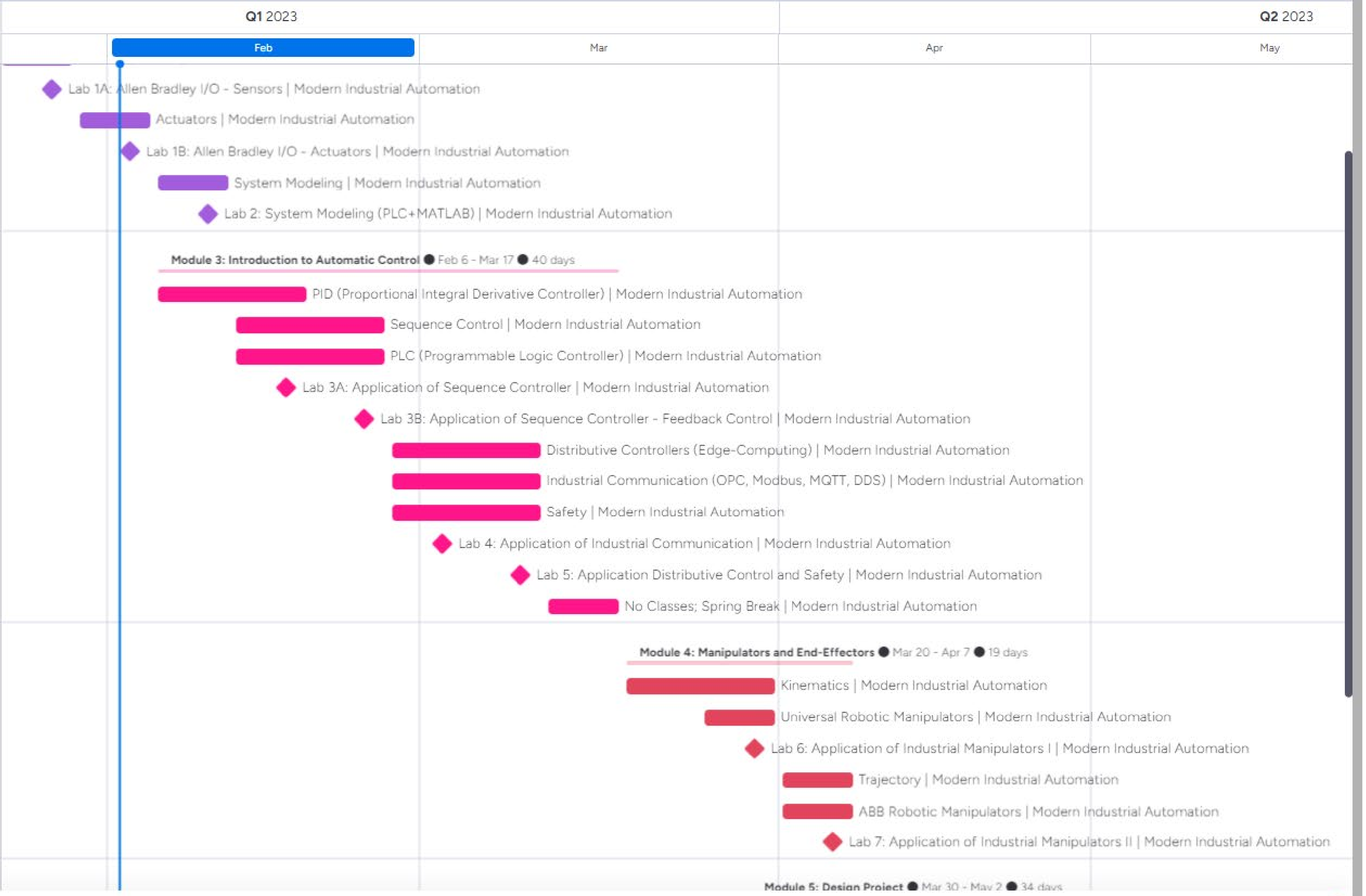
Lab 1A: Allen Bradley I/O - Se...	Jan 26
Actuators	Jan 30 - Feb 3
Lab 1B: Allen Bradley I/O - Act...	Feb 2
System Modeling	Feb 6 - 10
Lab 2: System Modeling (PLC...	Feb 9
Module 3: Introduction to Automatic Control	
PID (Proportional Integral Deri...	Feb 6 - 17
Sequence Control	Feb 13 - 24
PLC (Programmable Logic Co...	Feb 13 - 24
Lab 3A: Application of Seque...	Feb 16
Lab 3B: Application of Sequen...	Feb 23
Distributive Controllers (Edge...	Feb 27 - Mar 10
Industrial Communication (O...	Feb 27 - Mar 10
Safety	Feb 27 - Mar 10
Lab 4: Application of Industria...	Mar 2
Lab 5: Application Distributive...	Mar 9
No Classes; Spring Break	Mar 13 - 17
Module 4: Manipulators and End-Effectors	
Kinematics	Mar 20 - 31
Universal Robotic Manipulators	Mar 27 - 31
Lab 6: Application of Industria...	Mar 30
Trajectory	Apr 3 - 7
ABB Robotic Manipulators	Apr 3 - 7
Lab 7: Application of Industria...	Apr 6
[redacted]: Design Project	



Module 1: Introduction | Module 2: Measuremen... | Module 3: Introduction t... | Module 4: Manipulators ... | Module 5: Design Project

LECTURE 4: ACTUATORS

Introduction to PLC (Review)

Photosensors

Actuators

Laboratory 1 - Automation of Conveyor Belt

HW 1 DUE FEB 5TH 2023

Q1. Given the following desired task

1. Detecting the presence of the part
2. Detecting the location and orientation of the part
3. Detect the velocity of the workspace

Determine the best sensors for completing each of the above tasks—things to consider contact vs. non-contact, material properties, performance, and accuracy.

Q2.

This robot contains a numbers of sensors for detecting an object. Given the following data, determine the best sensor suitable for the task.

Q3.

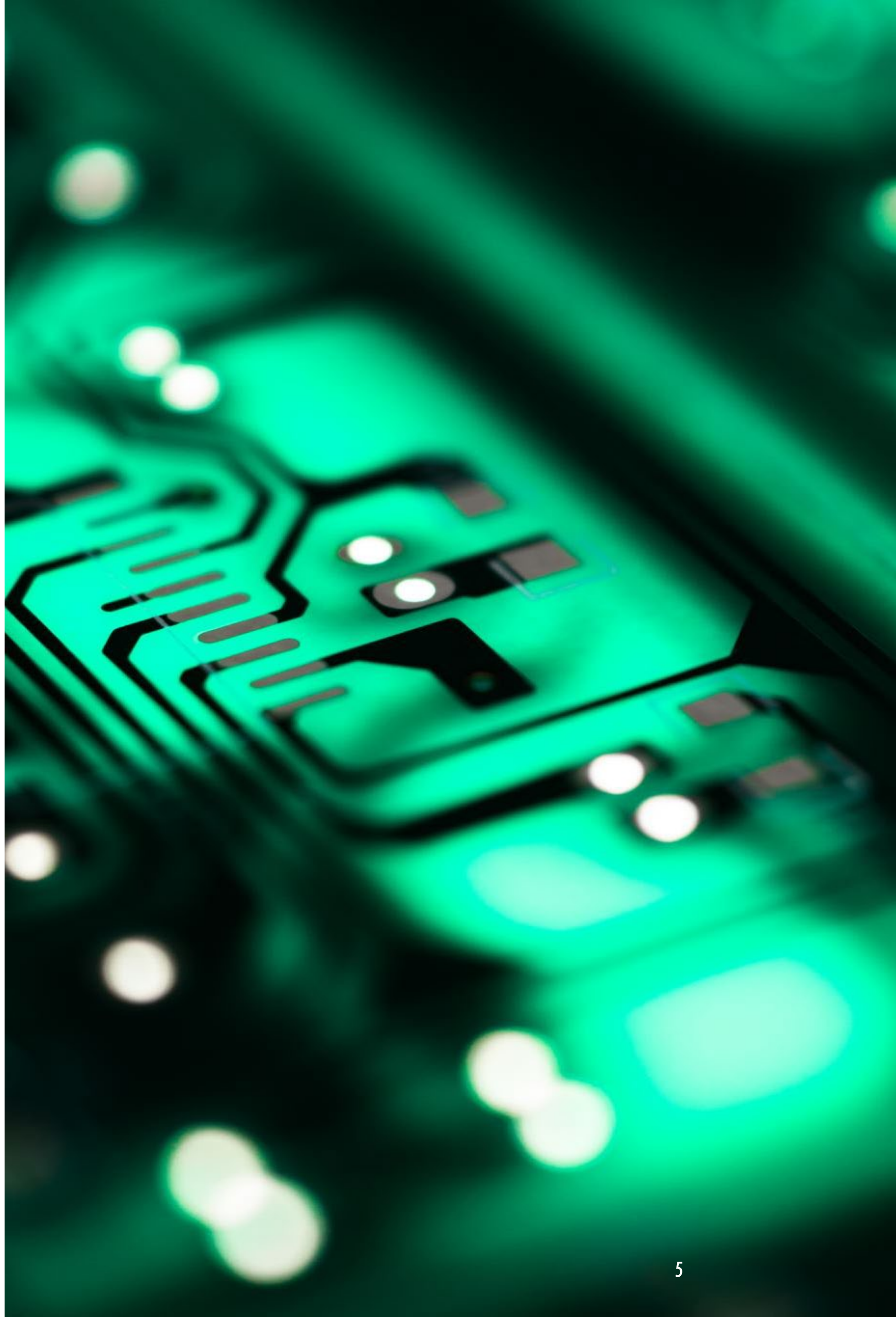
Given a dataset, derive a system model from the response time.

Q4.

Describe the sensor technologies in the article; ***Bin picking for ship-building logistics using perception and grasping systems***

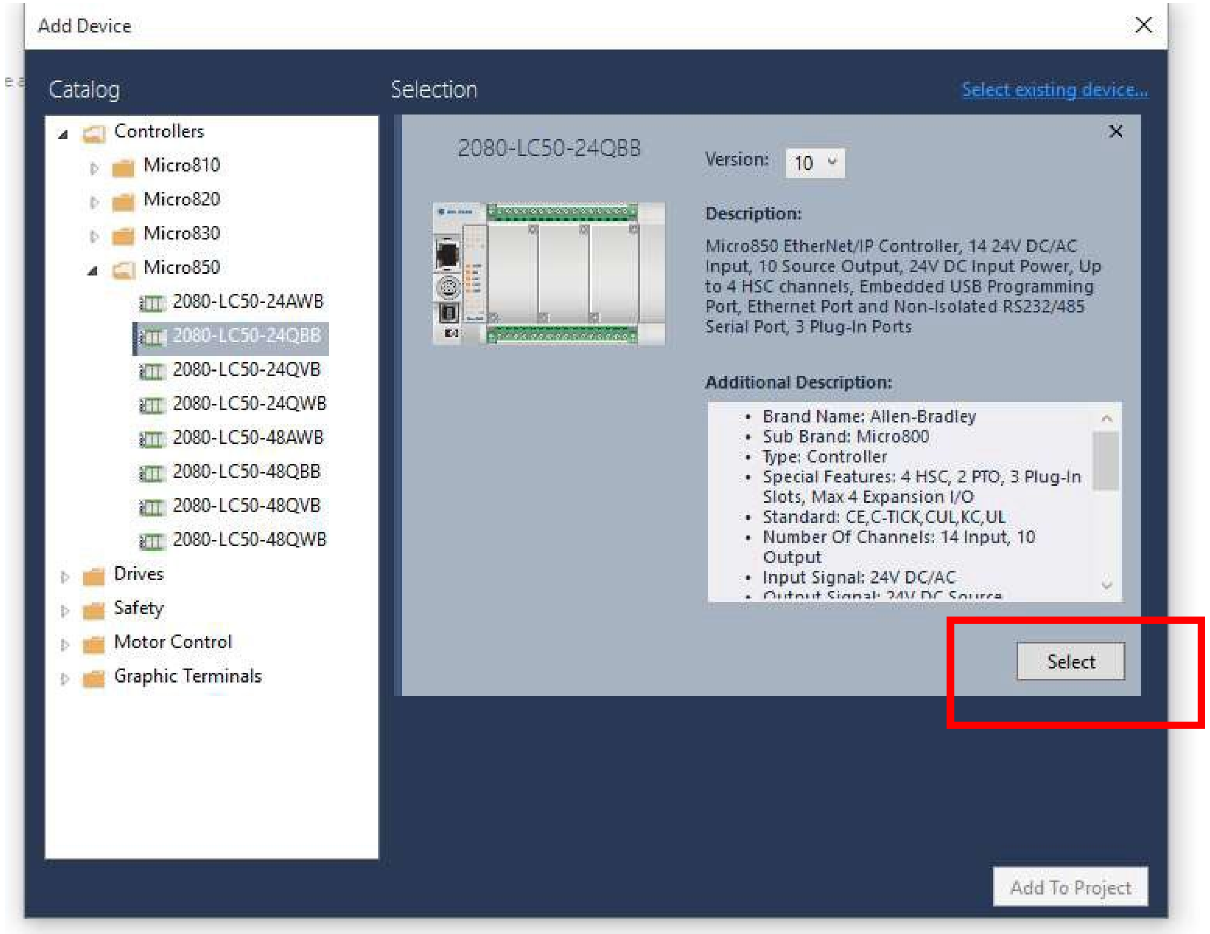
PROGRAMMABLE LOGIC CONTROLLER

Programmable controller is a digital electronic apparatus with a programmable memory for storing instructions to implement specific functions such as logic, sequencing, timing, counting, and arithmetic, to control machines and processes.



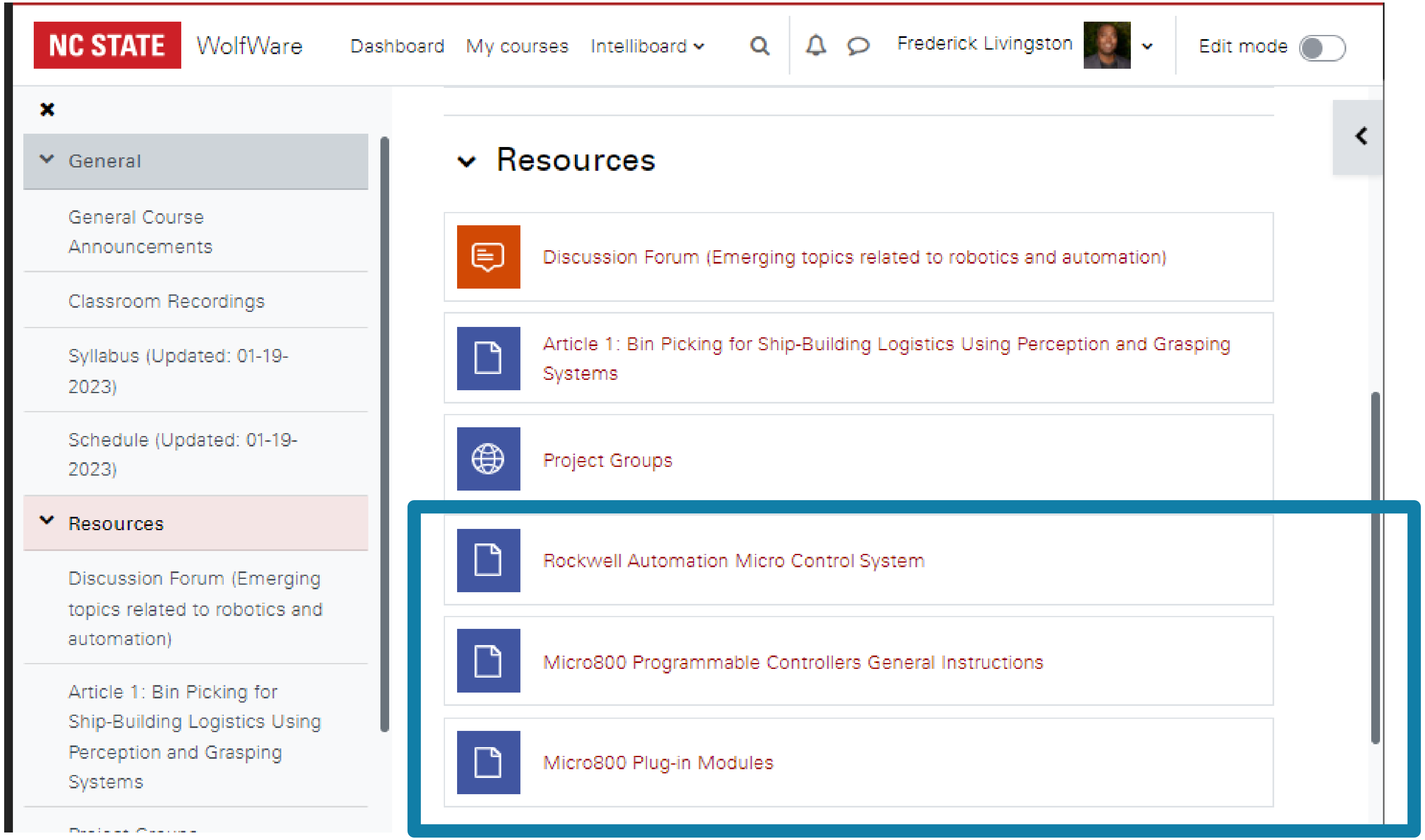
MICRO 850 (2080-LC50-24QBB)

