

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Ben Hathaway	Student ID number:	
Programme:	HNC Electrical/Electronic Engineering		
Module:	Programmable Logic Controllers		
Module code:	PCEE4005	Contribution to Overall Module Assessment (%):	50%
Lecturer:	Jason Pointer	Internal Verifier:	Lance Rutherford
Assignment Title:	PLC Program design and simulation	Word count (or equivalent):	2000
Submission deadline:	14/05/20	Return date of provisional marks & written feedback:	28/05/20
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)

1. Demonstrate an understanding of the concepts of process control using an industry standard PLC.
2. Undertake basic PLC system design and implementation processes, comparing theoretical expectations to actual outputs ensuring correct operation and consideration of maintenance and reliability.

STUDENT FEEDBACK FORM

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	15	9
Engagement with a wide range of literature, including sources retrieved independently.		
2. Knowledge and Understanding Skills	25	12.5
Task 1 achieved 50%. Task 2 achieved 50%. Knowledge of the basic underlying concepts and principles of the work required for Task 1 and 2. In places did lack some details in the explanation.		
3. Cognitive and Intellectual Skills	15	1.5
Little evaluation of the underlying concepts and principles applied to the construction of the programs for Task 3 and 4.		
4. Practical Application Skills	35	23.6
Task 3 achieved 70%. Task 4 achieved 65%. A very good application of the different software to produce nearly fully functional programs to cover the requirements of Task 3 and 4. Task 3 was missing the HMI but had been development in the classroom session. There was an error within the ladder logic for Task 4 and did not achieve all set specifications.		
5. Transferable Skills for Life and Professional Practice	10	5
Mostly ordered presentation and structure but in places does lack some coherence.		

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		52%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		



PROGRAMMABLE LOGIC CONTROLLERS

PLC Program design and simulation

Ben Hathaway

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Task 1 – PLC analogue and discrete I/O

Task 1a – PLC inputs

Push button

A push switch is one of the most commonly used inputs for a PLC system, a push button can be used as a start button when it has the normally open configuration and a stop button when it is used in a normally closed configuration, with this type of input the switch only has the ability to either give an input or give no input depending on the switch being open or closed making it a discrete input.

Figure 1 – Start/Stop circuit for PLC

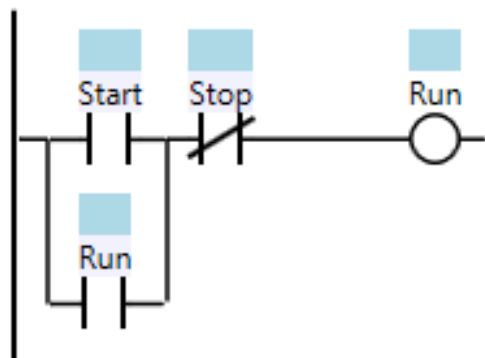


Figure one shows the configuration of a start stop circuit. The start button is usually in parallel with another component such as a relay, as the button is pressed pushed then released the relay below would energize, the stop button is normally closed and would not have any effect on the input to the PLC until it is pressed and breaks the circuit. ✓

Temperature sensor – Bimetallic strip

A type of temperature sensor that can be used to give a discrete input signal is a bimetallic strip, this is a very simple type of temperature measurement and works on the principle that the two metals that are fused together have a different coefficients of expansion. As current is drawn through the circuit the bimetallic strip starts to heat up and once it reaches the required temperature the bimetallic strip will bend out of shape and either make or break the contact.

Figure 2 – Bimetallic strip

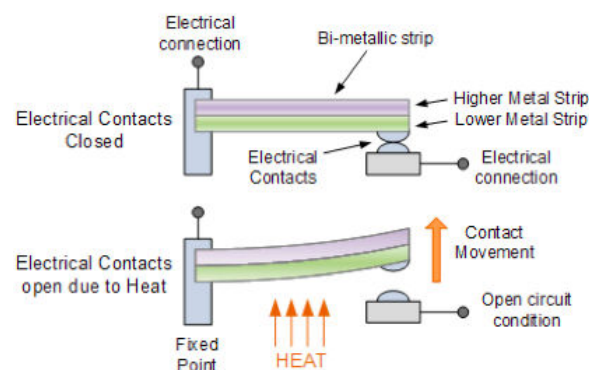
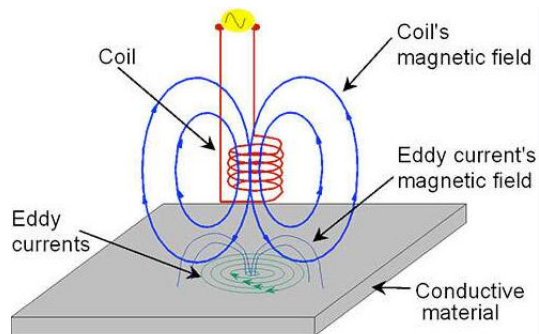


Figure two shows a bimetallic strip, when the circuit is running the two different metals will begin to heat up, if the circuit starts to draw over current the components will heat up, the lower metal has a lower coefficient of expansion so as it bends out of shape and opens the circuit. Bolton states in Programmable Logic Controllers states “the most commonly used are platinum, nickel or nickel alloys.” (p.24, 2006). ✓

Proximity sensor – Eddy current type

A proximity sensor is used to detect an object without making contact with it, it can be used as a discrete input and it will give a signal to a PLC if there is an object within the operational limits of the proximity sensor. The eddy current type of sensor works on the process of a magnetic field due to this only senses conductive materials.

Figure 3 – Process of eddy current proximity sensor



There is a constant AC current put on the coil within the sensor which produces a magnetic field, when a conductive material is within close proximity of the sensor 'eddy current' is produced. The eddy current then produces an E.M.F in the coils, which changes the voltage required to keep the magnetic field around the coil, this voltage can then be used to operate switch and give an input to a PLC. Bolton states in programmable logic controllers "The voltage amplitude is thus a measure of proximity of metallic objects." (p.20, 2006) ✓

Encoders – Increment encoder

An encoder gives a digital output which means it can give an exact value rather than just an on and off input signal and works off the principle of linear or angular displacement in the case of an increment encoder from an datum position. Bolton states in programmable logic controllers that the term encoder is used for a device that provides a digital output as a result of angular or linear displacement. (p.22, 2006).

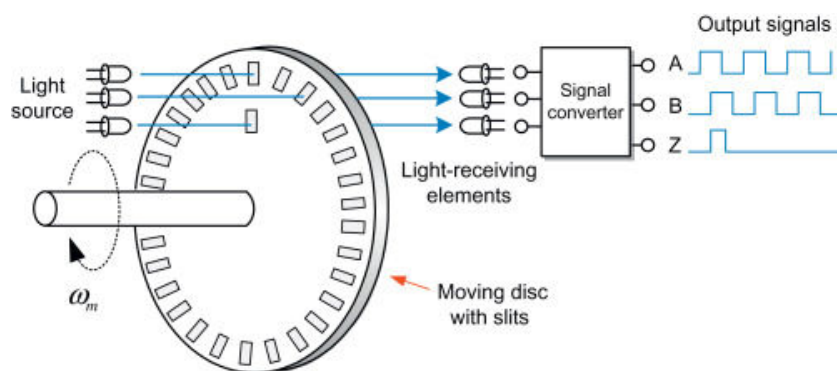


Figure 4 – An encoder with signal converter

A light source from an LED in the case of figure 4 passes through the slots on the encoder which is on the rotating shaft. The light is received by a sensor through the slits, the number of slits will be proportional to the 360° of a normal rotation,

for example if there were 10 slots each slot would be 36° of a full rotation. As the different sensors receive light from the LED's at different times it gives an exact position of where the shaft is in respect to 360°, this signal is then converted so it can be used as an input for a PLC. ✓



Task 1b – Analogue to digital conversion

The operation of analogue to digital conversion has four main components, the sample section, the hold section, the quantize section and the encoder.

Figure 5 – ADC conversion elements

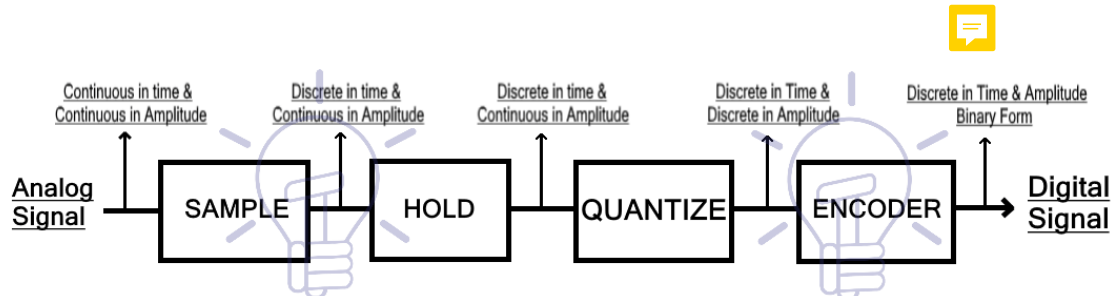


Figure 5 shows the sample block which is where the analogue measurement is taken from, the process then moves to the hold block, this is where the value is recorded and held as an analogue value, quantization is the process of converting a continuous range of discrete values, for example it would convert a 4 – 20mA into a digital signal by making its time and amplitude discrete. Finally, the encoder converts the digital signal into binary form, an example of a component that could be used to convert a 4 – 20mA signal into binary form is the ZN439 which is an integrated circuit that consists of 12 different pins. Bolton states in programmable logic controllers that “The analogue voltage has to change by the difference in analogue voltage between successive levels if the binary output is to change. (p.55, 2006) ✓

Figure 6 – Quantization error

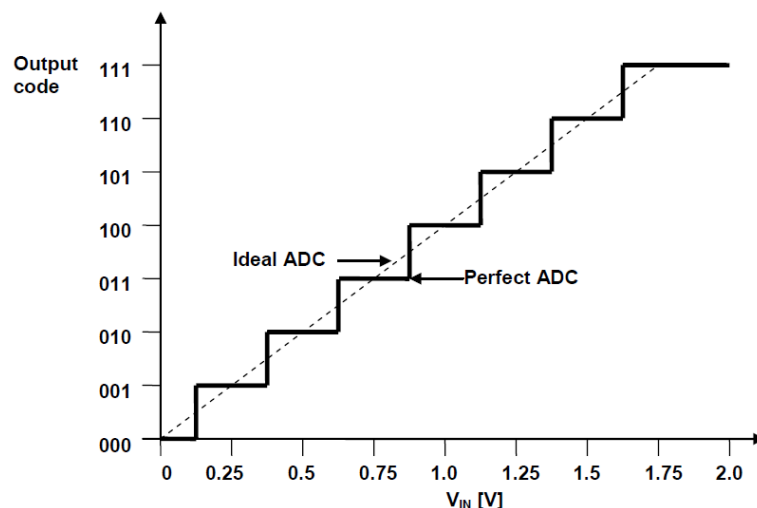


Figure 6 shows quantization error in ADC conversion. Quantization error is the difference between the analogue input signal to the system and the digital representation on the display screen, this is due to the sample being a continuous process and the value changing. ✓

Task 1c – Output devices for a PLC

D.C. Motor

A D.C motor can be used as an output for a PLC system with a push button switch being used as an input for it, the start button would be pressed and then the motor would start after the signal was passed through the PLC as long as it was satisfied and all interlocks in place.

Figure 7 – D.C motor

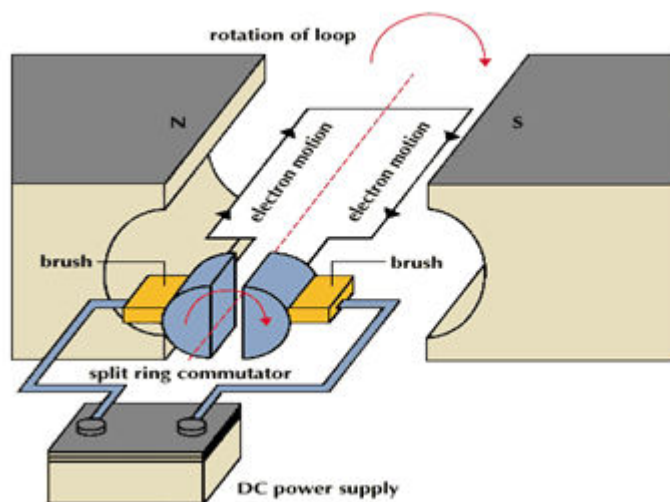


Figure 5 shows a magnetic field that is produced between the two permanent magnets using opposite poles, current produced by the power source which is a battery in the case of this diagram is fed to the coils of the motor via brushes on the commutator, Bird states in electrical and electronic principles and technology that “When current flows in the coil a magnetic field is set up around the coil which interacts with the magnetic field produced by the magnets.” (p.91/92 2008).

This is what causes the rotation of the shaft and is what starts the motor turning.

Relay

A relay is one of the most common outputs for a PLC this is due to them being used to switch much larger industrial machines such as motors and compressors.