https://www.rockwellautomation.com/en-us/products/details.2080-LC50-24QBB.html



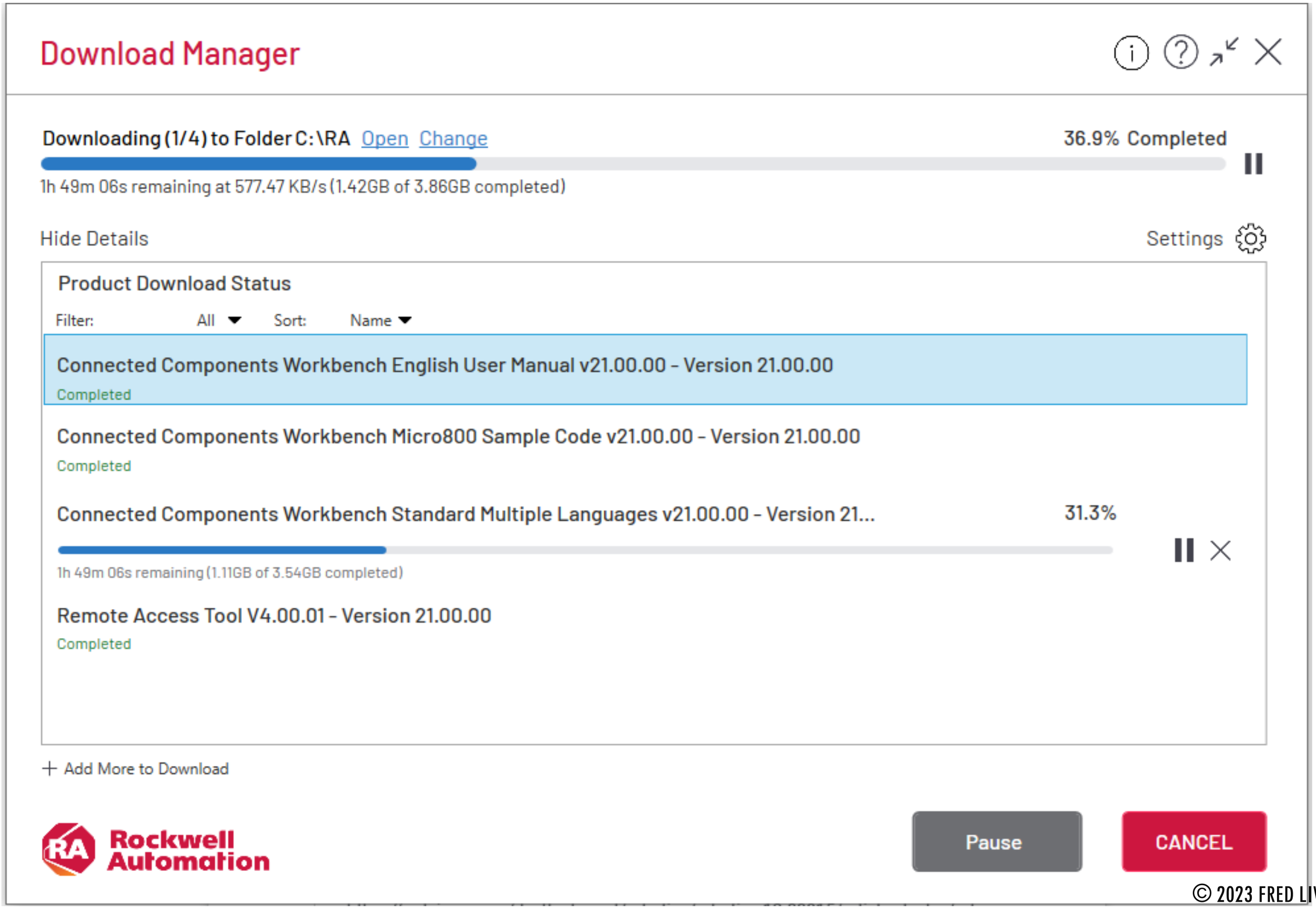
Micro850 EtherNet/IP Controller, 14 24 VDC/VAC Inputs, 10 Source Output, 24 DC Input Power, Up to 4 HSC channels, Embedded USB Programming Port, Ethernet Port and Non-Isolated RS232/485 Serial Port, 3 Plug-In Ports

MICRO 850 RESOURCES

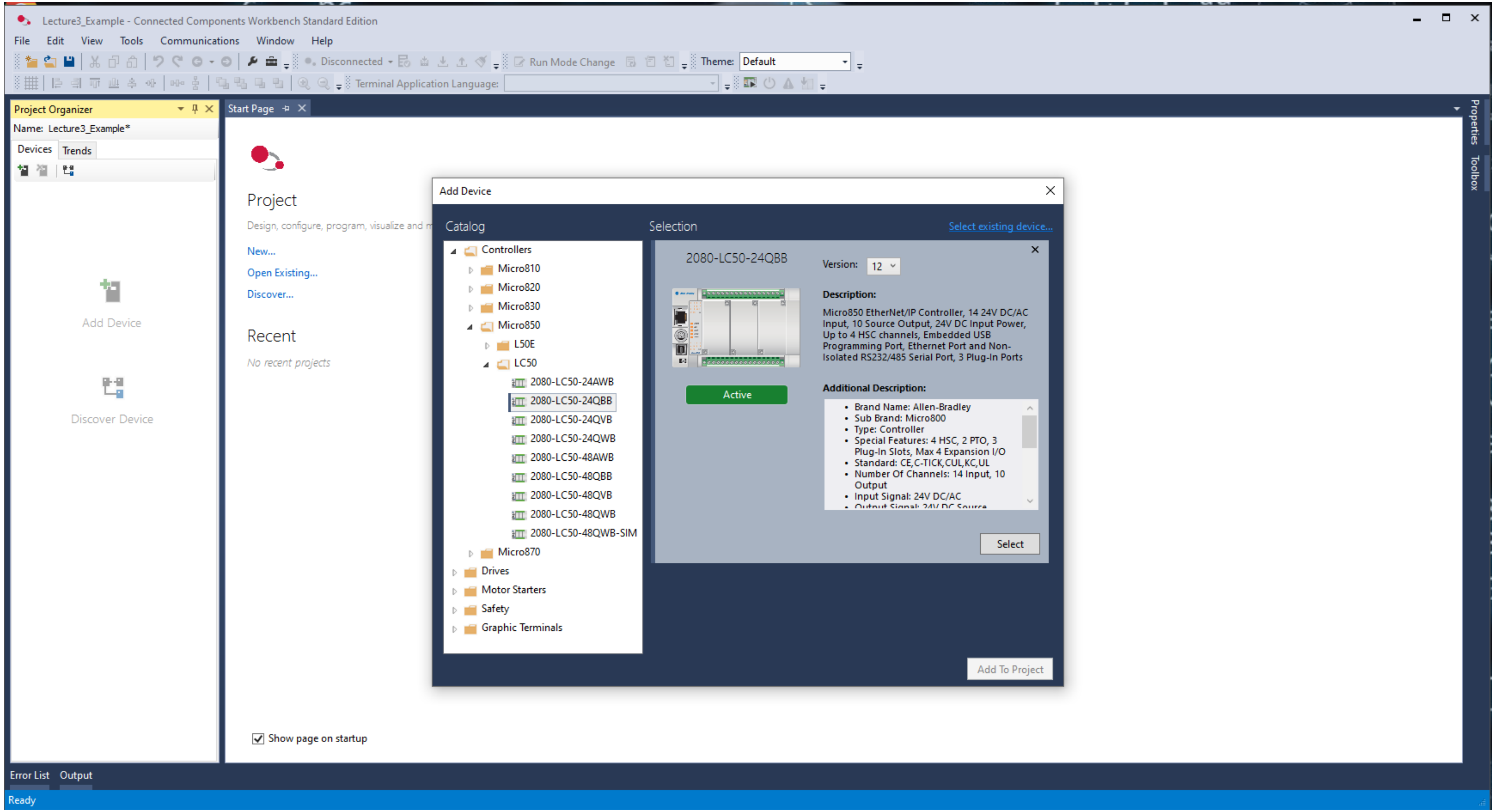


CONNECTED COMPONENTS WORKBENCH

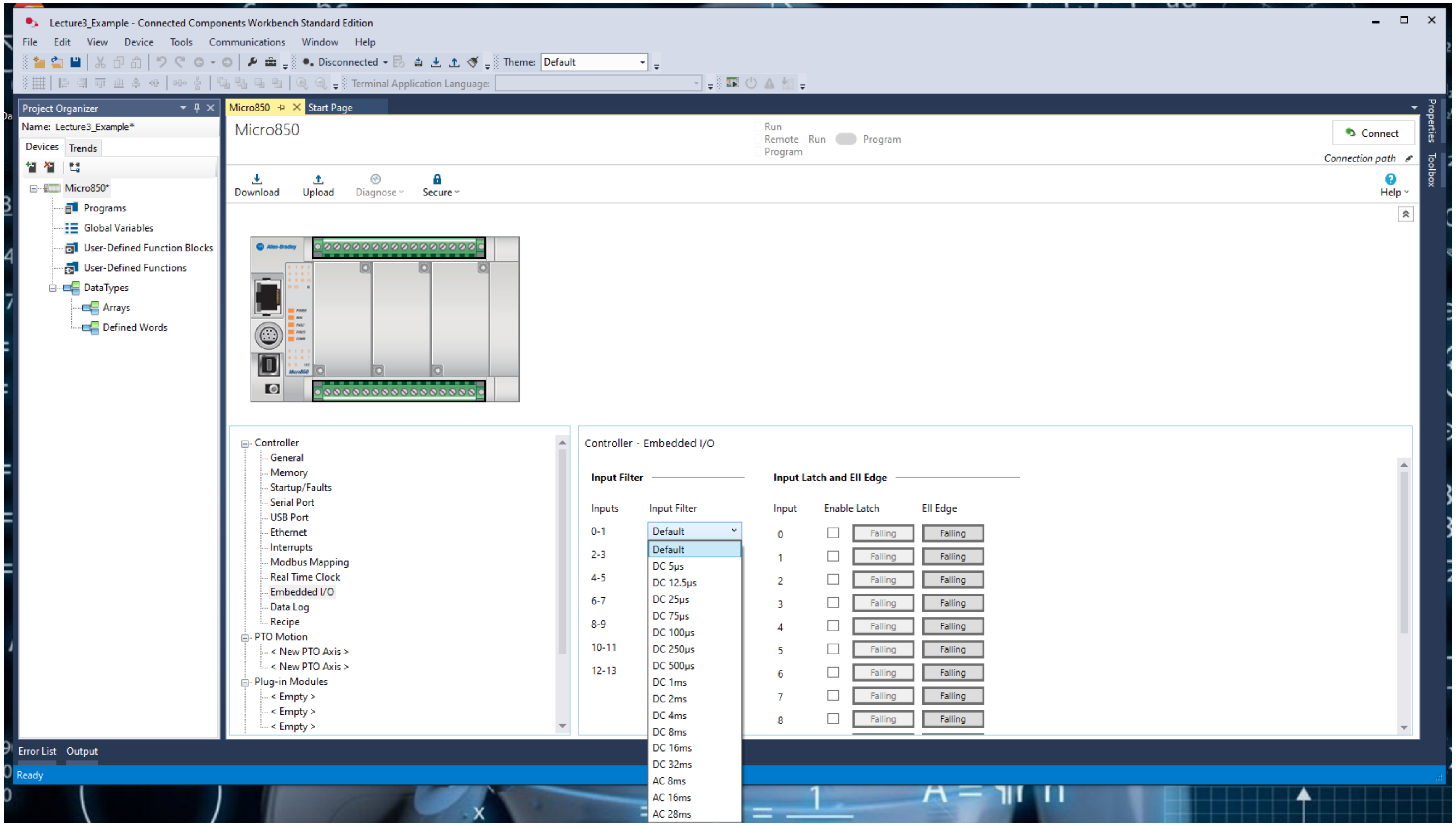
https://www.rockwellautomation.com/en-us/capabilities/industrial-automation-control/design-and-configuration-software.html



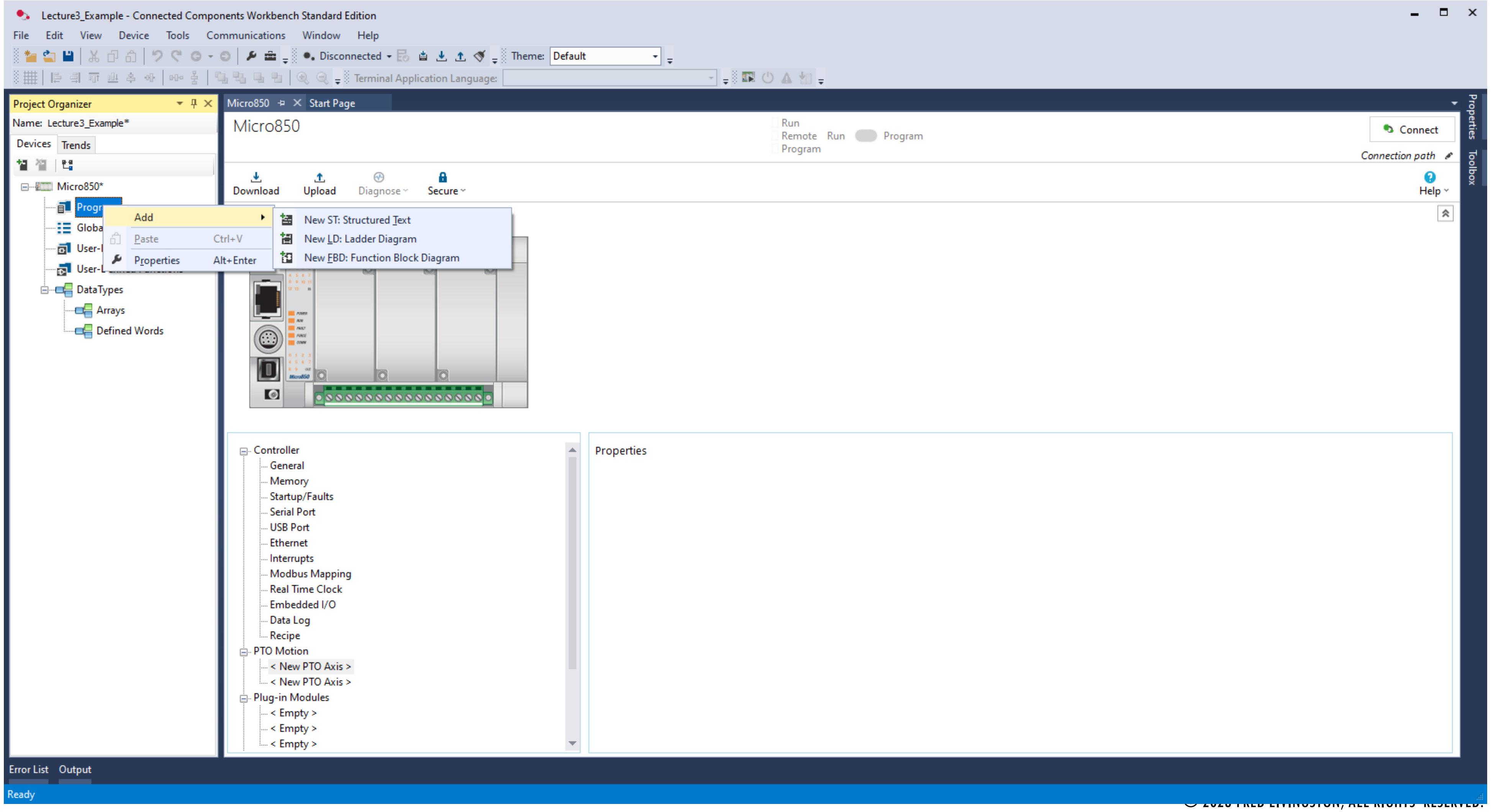
CCW – PROJECT CONFIGURATION



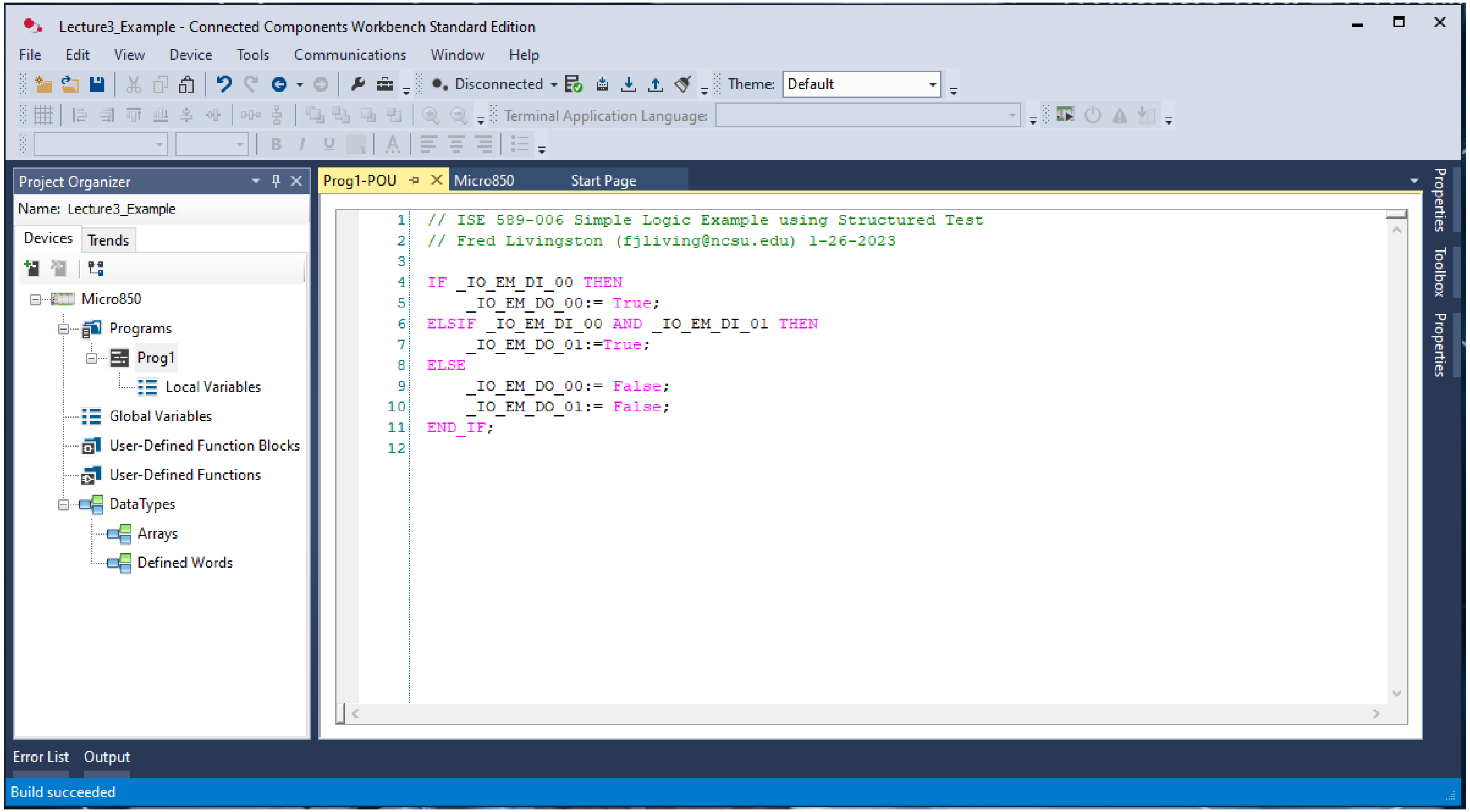
CCW – INPUT FILTERING



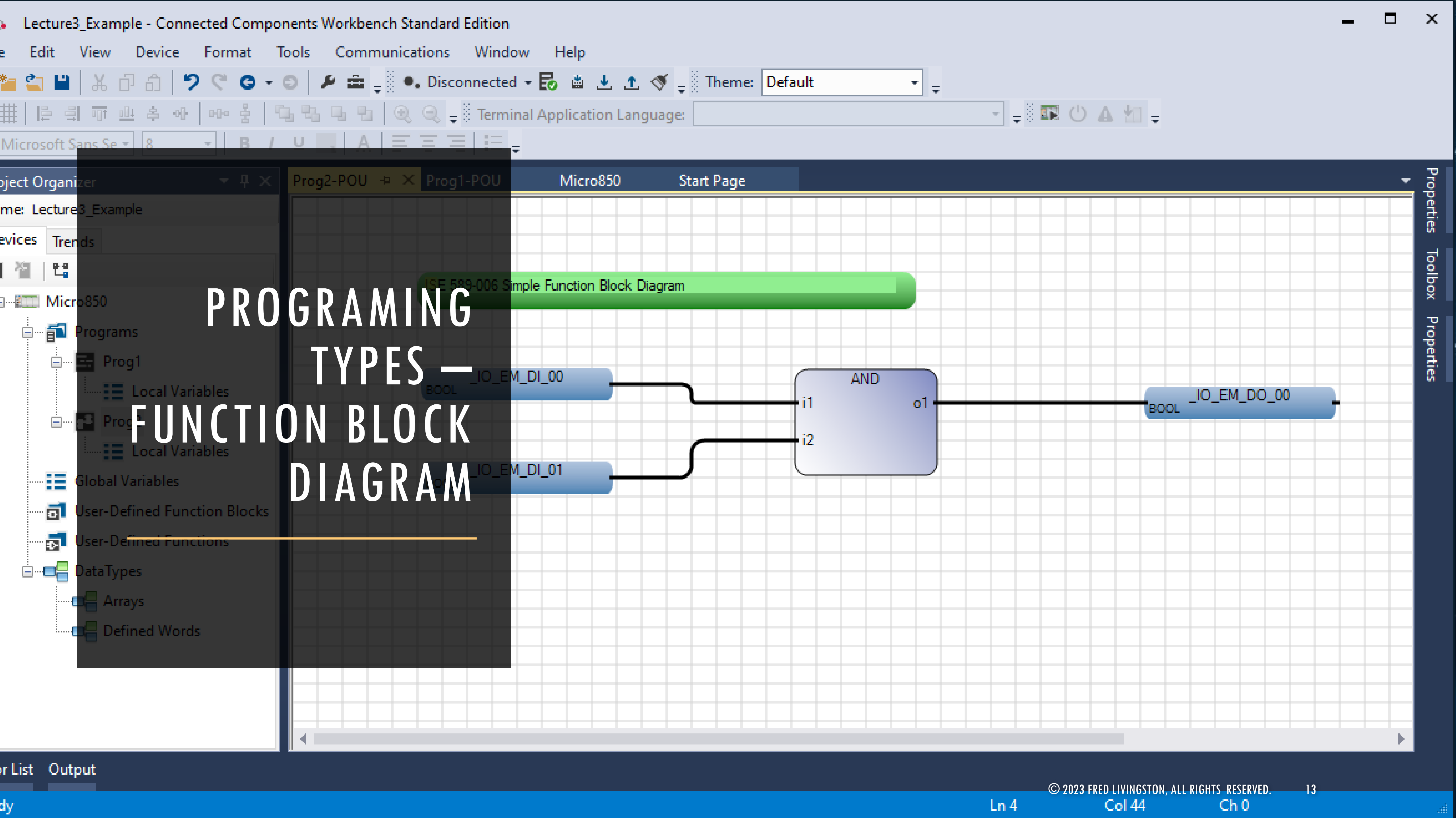
CCW – PROGRAMING TYPES



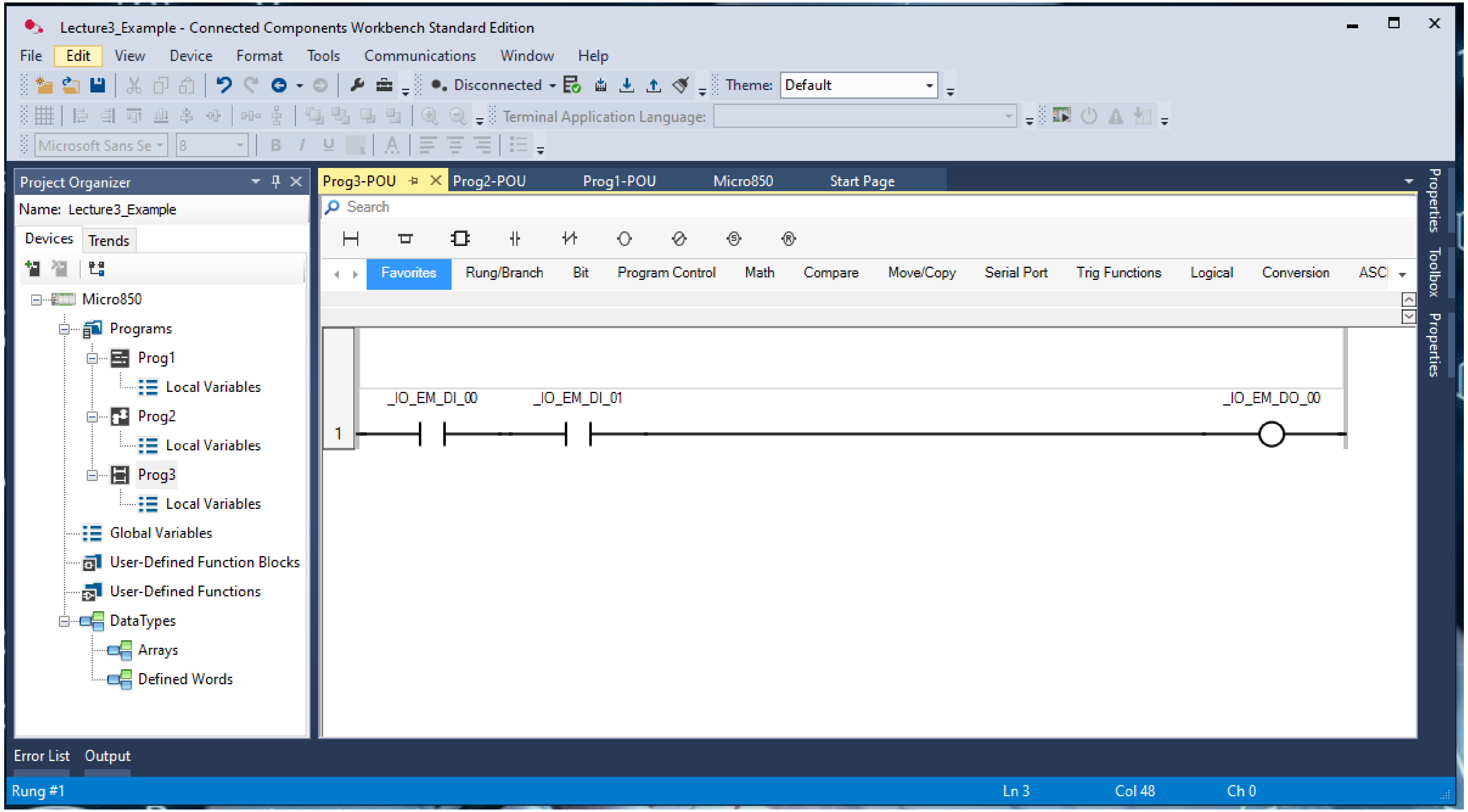
PROGRAMING TYPES – STRUCTURED TEXT



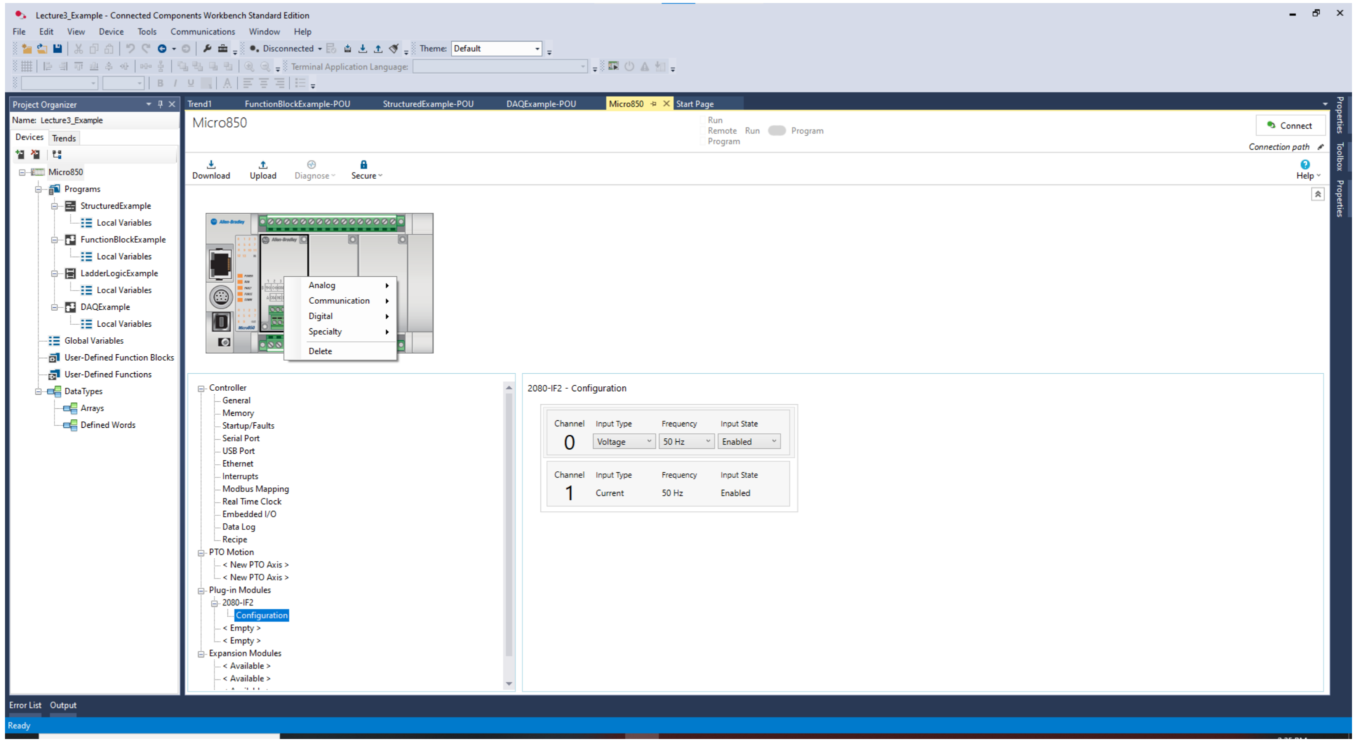
PROGRAMING TYPES — FUNCTION BLOCK DIAGRAM