Figure 8–Relay diagram

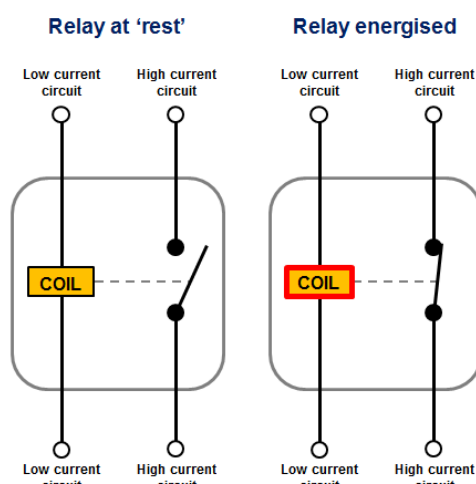
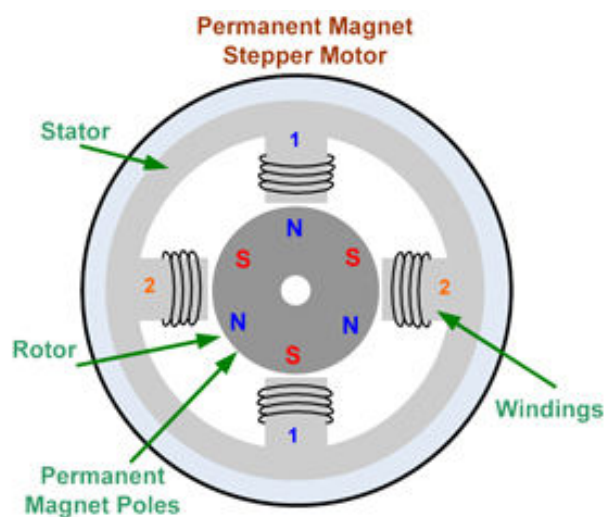


Figure 6 shows a relay when it is not energised which is at rest, it shows that without the low current circuit energised the larger circuit switch is not energised. It also shows that when the coil is energised the magnetic field produced pulls in the switch for the larger circuit and starts the industrial motor or compressor. In electrical and electronic principles and technology Bird states “When the coil is energised the hinged soft iron armature is attracted to the electromagnet.” (p.88, 2008). This occurs when there is current flowing to the coil of the low current circuit and this is what closes the contact on the larger circuit.

Stepper motor

A stepper motor is a brushless motor that uses equal angles to rotate, it is used on systems such as conveyer belts due to it being able to give a very accurate linear position which would be good as it could get objects exactly where they need to be. The stepper motors uses digital pulses and converts and uses them to rotate the shaft. Bolton states in programmable logic controllers that "Each pole is activated by a current being passed through the appropriate field winding". (p.36, 2006).

Figure 9 – Permanent magnet stepper motor



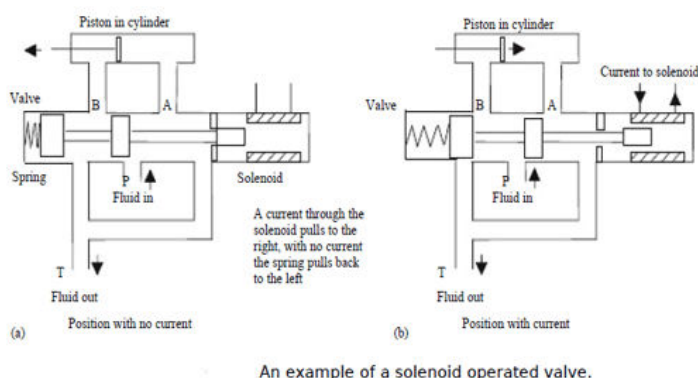
The input pulses to a stepper motor are proportionate to 360° . For example if there were four pulses each pulse would give the motor 90° of a full rotation, but a lot of stepper motors have much larger range of pulses. The permanent magnets activate when current flows to the windings. The magnetic field is then produced and as the result the motor turns to line up with the next magnet and then stops until the process occurs again but only when the polarities of the current are reversed. The number of pulses will determine how far the motor will turn before it stops.

✓

Directional operated valves

Solenoids are used in actuators to control valves, these valves may be used to control flow, levels or pressure systems, when using a solenoid in a valve it will only have the ability to be fully open or closed it wouldn't be able to be part open.

Figure 10 – Solenoid operated valve



As can be seen in figure 8, when there is no current in the cylinder the fluid would be free to flow through the system, whereas when current is applied to the coils of the solenoid it pulls the piston and closes the valve. Bird states in electrical and electronic principles and technology that "the magnetic field inside the

solenoid is practically uniform for a particular current" (p.87, 2008). This means that while the desired current is applied to the solenoid it will operate but as soon as the current is taken away it will de-energise.

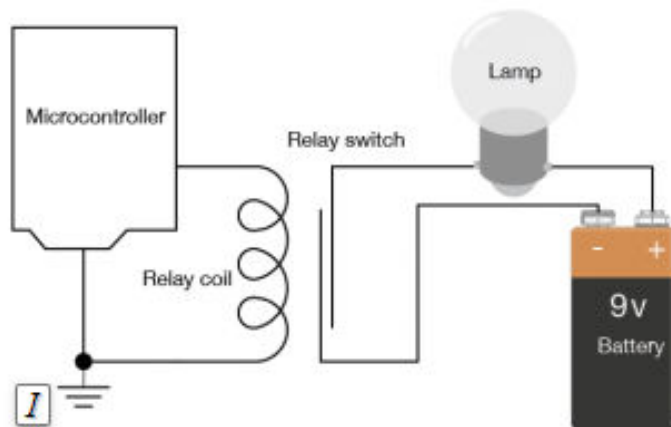
✓



Task 1d – Relays and transistors

The main types of switching devices used for outputs of a PLC are relays and transistors, the main difference is the operating principles of the two components, the operating principle of a relay is that it uses a magnetic field and a coil compared to a transistor which operates on a change of current or voltage.

Figure 11 – Relay connected to microcontroller



This figure shows a relay connected to a microcontroller, it has no physical connections to the larger circuit which is going to pull more current and operates at a higher voltage, an advantage of this configuration means there's not wiring between the lamp circuit and the microcontroller given it greater protection from fault current than a transistor. The relays can operate off both AC and DC voltage where as a

transistor is usually only used in an **AC circuit**, another benefit of a relay compared to a transistor is that there is no leakage current and it is either open or closed, as Bird states in electrical and electronic principles and technology "a small leakage current, flows from the collector to the base." (p.156, 2008). This indicates there can be a leakage current when using a transistor as a switching device. Another benefit of a relay is that it can be used in a normally open or normally closed configuration.

Figure 12 – Transistor connected to microcontroller

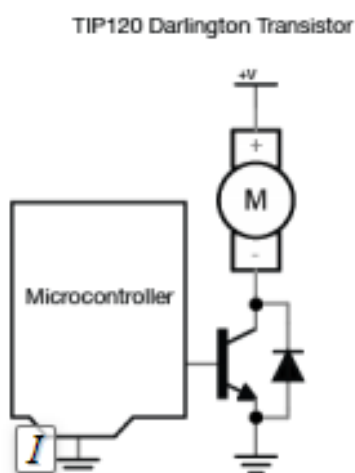
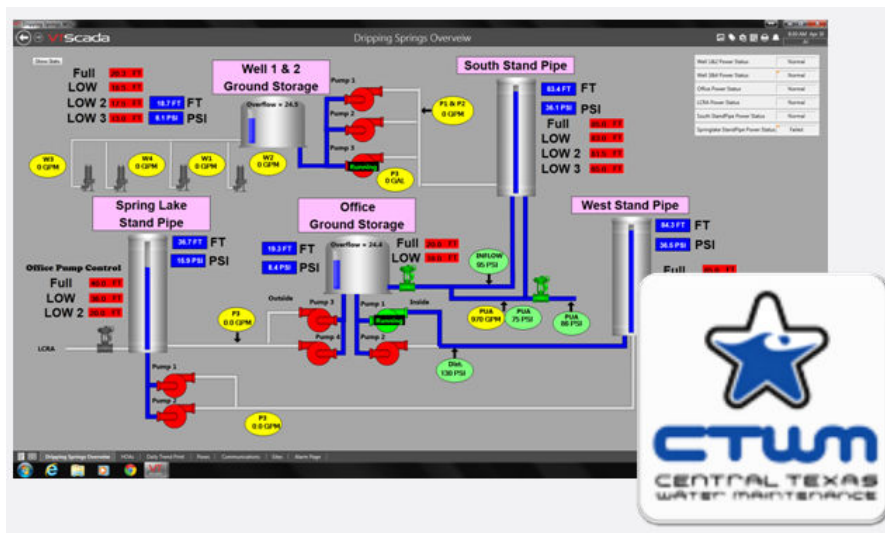