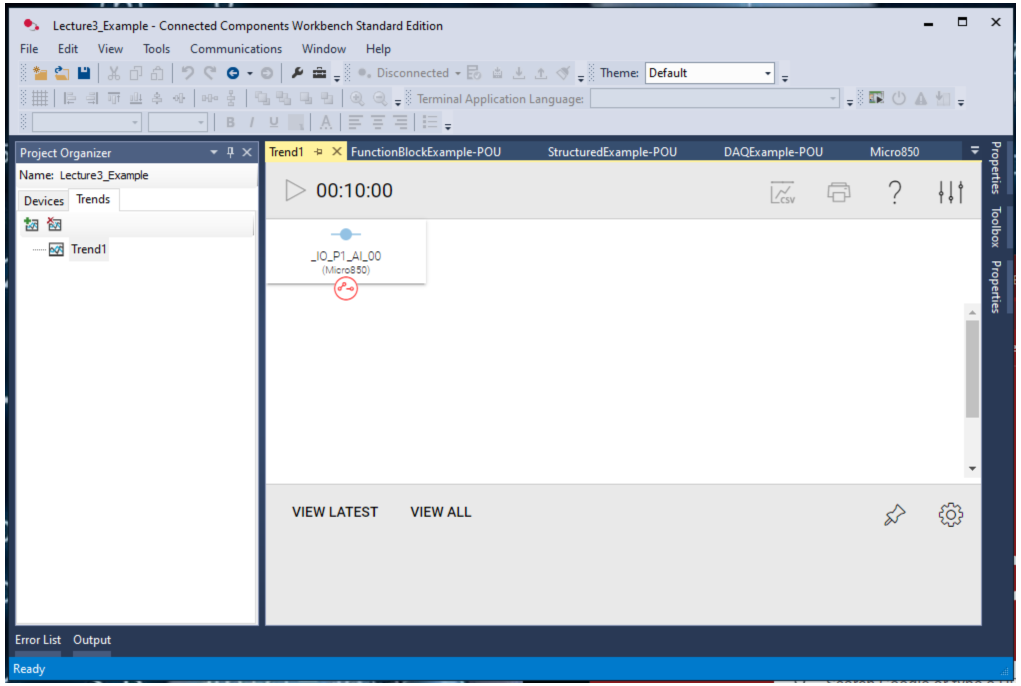


PROGRAMING TYPES – LADDER LOGIC



CCW – DATA AQUISTION



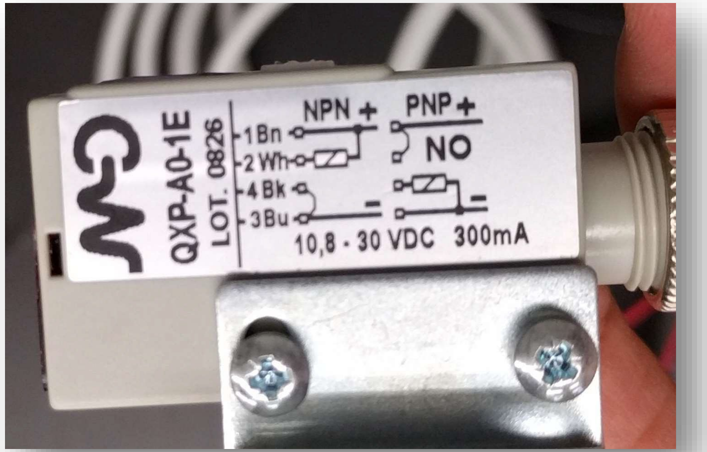


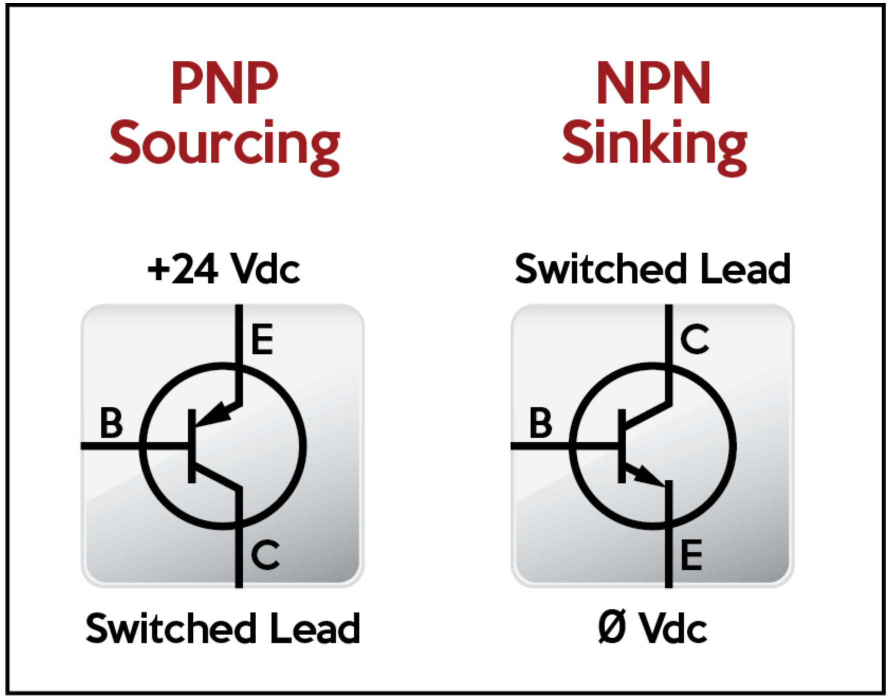
CONNECTING SENSORS TO PLC

Two types of 24 VDC sensors; PNP and NPN

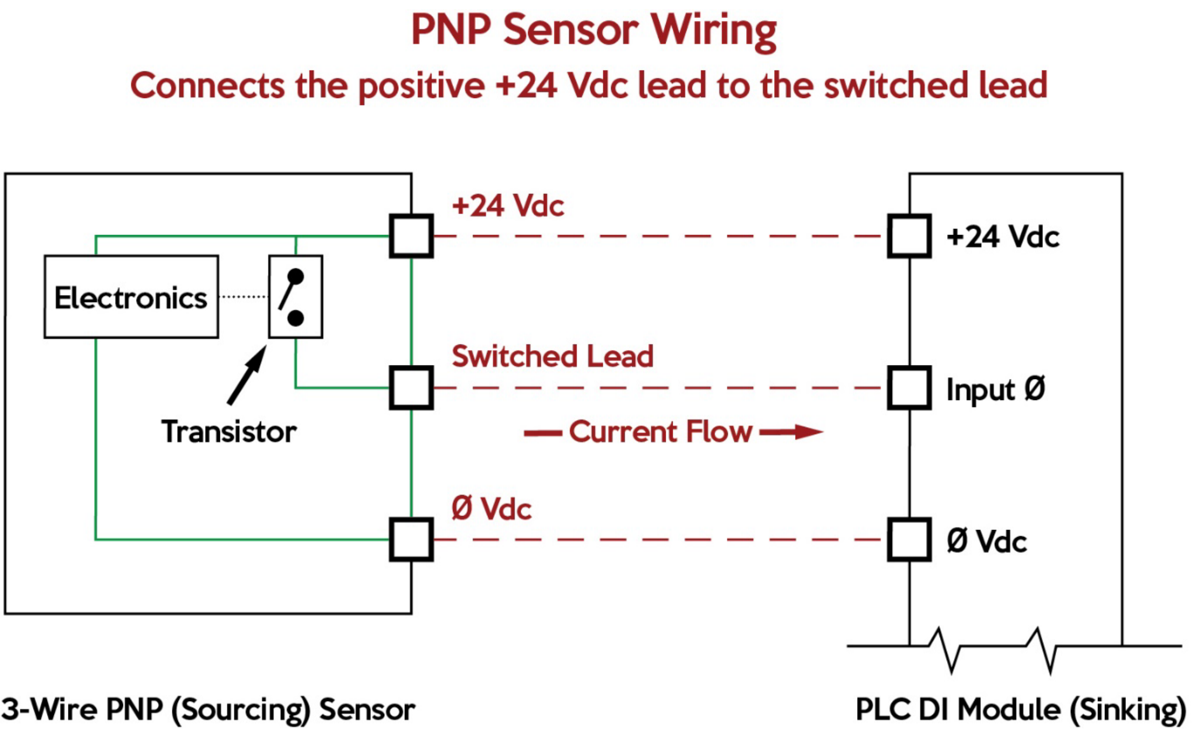
"P" and "N" refer to the arrangement of the semiconductor

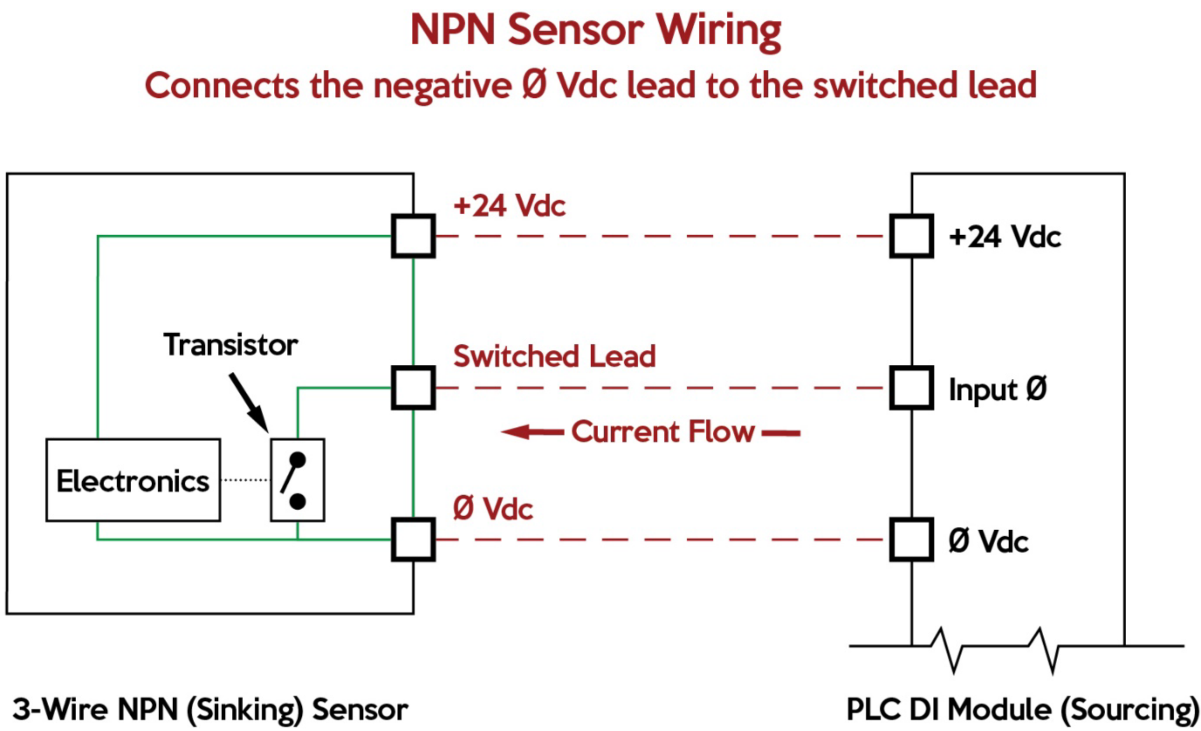
Rectangle head photo sensor





SENSOR WIRING





SOURCING VS SINKING CIRCUITS

- A sinking PLC DI is suitable for PNP field sensor devices and looks for +24 Vdc on the DI channel coming from the sensor switched lead to indicate a logical true condition.
- A sourcing PLC DI is suitable for NPN field sensor devices and looks for 0 Vdc on the DI channel coming from the sensor switched leas to indicate a logic true condition.

BENEFITS OF PNP VS NPN

- PNP sensors connect +24 Vdc to the switched lead when true, while NPN sensors connect 0 Vdc to the switched lead when true. If a PNP cable is damaged there is a chance the signal could short to ground and damage the sensor. If an NPN cable is damaged there is the chance the signal could short to ground and cause a false true signal, but there would be no damage to the circuit.

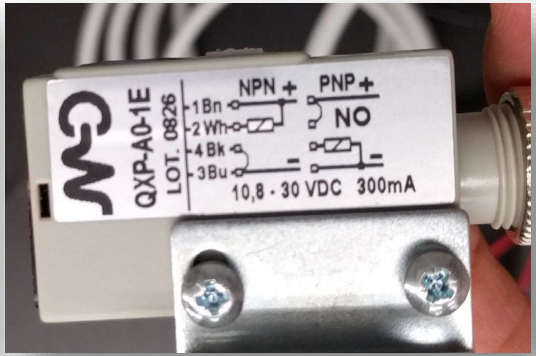
BENEFITS OF PNP VS NPN

- Using PNP instead of NPN is the resulting logic because +24 Vdc=On=True is easier for programmers and technicians to use and troubleshoot than 0 Vdc=On=True.

SENSORS

Inductive sensor

Inductive sensor

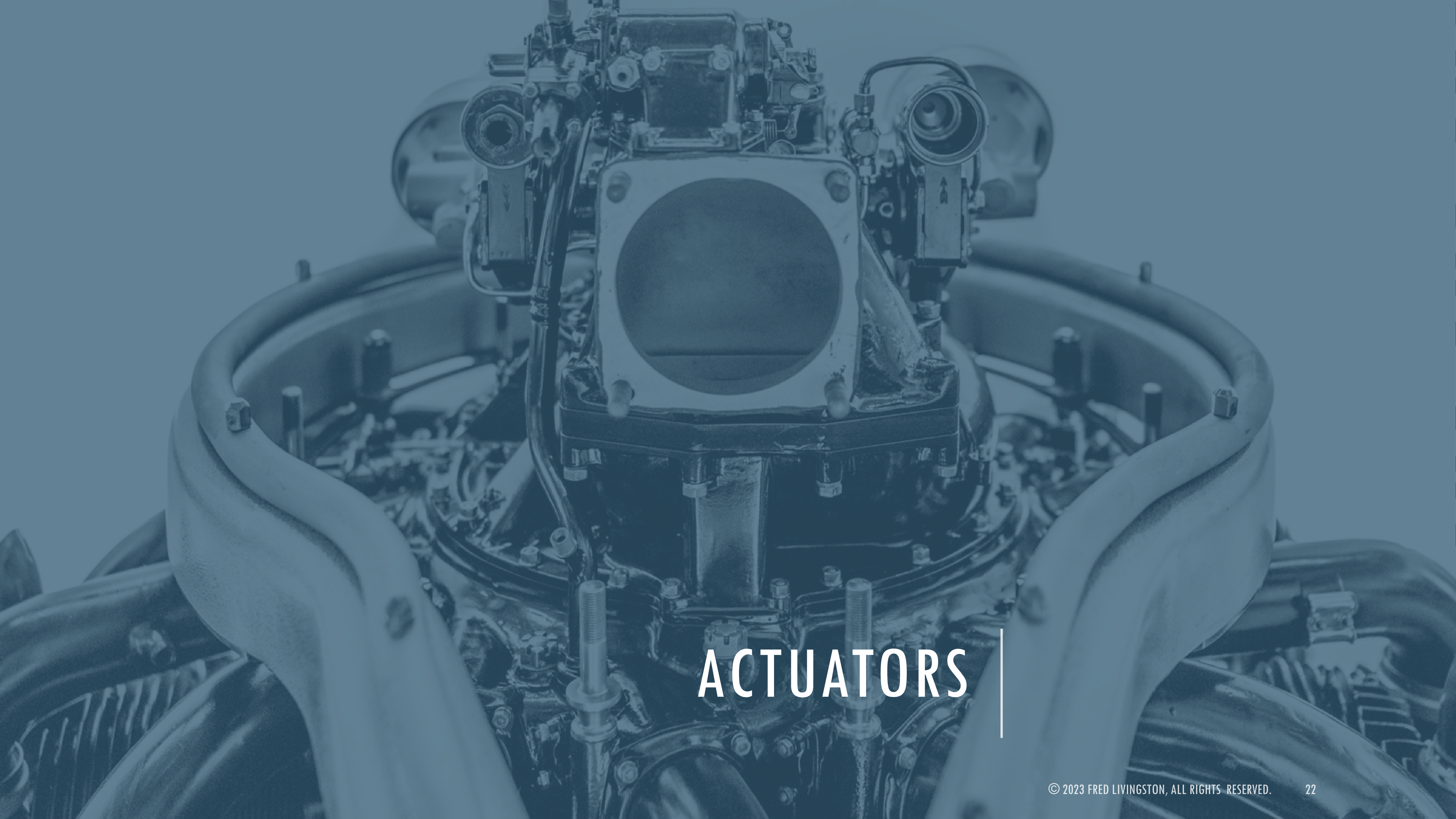


Rectangle head photo sensor

- If you are using an inductive sensor, connect the black wire to the PLC's Input0 (I-00), connect the brown wire the positive terminal block and connect he blue wire the negative terminal block.

- If connecting a photo sensor with a round head, connect the blue and pink wires to the negative terminal block. Connect the brown wire to the positive terminal block. Connect the black wire to the PLC's Input0 (I-00).

- If connecting a photo sensor with a rectangle head, connect the blue and black wires to the negative terminal block. Connect the brown wire to the positive terminal block. Connect the white wire to the PLC's Input0 (I-00)



ACTUATORS

ACTUATORS

- Actuator is hardware device that usually converts a controller command signal into a change in position or velocity of a mechanical device
- Classification based on the type of power used:
  - Electrical
  - Hydraulic
  - Pneumatic

TYPES OF ACTUATORS

- DC servo motor
- Stepping motor
- Induction motor (rotary)
- Hydraulic piston
- Pneumatic cylinder
- Solenoid
- Relay Switch

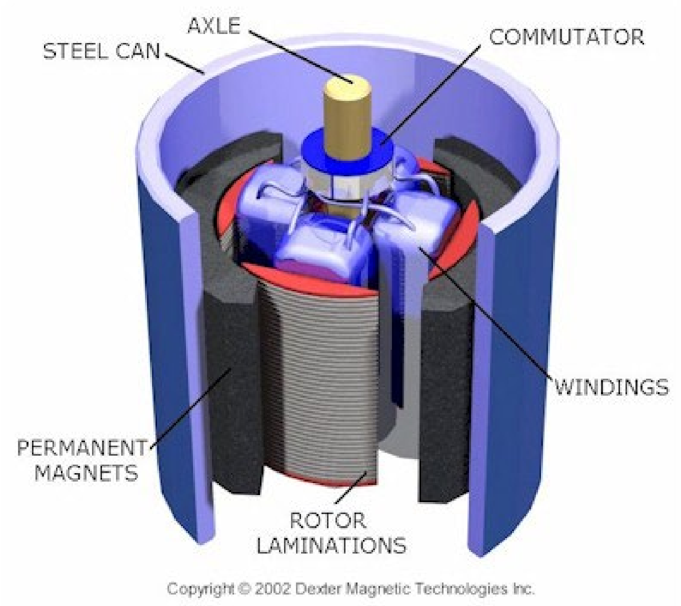
ELECTRICAL ACTUATORS

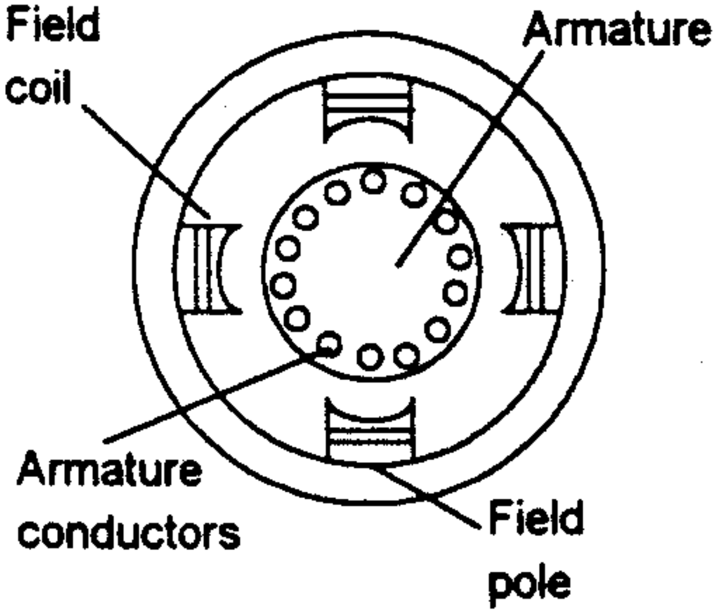
- Most common
- Different Types:
- DC servo motors, stepper motors, AC servomotors, and solenoids
- Electrical actuators include both linear devices (output is linear displacement) and rotational devices (output is rotational displacement or velocity)

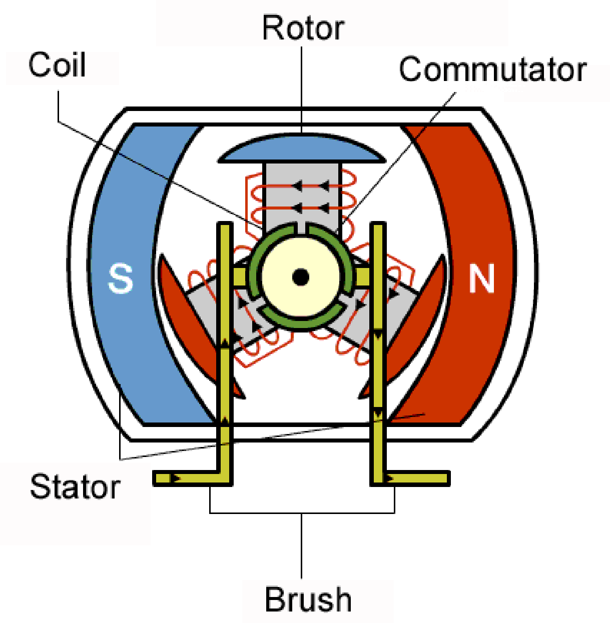
SUITABILITY OF ELECTRICAL ACTUATORS

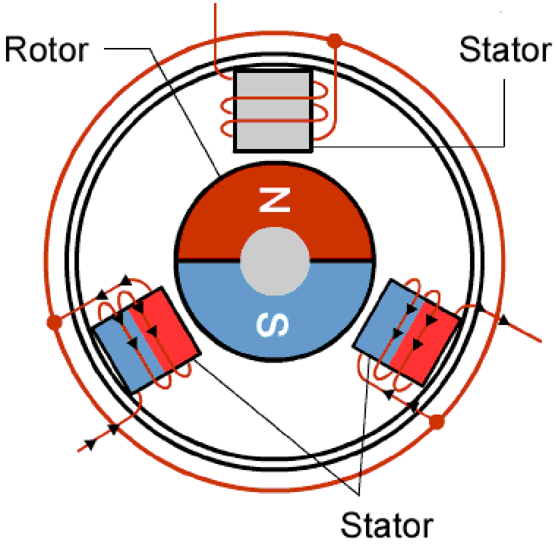
- Advantages:
  - Best accuracy and repeatability
  - Simple to use
  - Easy to maintain
  - Less expensive and easily available
  - possible to apply sophisticated control
- Disadvantages:
  - Low speed (unless direct drive)
  - Low payload
  - Usually need to convert for linear axis motion
  - Require gear trains or the like to transmit power
  - Gear backlash may limit precision

ELEMENTS IN DC MOTOR









ELECTRICAL DC SERVO MOTOR

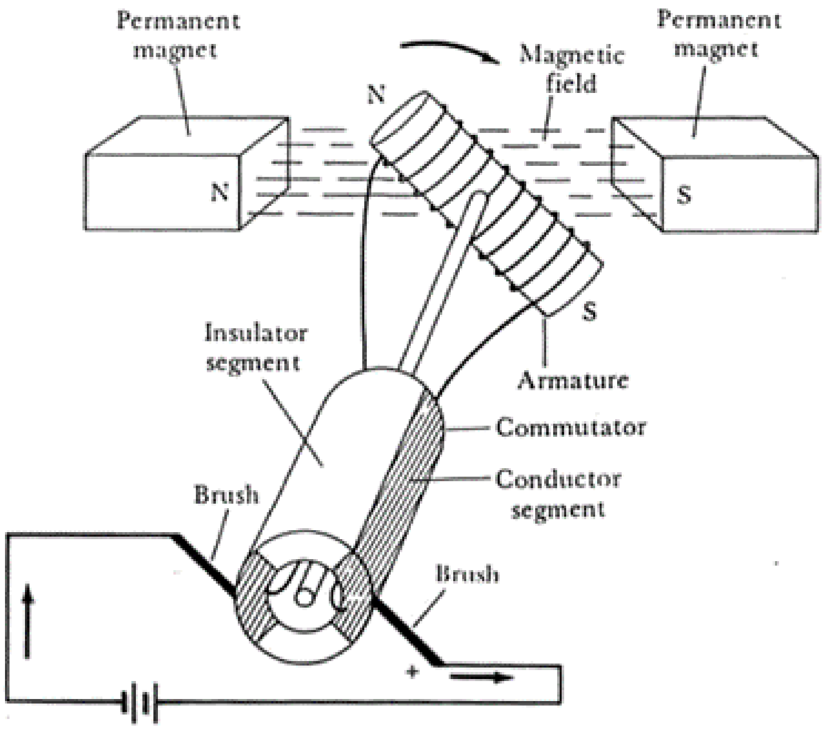
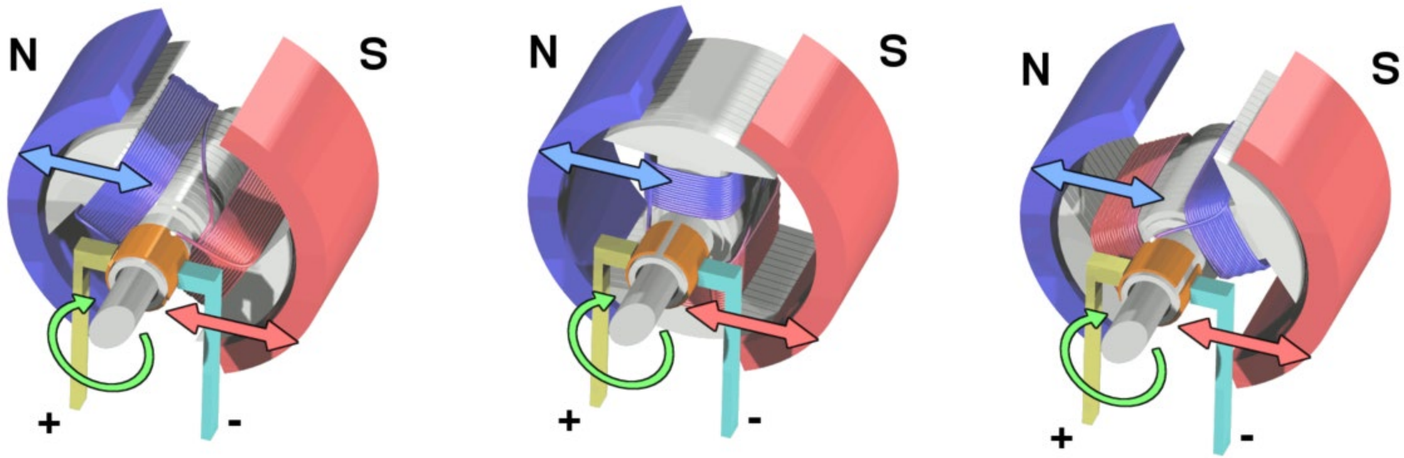


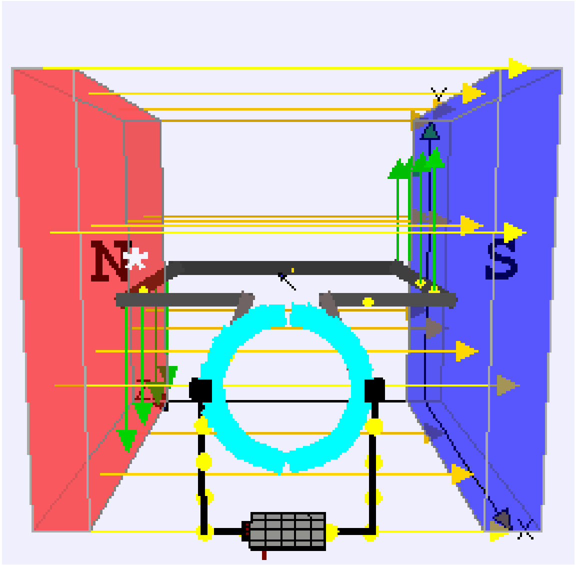
Figure 7–1 Basic Components of a DC Motor

Commutator continuously changes the relative polarity between rotor and stator, so that the magnetic field produces torque to turn the rotor all the time.

DC MOTOR: HOW IT WORKS

Lorentz law: When the current flows through the coil, the electromagnetic force will be induced





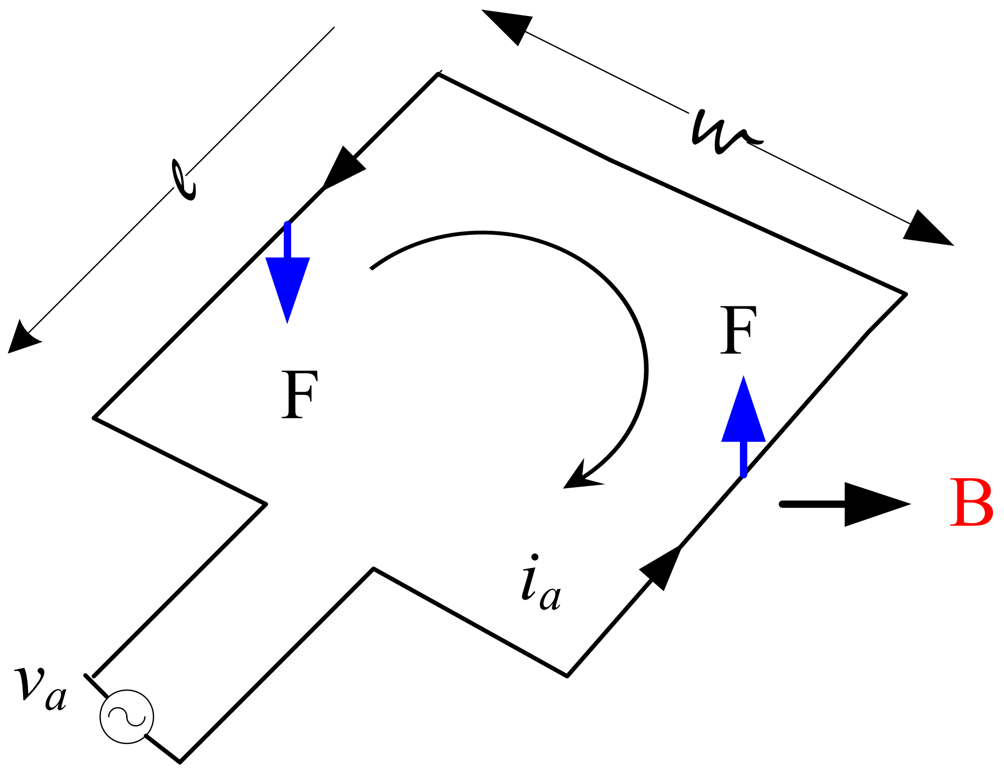
DC Motor
https://en.wikipedia.org/wiki/DC_motor

Brushed DC Electric Motor
https://en.wikipedia.org/wiki/Brushed_DC_electric_motor#Torque_and_speed_of_a_DC_motor

DC MOTOR – ELECTRIC MECHANICAL CONNECTIONS

Electric torque:

- $T_e = Fw = NBlwi_a = K_e i_a$



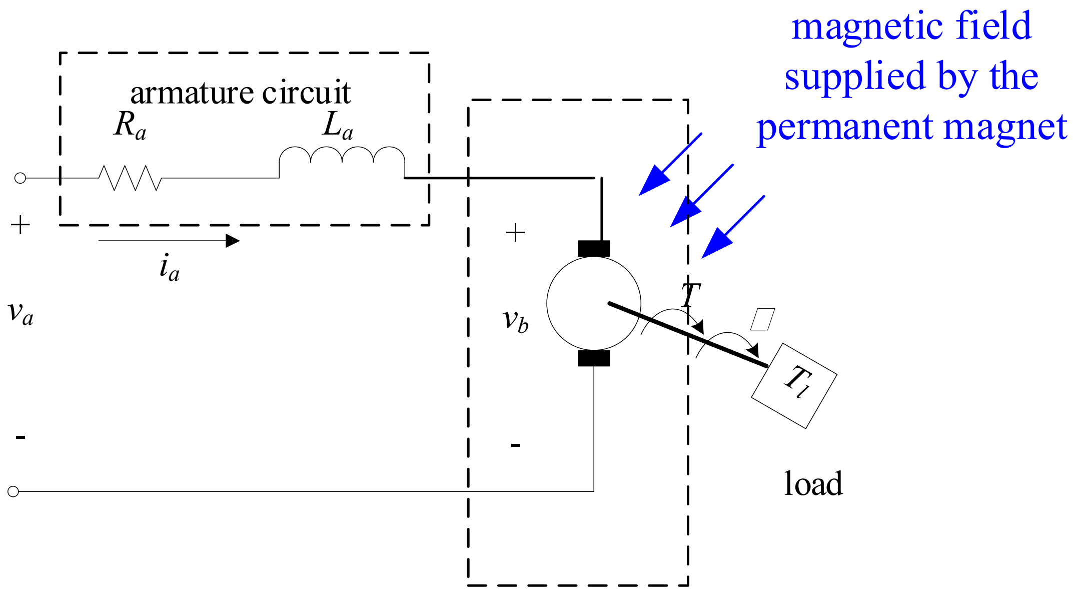
Back e.m.f:

- $v_b = k_2 B\omega = K_b \omega$

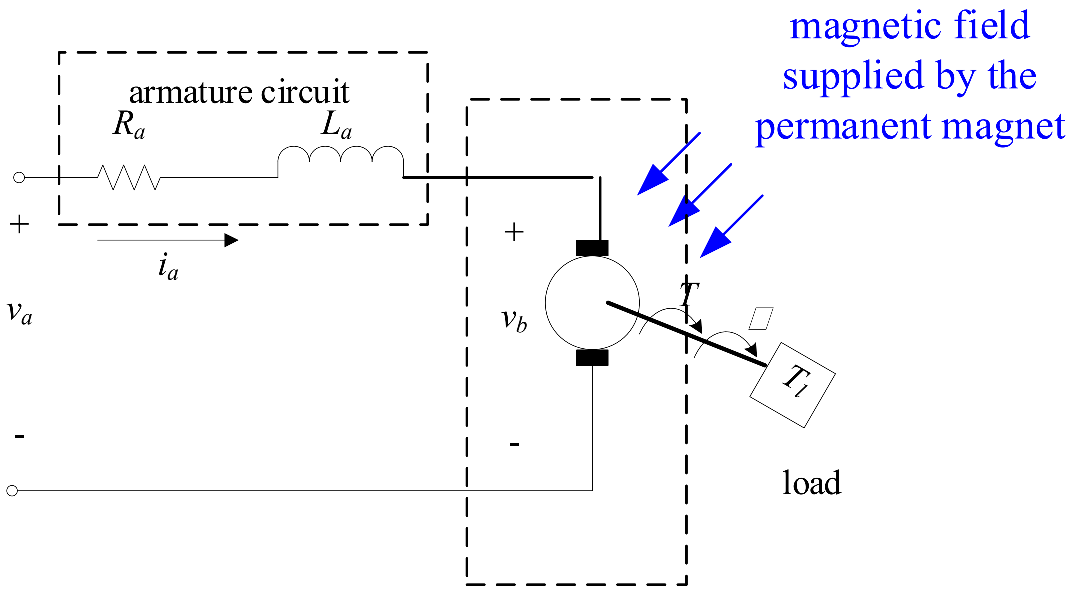
$F = Bli_a$ for one coil

$F = NBli_a$ for N coils

DC MOTOR DYNAMICS



DC MOTOR DYNAMICS



Armature circuit:

- $v_a - v_b = L_a \frac{di_a}{dt} + R_a i_a$
- $\frac{i_a}{v_a - v_b} = \frac{1}{L_a s + R_a}$

Rotating Motion:

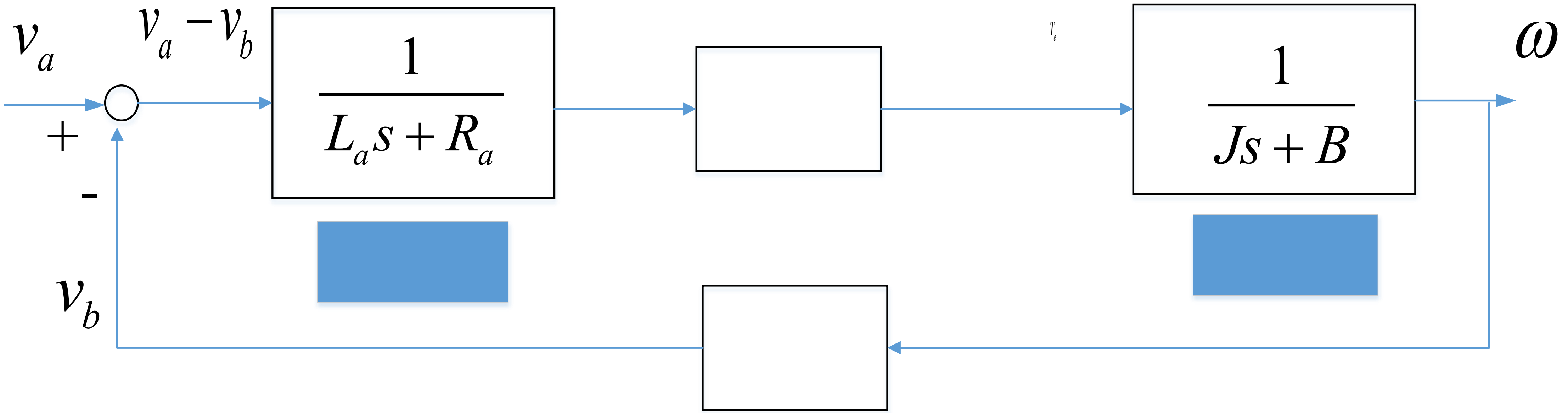
- $J \frac{d\omega}{dt} + B\omega = T_e,$
- $J \frac{d^2\theta}{dt^2} + B \frac{d\theta}{dt} = T_e,$

$$\frac{\omega}{T_e} = \frac{1}{Js + B}$$

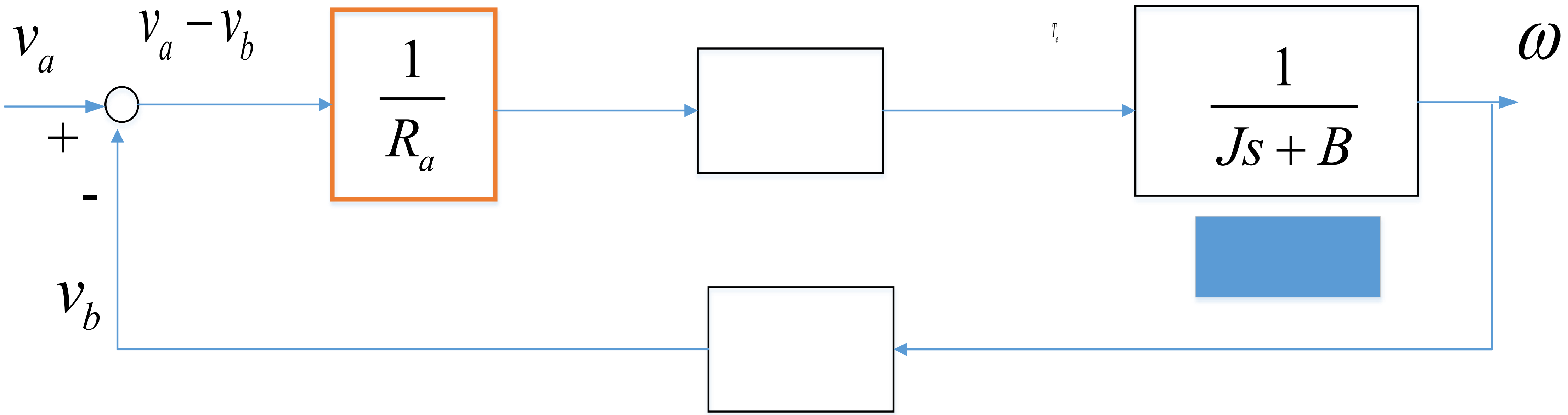
$$\frac{\theta}{T_e} = \frac{1}{s(Js + B)}$$

DC MOTOR TRANSFER FUNCTION

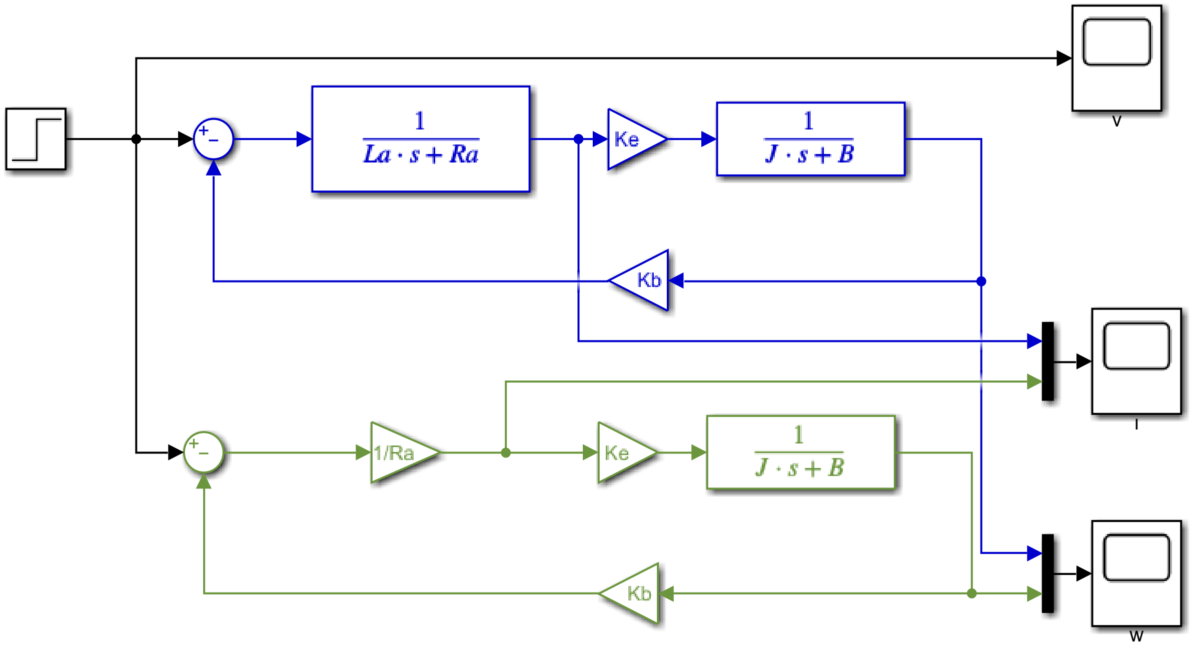
- DC motor dynamic block diagram:

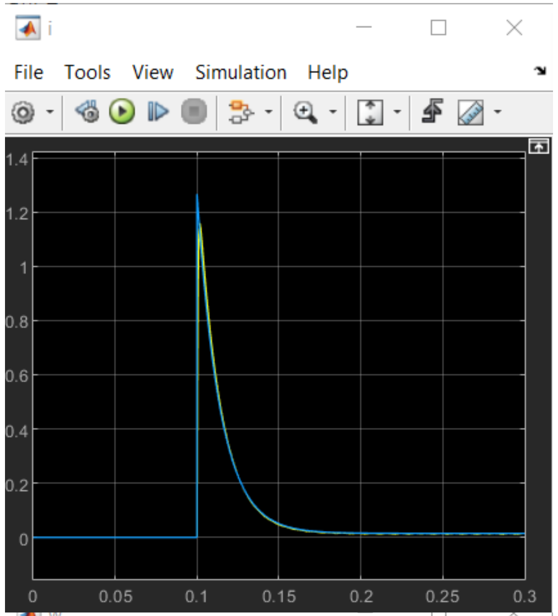


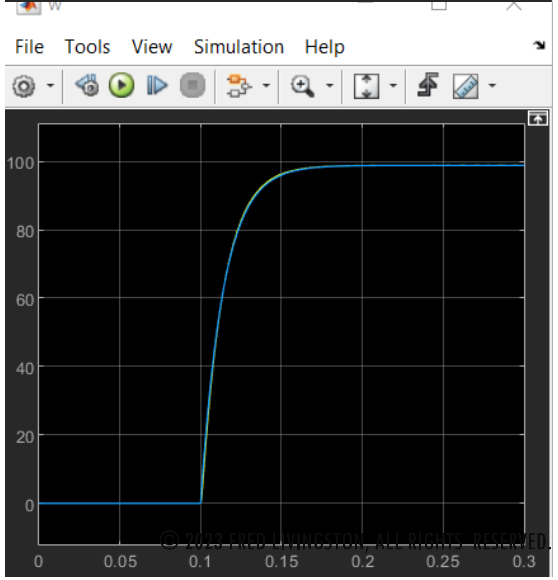
DC MOTOR SIMPLIFIED TRANSFER FUNCTION



DC MOTOR MODEL PERFORMANCE COMPARISON







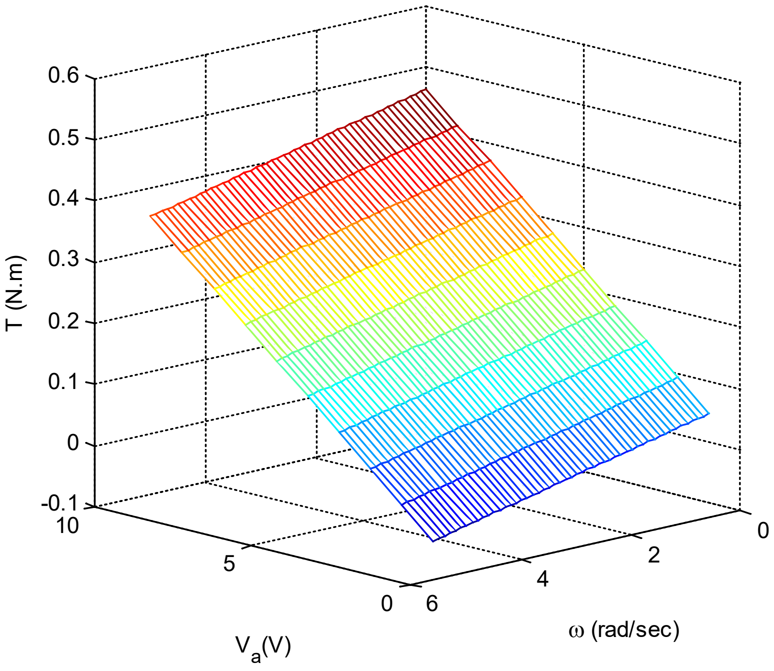

```
La = 0.37e-3  % inductance
Ra = 0.79     % terminal resistance
J = 1.62e-6   % Rotor inertia
B =1.34e-6    % Viscous damping factor
Ke = 0.009    % Torque constant
Kb = 0.01     % Motor constant
```

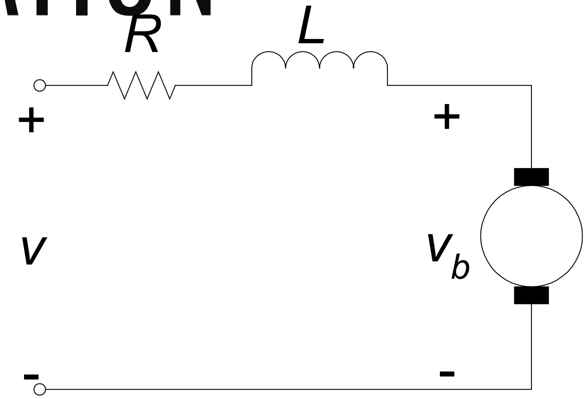
DC MOTOR STEADY-STATE OPERATION

At steady-state: $di/dt = 0$ and $d\omega/dt = 0$

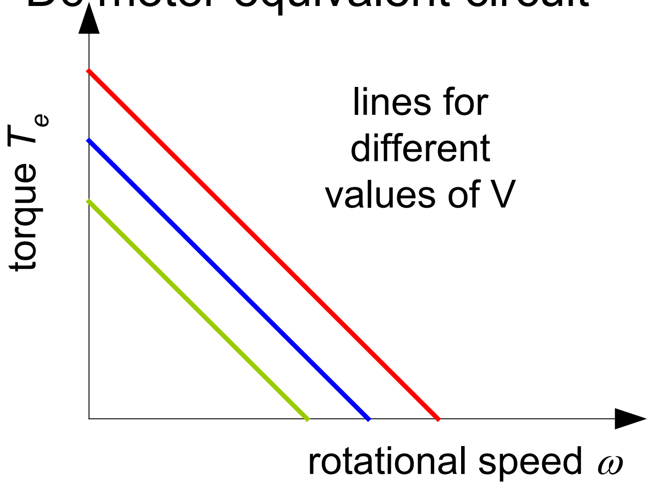
$$\Rightarrow \quad i_a = \frac{v_a - v_b}{R_a} = \frac{v_a - K_b\omega}{R_a}$$