Figure 12 shows a transistor connected to a **microcontroller**, it has a physical connection to the larger circuit so any fault current would travel back to the microcontroller. The benefit of using this is that it is a very quick switching device and operates quicker than a relay which is a mechanical type of switch which can make it more reliable. A benefit of using a transistor is that it can be used for analogue conversion and they are much smaller in size. Another benefit is it can be used in a range of applications due to its properties and different configurations such as PNP junction and NPN junction. ✓

Task 2 – SCADA (Supervisory Control and Data Acquisition)

SCADA is a software package that is used in industrial systems and processes as well as some training and competency tests. According to the website; 'inductiveautomation.com' "The basic SCADA architecture begins with programmable logic controllers (PLCs)" (Date unknown). The main features of using SCADA for an industrial process point is that it allows you to control process remotely, this means an operator who is sitting in a control room can make changes to the running plant, another benefit is that it allows you to gather feedback remotely and gives you real time feedback. HMI is used to control valves and other industrial processes. PLC's are used as it allows you to send inputs remotely and will produce and output depending on the programme that is preloaded in it, SCADA allows you to watch this from a different location. A big benefit of SCADA is that if anything went wrong on an industrial process which could be unsafe to shut down manually it can be done from a remote location meaning no one needs to enter a dangerous area.

Figure 13 – HMI (human machine interface)



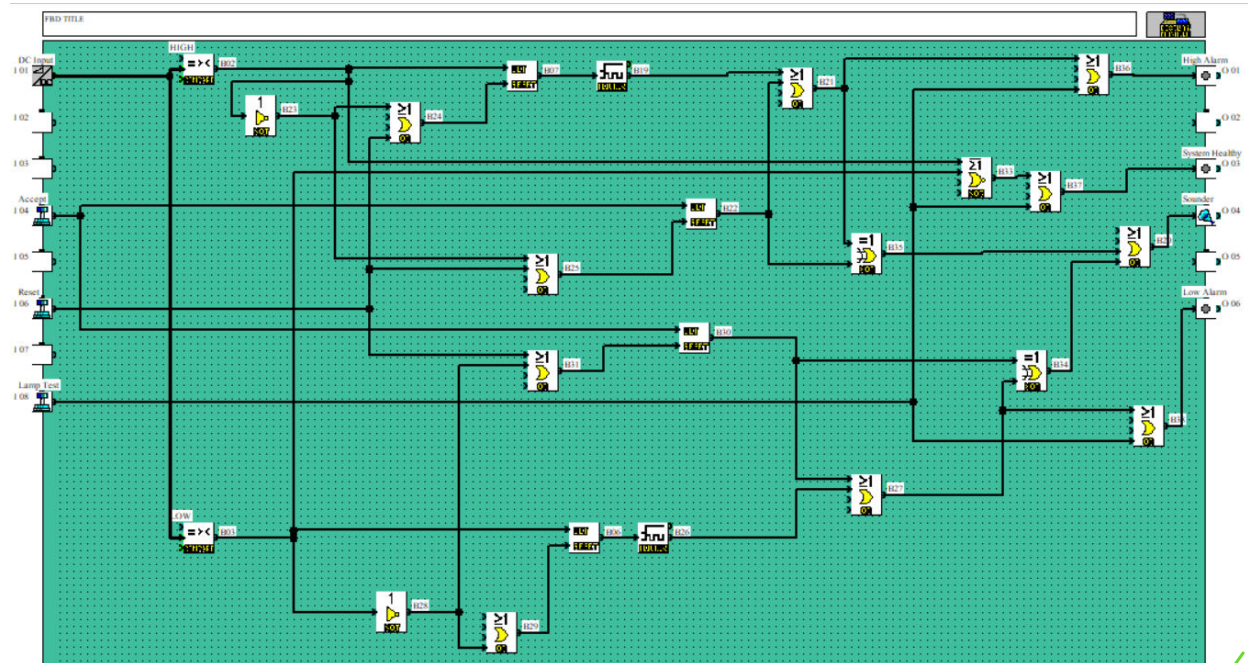
This figure shows what a HMI could potentially look like, this shows when pumps and valves are off and shut by a red indication on them, and shows when they are running and open with a green indication, it also shows the flow in pipes and the level and pressure in tanks.

These systems will also give alarms for high pressure, low pressure and high and low level in tanks. From this page the operator of the system would be able to make adjustments to the running plant by clicking on the pumps and valves to meet operational needs. ✓

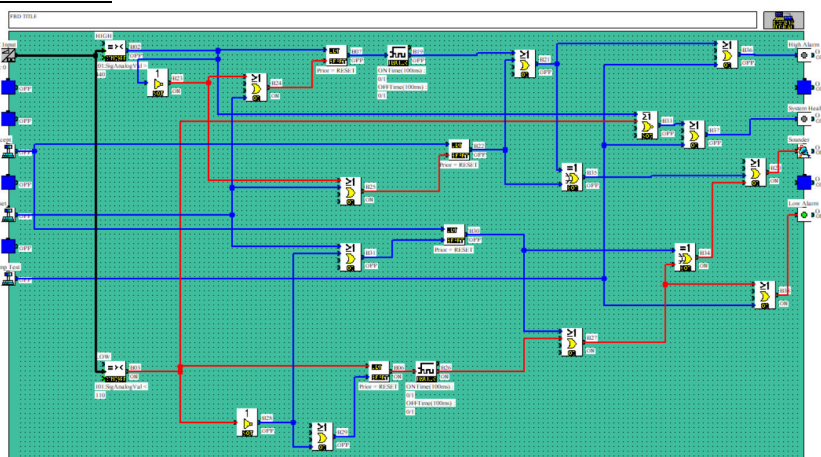
Task 3 – Process Alarm Panel

The images below show my programme finished and in the different states that the programme required.