$$T_e = K_e i_a = K_e \frac{(v_a - K_b\omega)}{R_a}$$





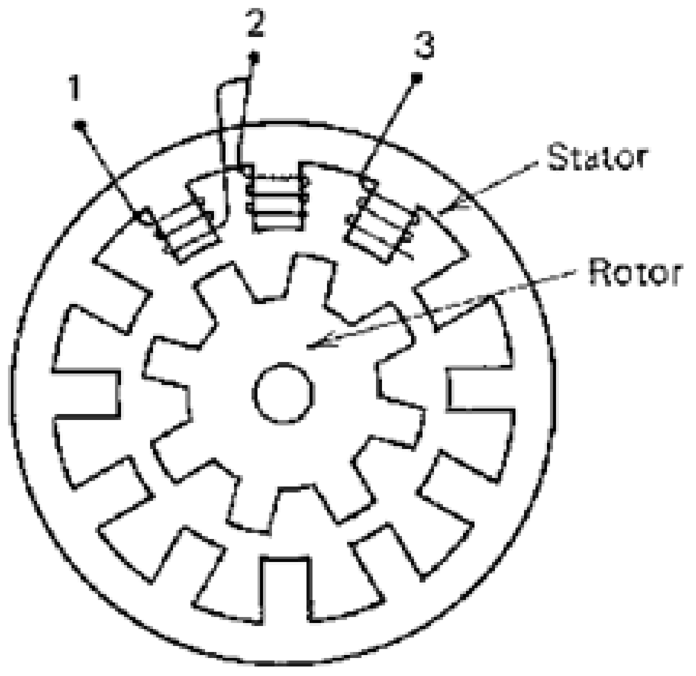
Dc motor equivalent circuit

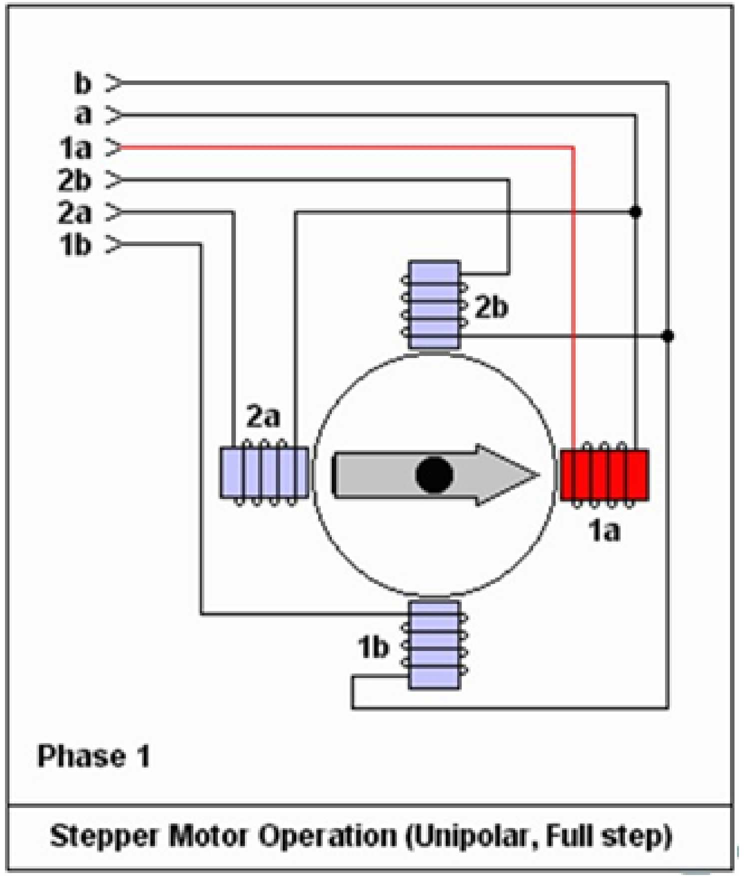


torque-speed characteristic with different input voltage

STEPPER MOTORS

convert electrical pulses into proportional mechanical motion





STEPPER MOTORS

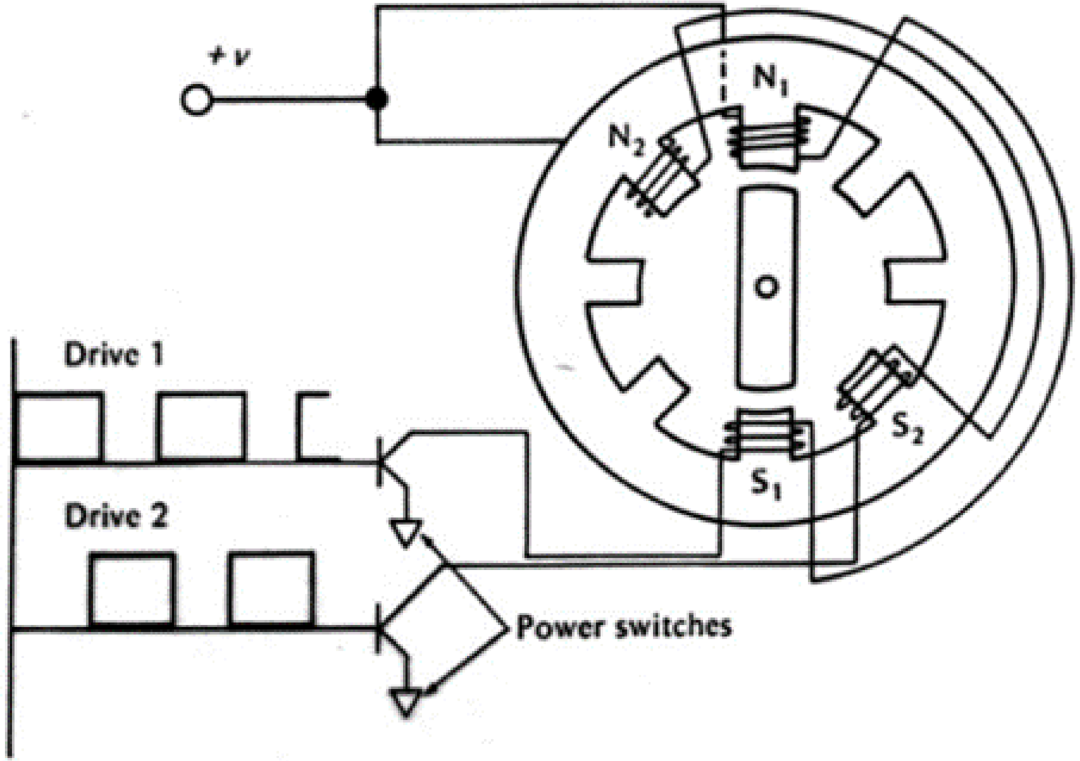
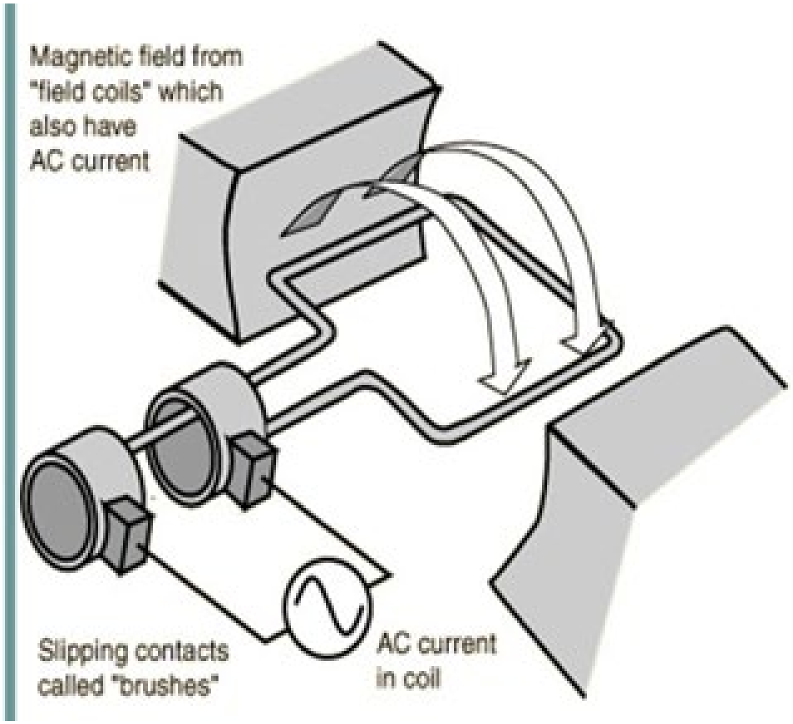


Figure 7–28. Basic operation of a stepper motor.

AC MOTORS



An outside stationary stator having coils supplied with AC current to produce a rotating magnetic field

An inside rotor attached to the output shaft that is given a torque by the rotating field

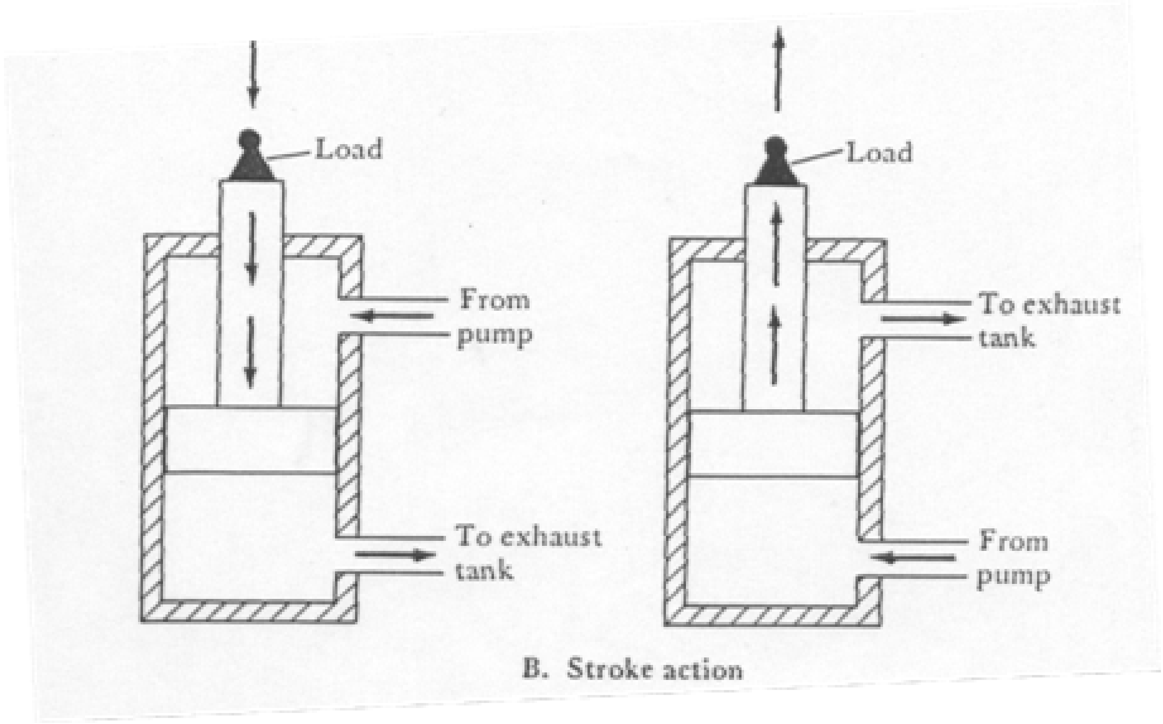
No brushes needed

HYDRAULIC ACTUATORS

- Hydraulic actuators use hydraulic fluid (oil) to amplify the controller command signal.
- The available devices provide both linear and rotational motion.
- Hydraulic actuators are often specified when large forces are required.

HYDRAULIC PISTON

- Piston inside cylinder exerts force and provides linear motion in response to hydraulic pressure.
- High force capability.



HYDRAULIC CYLINDER

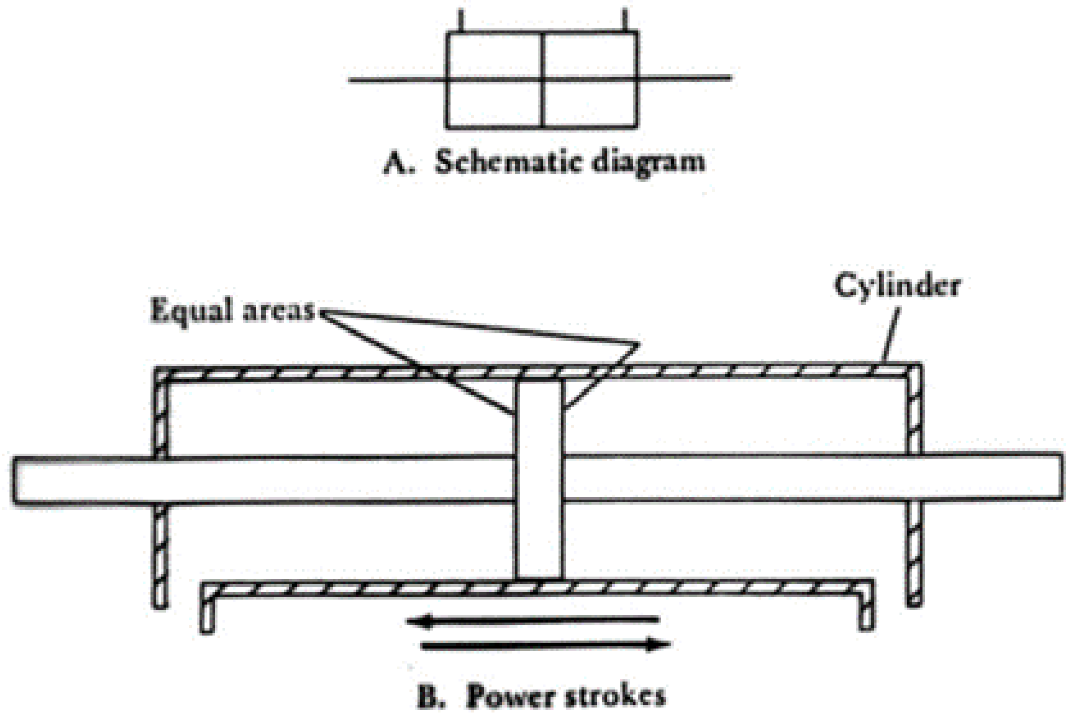
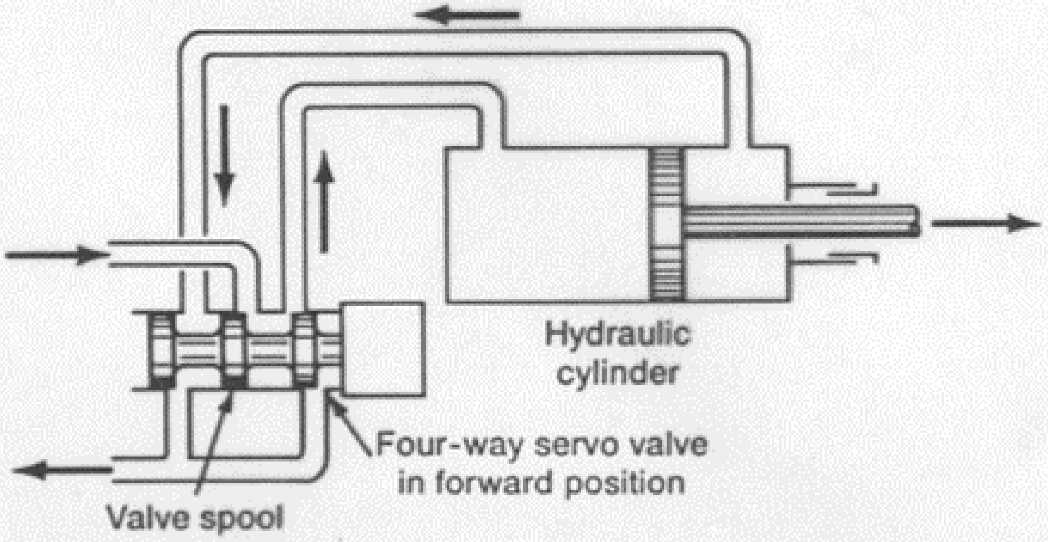


Figure 6–11 Double-Rod Cylinder

HYDRAULIC CYLINDER

Figure 4.1 Simplified diagram of a hydraulic cylinder and saervo valve used for control (from Versatran [12]).

Source: Prab Robots, Inc. Used by permission



HYDRAULIC MOTOR

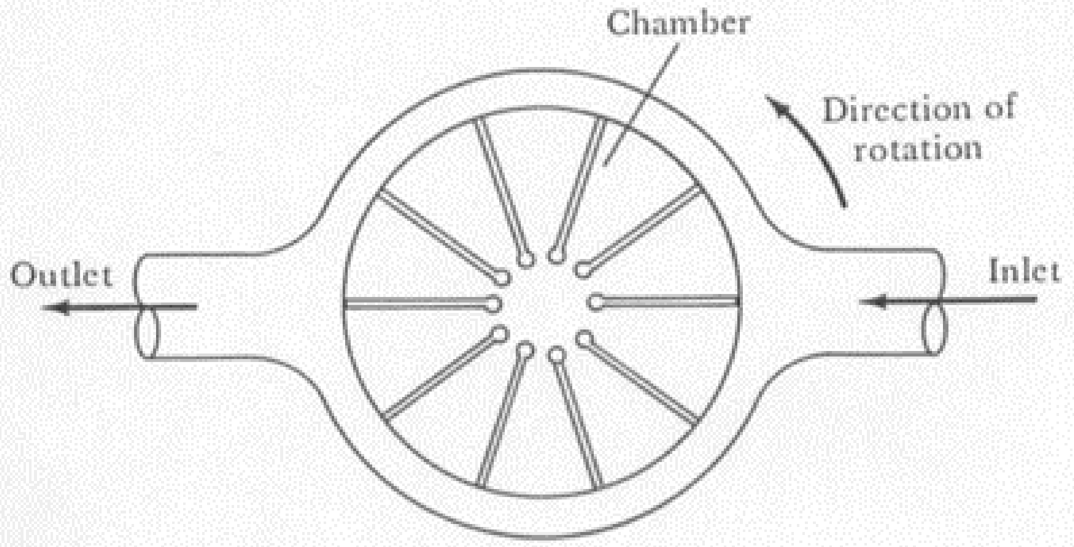


Figure 6–12 Hydraulic Motor

SUITABILITY OF HYDRAULIC ACTUATORS

Advantages
- Mechanical simplicity
- Physical strength
- Moderate speed
- Higher power to weigh ratio
- Accurate Control, compared with pneumatic actuator

Disadvantages
- Hydraulic systems are expensive
- Oscillation in deceleration to a point if used for fast motion
- Extra space for hydraulic pump, tanks, etc.
- High cost of maintenance
- Oil filtering, oil change, hydraulic line rupture, oil leakage, …..
- Pollution of workplace with oil
- High noise

PNEUMATIC ACTUATORS

- Use compressed air (typically “shop air” in the factory environment) as the driving power.
- Both linear and rotational pneumatic actuators are available.
- Usually limited to relatively low force applications (due to relatively low air pressures) when compared to hydraulic actuators
- Limited servo applications due to the compressibility of air

PNEUMATIC CYLINDER

- Piston inside cylinder exerts force and provides linear motion in response to air pressure.

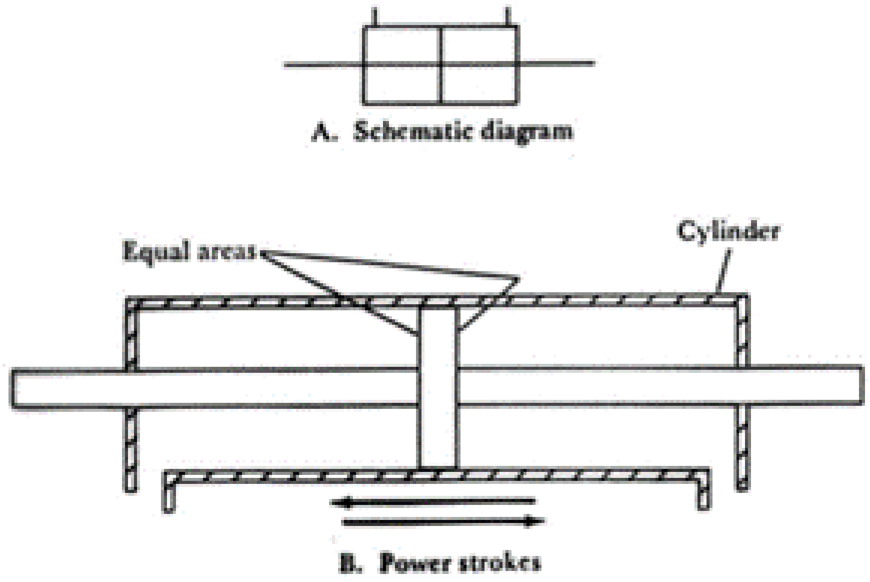


Figure 6–11 Double-Rod Cylinder

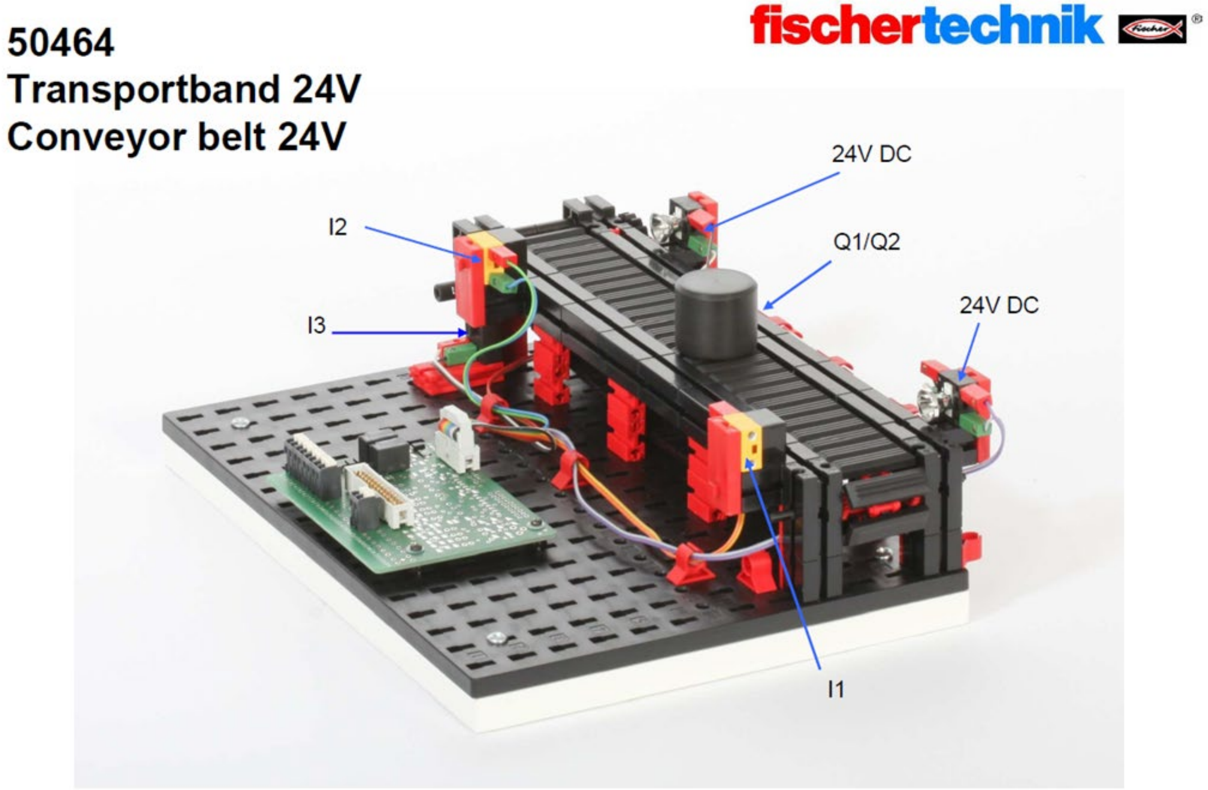
SUITABILITY OF PNEUMATIC ACTUATORS

- Advantages:
  - Low cost of maintenance and operation
  - High speed
- Disadvantages:
  - Compressibility of air, limited accuracy for servo control
  - Air filtering and drying
  - Mostly open loop
  - Very difficult to control position