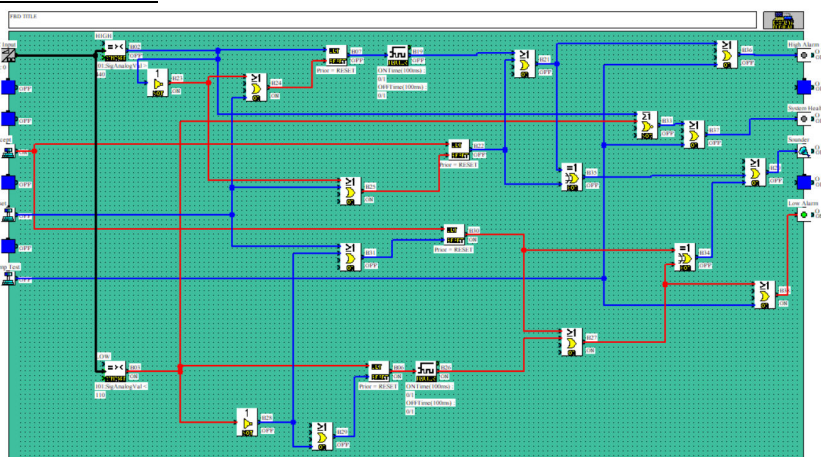
Final System



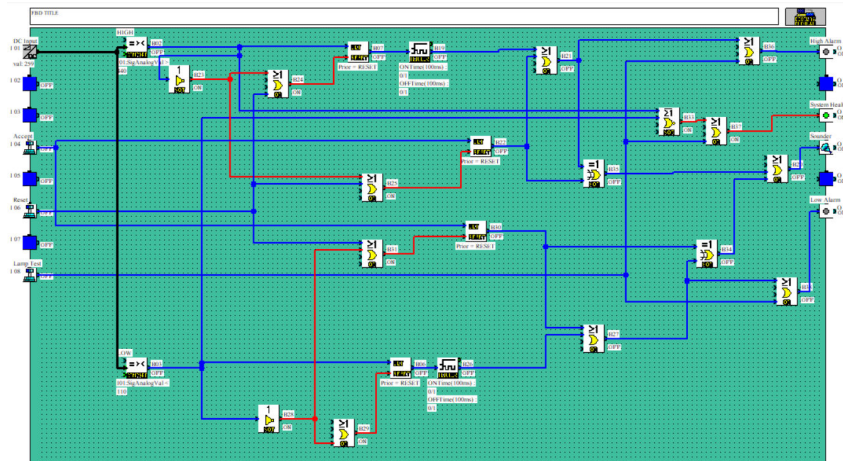
Low Alarm



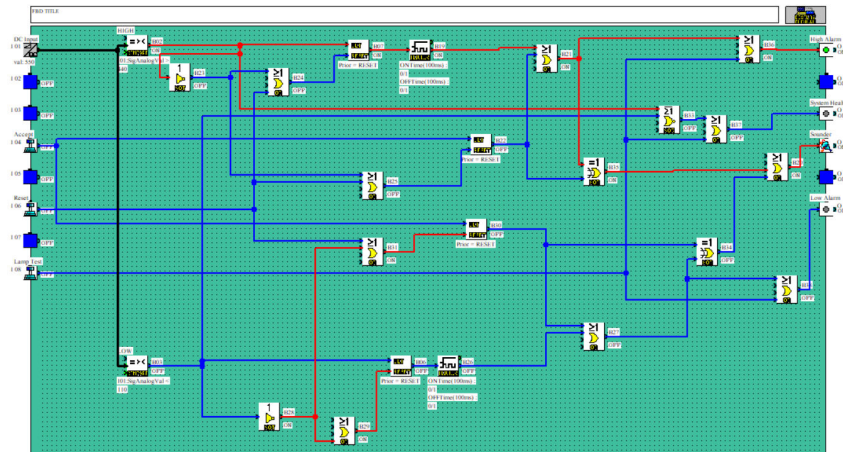
Low Alarm Set



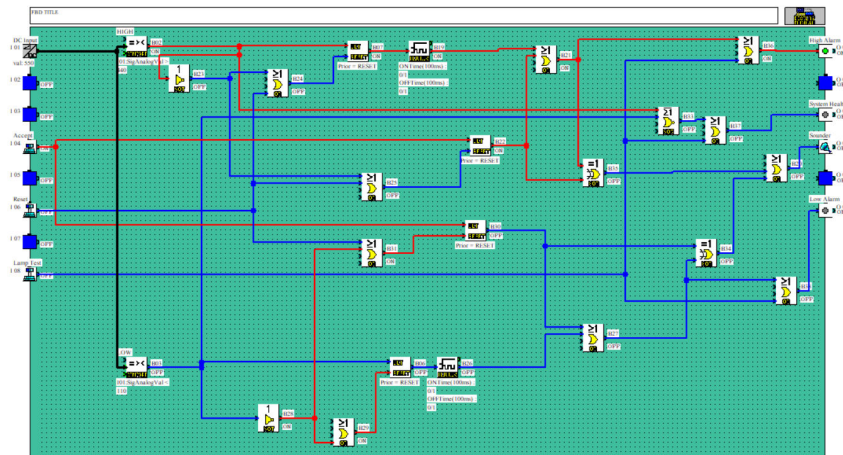
Healthy



High Alarm

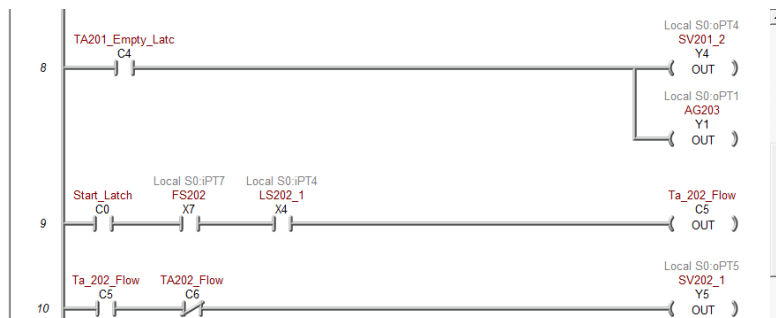
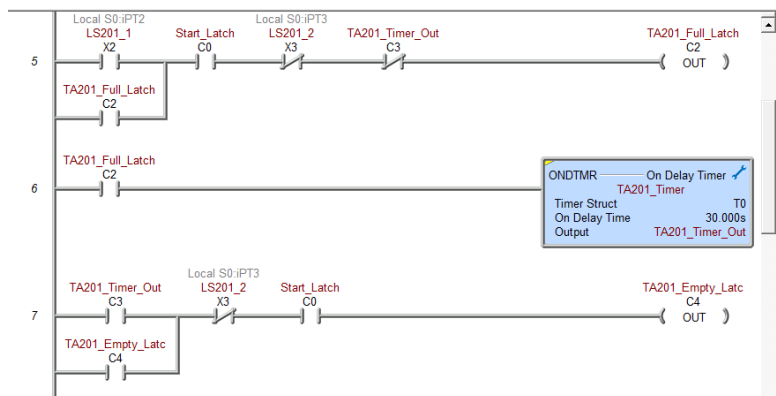
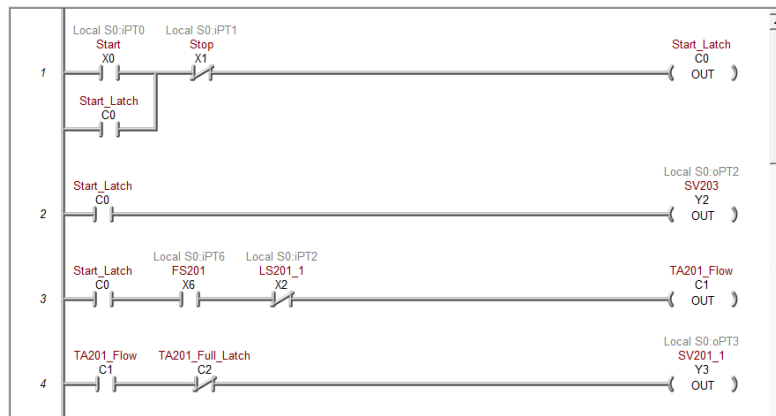


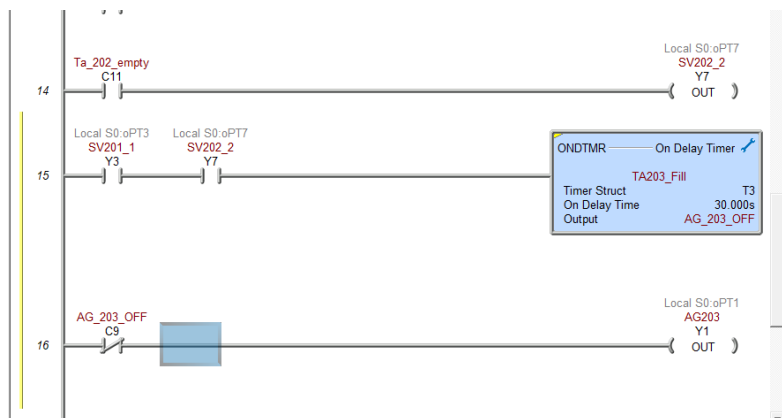
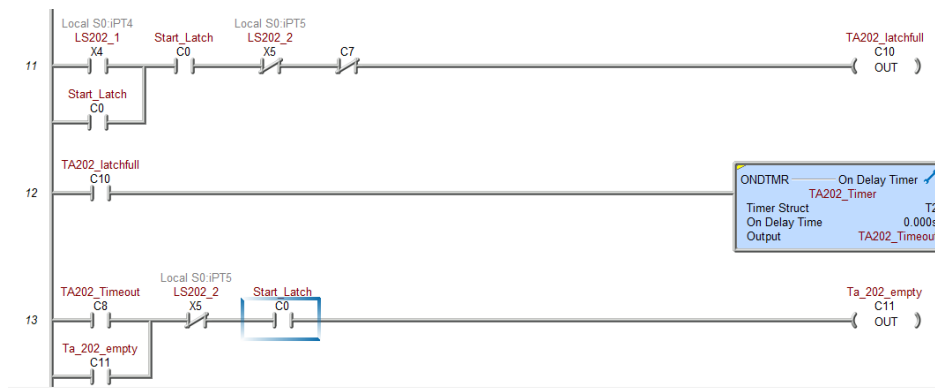
High Alarm Set



Task 4 – Programming problems

Copy of finished tank blending operation





References

Figures

- 1 - <http://www.contactandcoil.com/patterns-of-ladder-logic-programming/startstop-circuit/>
- 2 - <https://www.chegg.com/homework-help/questions-and-answers/traditional-thermostat-two-pieces-different-metals-brass-iron-bolted-together-form-bimetal-q11270673>
- 3 - <https://www.edn.com/the-difference-between-inductive-proximity-displacement-and-eddy-current-sensors/>
- 4 - <https://www.sciencedirect.com/topics/engineering/incremental-encoder>
- 5 - <https://microchipdeveloper.com/adc:adc-quantization-error>
- 6 - <https://www.electricaltechnology.org/2019/02/analog-to-digital-converter-adc.html>
- 7 - <https://www.elprocus.com/dc-motor-basics-types-application/>
- 8 - <https://www.12voltplanet.co.uk/relay-guide.html>
- 9 - <https://www.digikey.com.au/en/articles/techzone/2011/oct/psoc-3-stepper-motor-control-with-precision-microstepping>
- 10 - <https://www.wisdomjobs.com/e-university/programmable-logic-controllers-tutorial-523/output-devices-14631.html>
- 11 - <https://itp.nyu.edu/physcomp/lessons/electronics/transistors-relays-and-controlling-high-current-loads/>
- 12 - <https://itp.nyu.edu/physcomp/lessons/electronics/transistors-relays-and-controlling-high-current-loads/>

Websites visited

<https://realpars.com/scada/>

<https://inductiveautomation.com/resources/article/what-is-scada> 09/02/2020

Books used

- Bird J. Electrical and Electronic Principles and Technology, 6th Edition (2007)
- Hughes E, Hiley J, Brown K, MacKenzie-Smith I. Hughes Electrical and Electronic Technology, 12th Edition (2008)
- Hambley A R. Electrical Engineering: Principles and Applications, International Edition (2013)
- Bird J. Electrical Circuit Theory and Technology. (2010)
- Robertson C R. Fundamental Electrical and Electronic Principles, third edition (2008)
- W.Bolton Programmable Logic Controllers, Fourth edition, (2006)

Bibliography

Websites accessed

<https://inductiveautomation.com/resources/article/what-is-scada> 09/02/2020

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Bird J. Electrical and Electronic Principles and Technology, 6th Edition (2007)

Hughes E, Hiley J, Brown K, MacKenzie-Smith I. Hughes Electrical and Electronic Technology, 12th Edition (2008)

Hambley A R. Electrical Engineering: Principles and Applications, International Edition (2013)

Bird J. Electrical Circuit Theory and Technology. (2010)

Robertson C R. Fundamental Electrical and Electronic Principles, third edition (2008)

W.Bolton Programmable Logic Controllers, Fourth edition, (2006)

Appendix

Datasheet for Carlo Gavazzi mushroom push button that can be used as a start or stop button.

(https://carlogavazzisales.com/pdfs/Datasheet_Mushroom.pdf)

Panel Actuators and Indicators Type PA2 Contact Block

CARLO GAVAZZI



- High switching power
- Double switch
- Industrial applications
- 10A switching capacity
- Up to 500VAC
- Modular mounting (up to 3 elements)
- Screw terminals
- High reliability
- cULus and CE
- According to EN ISO 13850 (only NC slow action)
- IEC/EN 60947-5-1, IEC/EN 60947-5-5, UL 508

Product description

Switching element equipped with two independent elements. Available in different switching configurations. Pole and throw configurations can be single

pole single throw (SPST) or double pole single throw (DPST). Elements can be snapped to each other on the bottom, up to 3.