LABORATORY 1

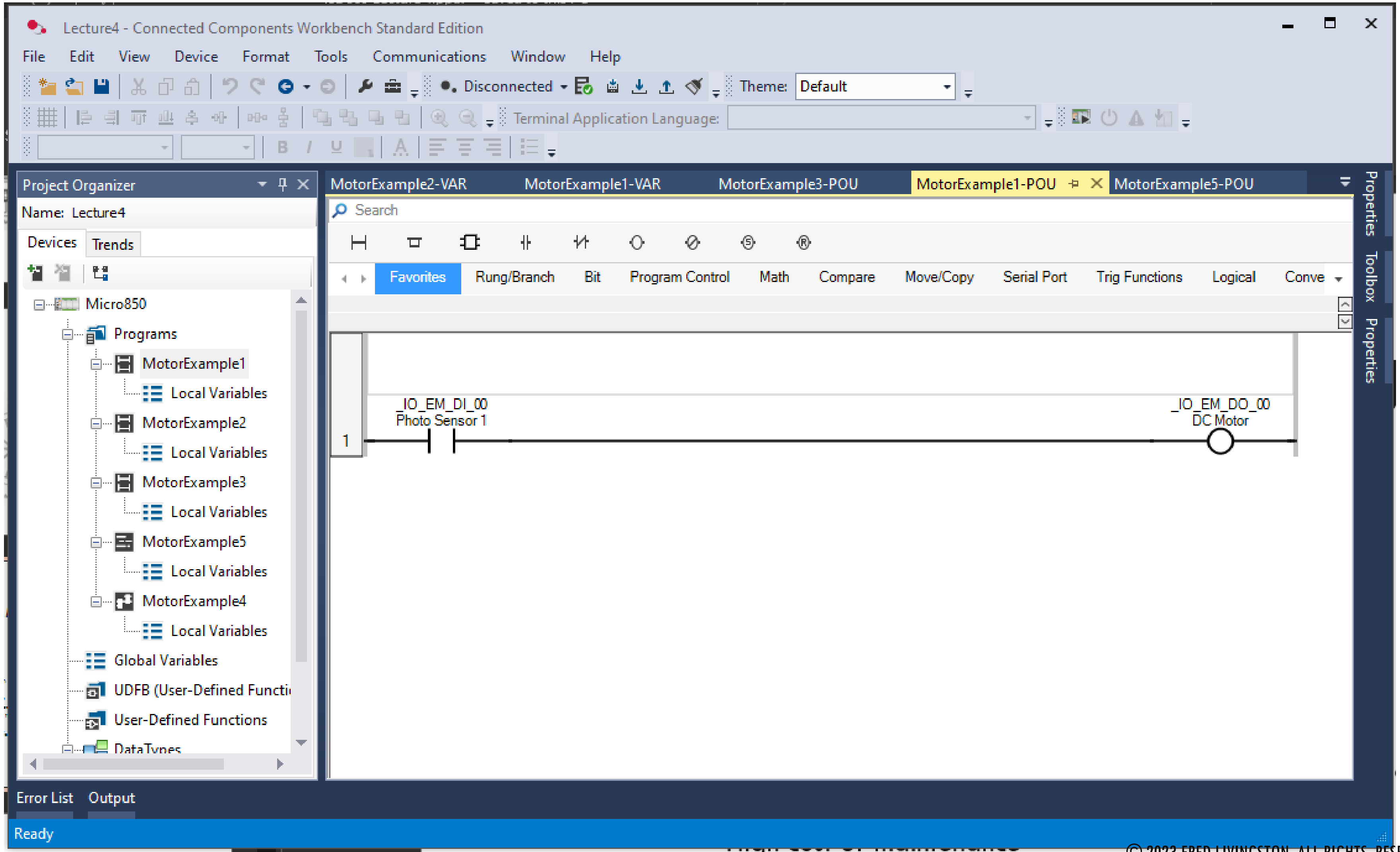
AUTOMATION CONTROL OF CONVEYOR BELT

https://docs.google.com/document/d/1RJWIY5vqn8Hu-hYFN8h5WZ-eERnEdx75JW40znO_JFc/edit?usp=sharing

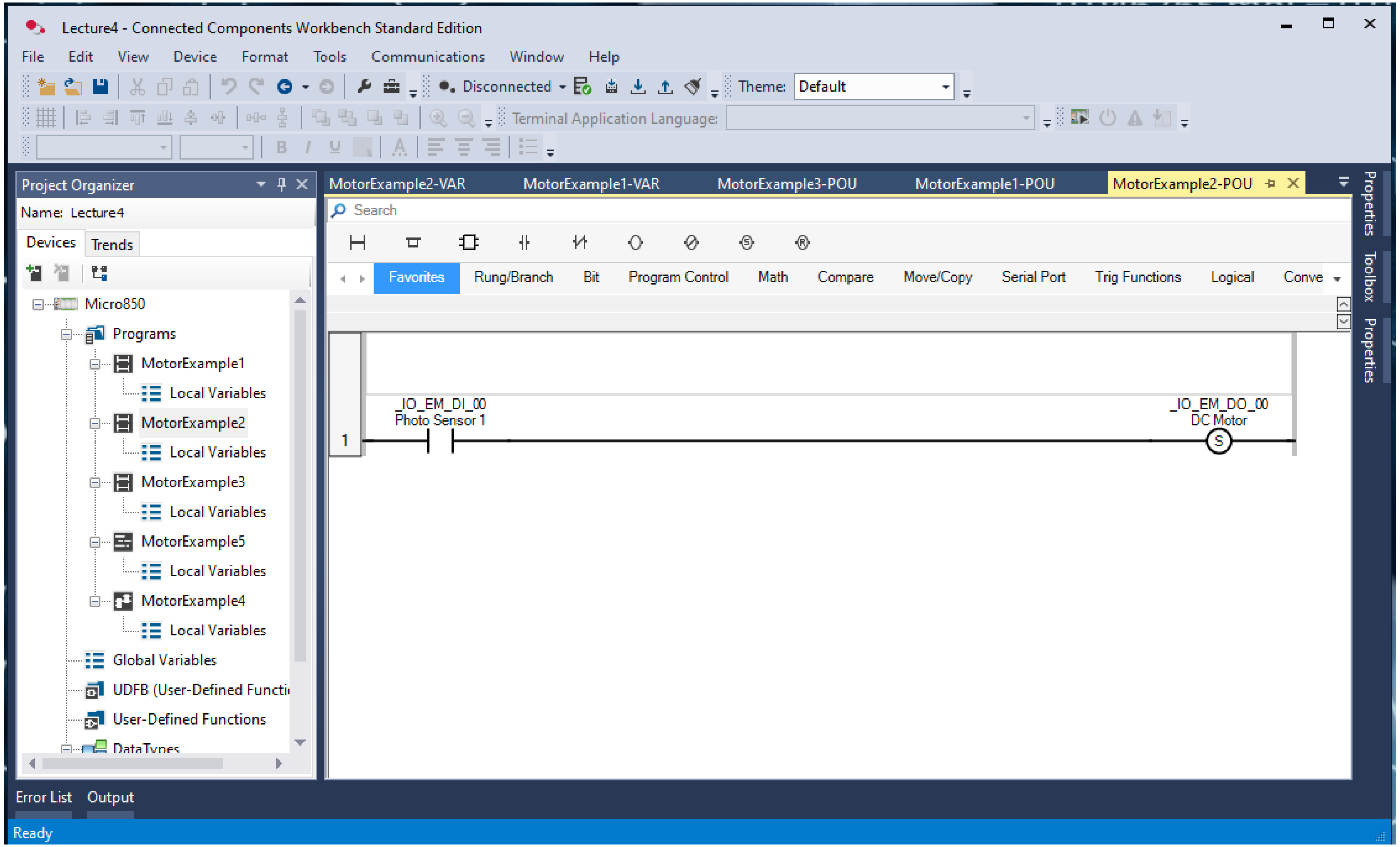


In this laboratory, you will automate and control a conveyor belt system. This system consists of a 24 vDC motor and two NPN phototransistors. The conveyor belt is initially inactivated. After detecting an object, the conveyor belt moves it until a second NPN phototransistor deactivates it. You can demonstrate this using the project using the sensors and actuators found in the Automation Lab or using the 50464 Trainer.

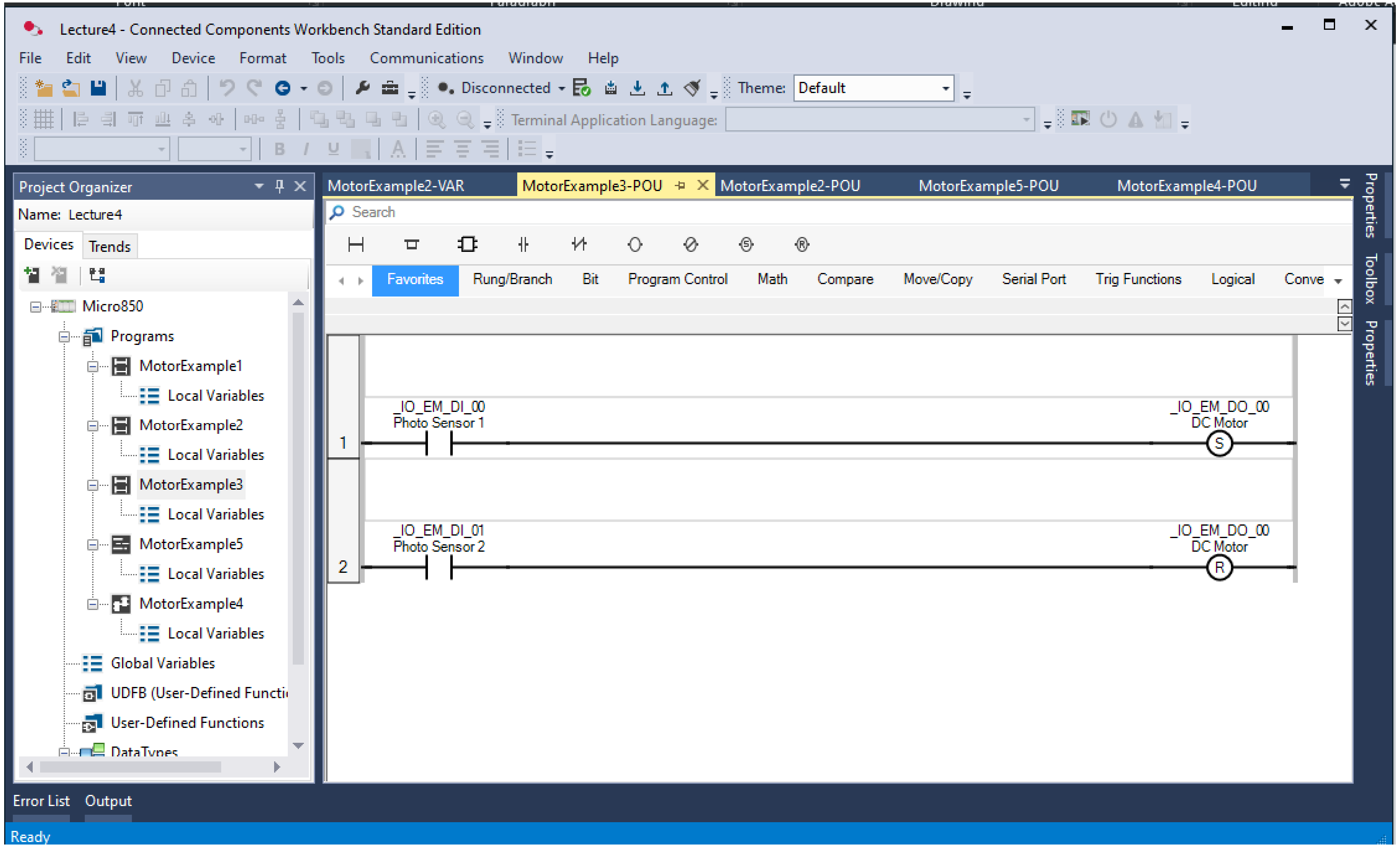
CCW – MOTOR EXAMPLE I



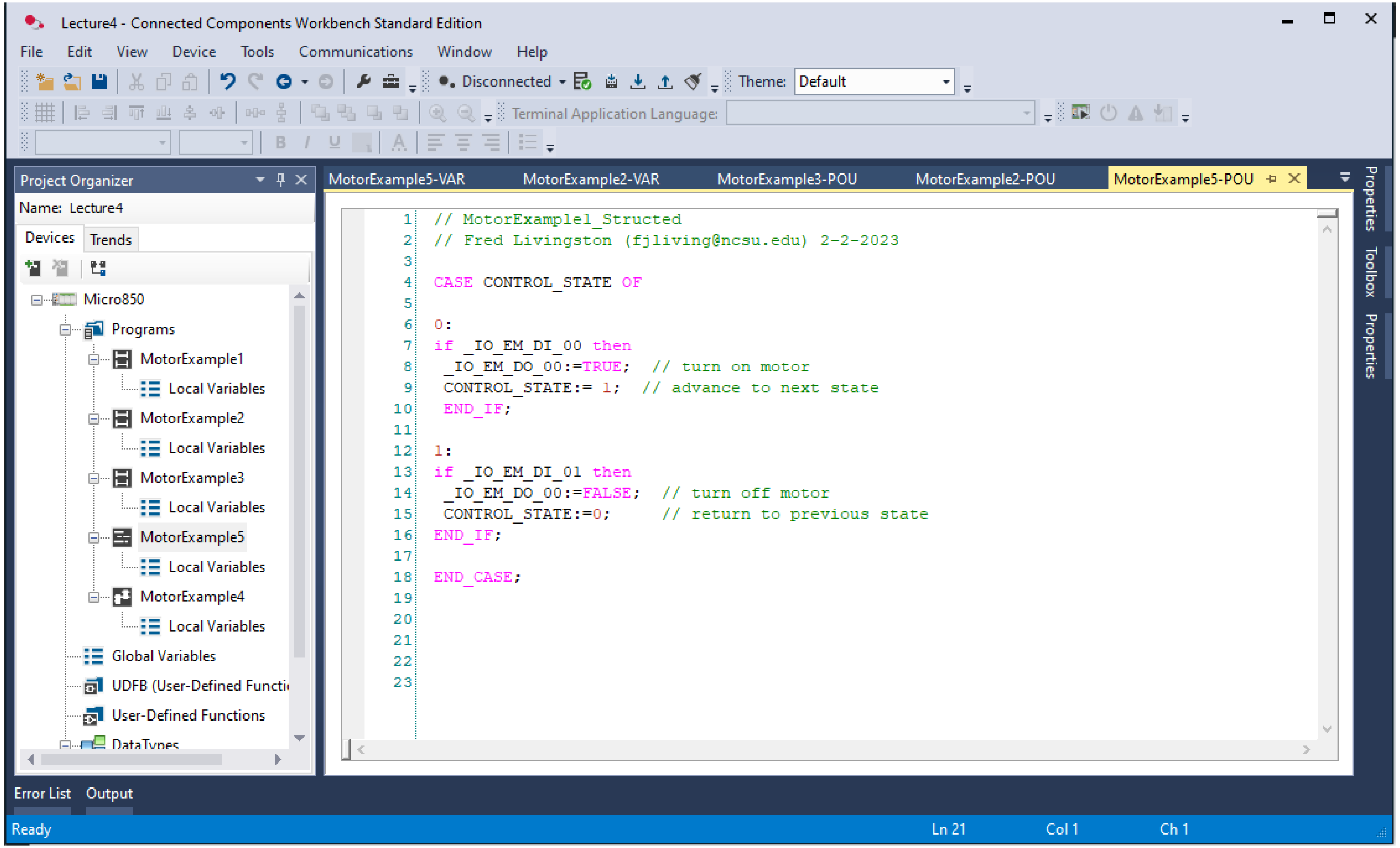
CCW – MOTOR EXAMPLE II



CCW – MOTOR EXAMPLE III



CCW – MOTOR EXAMPLE IV



END OF LECTURE