Approvals



Technical data

Contact resistance	≤50mΩ
Travel	5.8 ± 0.2mm (2.28" ± 0.08")
Rated insulation Voltage U_i	660VAC/DC (acc. to IEC 60947-5-1) 600VAC/DC (acc. to UL508)
Rated imp. withstand voltage U_{imp}	2500VAC 50Hz 1min.
Minimum switching power	
Min Current	100mA
Min Voltage	24V
Switch housing	PC
Contact parts	Cu
Contact material	
Standard	Hard silver
Optional	Gold/silver
Optional for aggressive atmospheres	Silver/palladium
Operating temperature	-25 to +70°C (-13 to +158°F)
Storage temperature	-30 to +80°C (-22 to +176°F)

Terminals

Screw terminals

Max. section single-core wire

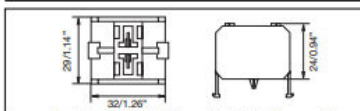
Max. section stranded wire

Copper conductor wire

Terminal tightening torque

2 x 2.5mm² (0.004sq.inch)
2 x 1.5mm² (0.002sq.inch)
14 AWG @ 60°C or 75°C
CU conductor
1.2Nm (10.6in.lb.)

Dimensions mm/inches



Ordering key

PA 2 110 / 1

Type

Number of contacts

Contact code

Options (1 = Snap action

2 = Slow action with forced opening (NC contact)

Contact code

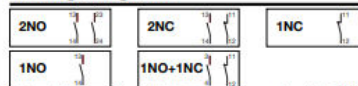
Contact configuration	Contact code
2 NO contacts (DPST)	200
2 NC contacts (DPST)	020
1 NC contact (SPST)	010
1 NO contact (SPST)	100
1 NC + 1 NO contacts (DPST)	110

Contact characteristics

Contact Rating AC1	10A @ 250VAC
Contact Rating (acc. to IEC 60947-5-1)	
	AC15 DC13
@ 24V	10A 6A
@ 110V	8A 1A
@ 220V	6A 0.5A
@ 380V	4A -
@ 500V	2.5A -
AC Contact Rating (acc. to UL 508)	A600 B600
B600 (all snap codes)	@ 120V 6A 3A
A600 (all slow codes)	@ 240V 3A 1.5A
	@ 480V 1.5A 0.75A
	@ 600V 1.2A 0.6A
DC Contact Rating (acc. to UL 508)	Q600 Q300
Q600 (all snap codes)	@ 125V 0.55A 0.55A
Q600 (100, 200 slow codes)	@ 250V 0.27A 0.27A
Q300 (010, 020, 110 slow codes)	@ 480V 0.10A -
	@ 600V 0.10A -

Contact designation	Terminal designation	Rated current, amperes	Maximum current, amperes (acc. to UL508)	Maximum volt-ampere
			120V 240V 480V 600V	
			Make Break Make Break Make Break Make Break	
A600	10	60	6.00 3.00 1.50 0.75	12 1.2 7200 720
B600	5	30	3.00 1.50 0.75 0.375	6 0.6 3600 360
Q600	2.5	0.55	0.27 0.10	69
Q300	2.5	0.55	0.27 -	69

Wiring diagram



3 Specifications are subject to change without notice. Pictures are just an example. For special features and/or customization, please ask to our sales network. 240809

Datasheet for bimetallic strip

This is an airpax circuit protector datasheet which works on the principle of a bimetallic strip.

(<http://www.farnell.com/datasheets/1604972.pdf>)

ATR Thermal Circuit Protector for Equipment



Specifications:

Current Ratings: 0.5A - 16A, Standard Ratings Available
Rated Voltage: 240 Vac, 50/60HZ, 32Vdc, 24Vdc (VDE)
Resettable Overload Capacity: $8 \times I_n$ for $< 6A$,
 $6 \times I_n$ or 60A max. $\geq 6A$

Operating Temperature: 60°C Max. Ambient

Max. Interrupting Capacity: 1000A

Insulation Resistance: >100 megohms

Dielectric Strength: 1.5 KV for 1 min. (per IEC 60934)

Operational Life: 1000 Cycles @ $2 \times I_n$

Designed to meet: Shock: per MIL-STD-202, method 213,
test condition I

Vibration: per MIL-STD-202, method 204
test condition A

Warranty: 24 months from date of
manufacture, as marked on unit

Airpax Expands Offering

Airpax, a global leader in the supply of power protection products, has expanded its offering to include the new ATR thermal circuit protector for equipment. The ATR is a single pole, thermally operated overload protector with a snap-acting trip mechanism that provides reliable, trip-free operation on current overloads.

The ATR comes with an unequalled 24-month warranty.

Please contact Airpax for assistance in applying the ATR thermal circuit protector to meet your power protection needs.

AIRPAX
www.airpax.net

Airpax Corporation
807 Woods Road
Cambridge, Maryland 21613 USA
Tel: 410.228.1500 Fax: 410.228.3456

AIRPAX

Application: Typical applications include power strips, single-phase motors, transformers, solenoids, UPS, etc.

Operation: The trip mechanism of the circuit protector is designed to open the contacts in the event of a current flow in excess of the rated current and in accordance with the time/current characteristics of the device. A bimetal strip deflects and releases the latch mechanism when heated by an overload. The strip has the advantage of being immune to high inrush currents and line transients. The contacts open and close with a positive snap action, and the tripped state is clearly indicated by the protruding reset button.

Shunt Terminal (Option N): Available on units of up to 6 amps equipped with a heater winding, an optional additional terminal can be provided as a parallel circuit to the main current-sensing circuit. The shunt circuit between terminals 1 and 3 may be used for any signal that may be required in addition to the main circuit. However, since the circuit makes use of the bimetal strip as a current-carrying path, the trip time of the circuit protector may be slightly influenced.

Time/Current Characteristics: The standard characteristic is valid for an ambient temperature of 23°C. However, if the device is to be used in an ambient temperature other than 23°C, an allowance must be made when selecting the current rating. See the following guidelines:

Ambient Temperature Correction Factor

Ambient Temp. (°C)	-20	-5	0	+10	+20	+30	+40	+50	+60
Multiplication Factor	0.8	0.88	0.9	0.96	1	1.05	1.12	1.2	1.3

Example:
Normal Continuous Current:

1.8 A

Ambient Temp.: 40°C

Multiplication Factor:

1.12

Recommended Rating:

$1.8 \times 1.12 = 2.016$

Select the Nearest Rating:

2 A

Approvals:



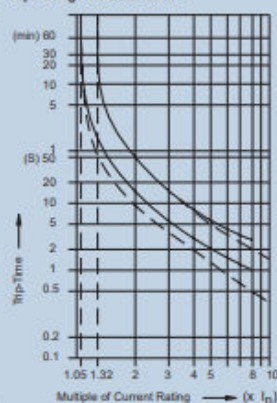
Up to 16A



Up to 12A

**RoHS
Compliant**

Operating Characteristics:



Rated Current
Ambient Temperature

$< 6A$
 $\geq 6A$
23°C

Datasheet for proximity sensor

Datasheet for E2E small diameter proximity sensor

(<https://www.mouser.com/datasheet/2/307/Omron-E2E-Small-Diameter-ProxSensor-Datasheet-1100481.pdf>)

E2E

Ratings and Specifications

Item	Size Type Model	3 dia.		4 dia.		6.5 dia.		M4		M5	
		Shielded EZE-C03S16□	Unshielded EZE-C03UN16□	Shielded EZE-C04S12□	Unshielded EZE-C04UN12□	Shielded EZE-C06S02□	Unshielded EZE-C06UN02□	Shielded EZE-S04S08□	Unshielded EZE-S04UN08□	Shielded EZE-S05S12□	Unshielded EZE-S05UN12□
Sensing distance (at 23°C)		0.8 mm ±10%	2 mm ±10%	1.2 mm ±10%	3 mm ±10%	2 mm ±10%	4 mm ±10%	0.8 mm ±10%	2 mm ±10%	1.2 mm ±10%	3 mm ±10%
Setting distance *1 (Sensing distance × 0.7)		0 to 0.56 mm	0 to 1.4 mm	0 to 0.84 mm	0 to 2.1 mm	0 to 1.4 mm	0 to 2.8 mm	0 to 0.56 mm	0 to 1.4 mm	0 to 0.84 mm	0 to 2.1 mm
Differential travel		15% max. of sensing distance									
Detectable object		Ferrous metal (The sensing distance decreases with non-ferrous metal. Refer to Engineering Data on page 7.)									
Standard sensing object		Iron, 3 × 3 × 1 mm	Iron, 6 × 6 × 1 mm	Iron, 4 × 4 × 1 mm	Iron, 9 × 9 × 1 mm	Iron, 6.5 × 6.5 × 1 mm	Iron, 12 × 12 × 1 mm	Iron, 3 × 3 × 1 mm	Iron, 6 × 6 × 1 mm	Iron, 4 × 4 × 1 mm	Iron, 9 × 9 × 1 mm
Response frequency		5 kHz	3.5 kHz	4 kHz	2 kHz	3 kHz	3 kHz	5 kHz	3.5 kHz	4 kHz	2 kHz
Power supply voltage *2		10 to 30 VDC (including 10% ripple (p-p))									
Current consumption		10 mA max.									
Control output *3	Load current	50 mA max.		100 mA max.		200 mA max. (60 to 70°C: 100 mA)		50 mA max.		100 mA max.	
	Residual voltage	2 V max. *5									
Indicators		Operation indicator: Yellow (complies with European standard EN60947-5-2) Lights during output.									
Operation mode (with sensing object approaching)		B1/B2: PNP open collector, C1/C2: NPN open collector B1/C1 models: NO, B2/C2 models: NC									
Protection circuits		Output reverse polarity protection, Power source circuit reverse polarity protection, Surge suppressor, Load short-circuit protection									
Ambient temperature range		Operation and storage: -25 to 70°C (with no ice or condensation)									
Ambient humidity range		Operation and storage: 35% to 95% (with no condensation)									
Temperature influence		±15% max. of sensing distance at 23°C within temperature range of -25 to 70°C									
Voltage influence		±2.5% max. of sensing distance at rated voltage in the rated voltage ±15% range									
Insulation resistance		50 MΩ min. (at 500 VDC) between current-carrying parts and case									
Dielectric strength		500 VAC, 50/60 Hz for 1 minute between current-carrying parts and case									
Vibration resistance		Destruction: 10 to 55 Hz, 1.5-mm double amplitude for 2 hours each in X, Y, and Z directions									
Shock resistance		Destruction: 500 m/s ² 10 times each in X, Y, and Z directions									
Degree of protection		IEC 60529 IP67, in-house standards: oil-resistant *6									
Connecting method	Pre-wired Models	Yes		Yes		Yes		Yes		Yes	
	M8 Pre-wired Connector Models	Yes		Yes		Yes		Yes		Yes	
	M8 Connector Models	No		Yes		Yes		No		Yes	
Weight (packed state)	Pre-wired Models	Approx. 25 g	Approx. 30 g	Approx. 35 g	Approx. 35 g	Approx. 55 g	Approx. 55 g	Approx. 30 g	Approx. 30 g	Approx. 35 g	Approx. 40 g
	M8 Pre-wired Connector Models	Approx. 20 g	Approx. 20 g	Approx. 15 g	Approx. 20 g	Approx. 20 g	Approx. 25 g	Approx. 20 g	Approx. 20 g	Approx. 20 g	Approx. 20 g
	M8 Connector Models	---	---	Approx. 10 g	Approx. 10 g	Approx. 10 g	Approx. 15 g	---	---	Approx. 15 g	Approx. 15 g
Materials	Case	SUS303 (EN1.4305 *7)									
	Sensing surface	Heat-resistant ABS									
	Clamping nuts *4	No						SUS430 (EN1.4016 *7)			
	Toothed washer *4	No						SUS303 (EN1.4305 *7)			
	Cable	PVC									
Accessories	Instruction manual	Yes									
	Model label	Yes									
	Mounting brackets	Sold separately									

*1. Operating within the set distance enables high-speed responsiveness and a more stable repeat accuracy.

*2. When used with a 12 V power source, the Sensor is less susceptible to the effects of internal heat generation. Therefore a more stable repeat accuracy can be obtained.

*3. When the control output is 20 mA or less, the Sensor is less susceptible to the effects of internal heat generation. Therefore a more stable repeat accuracy can be obtained.

*4. Nuts: 2 pieces, toothed washer: 1 piece

*5. 3 dia., M4: load current 50 mA, cable length 2 m

4 dia., M5: load current 100 mA, cable length 2 m

6.5 dia.: load current 200 mA, cord length 2 m

*6. Oil resistance in-house standard: Performance with respect to water insoluble oil.

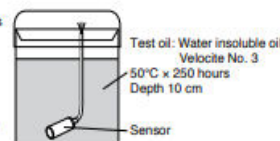
(Test at right)

*7. Material name in EN standards.

Oil resistance test

After the test time elapses, the characteristics below are checked for problems.

- (1) Visual appearance (no damage that affects product characteristics)
- (2) Operation check (ON/OFF)
- (3) Insulation resistance (50 MΩ min. at 500 VDC)
- (4) Dielectric strength (500 VAC, 1 min.)
- (5) Water resistance (IP67)



Datasheet for increment encoder

This is a datasheet from the E6C3-C model of the increment encoder.

(https://assets.omron.eu/downloads/datasheet/en/v2/e6c3-c_rugged_incremental_rotary_encoder_datasheet_en.pdf)

E6C3-C

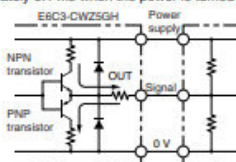
Ratings and Specifications

Item	Model	E6C3-CWZ5GH	E6C3-CWZ3EH	E6C3-CWZ3XH
Power supply voltage		12 VDC -10% to 24 VDC +15%, ripple (p-p): 5% max.	5 VDC -5% to 12 VDC +10%, ripple (p-p): 5% max.	
Current consumption*1		100 mA max.		
Resolution (pulses/rotation)		100, 200, 300, 360, 500, 600, 720, 800, 1,000, 1,024, 1,200, 1,500, 1,800, 2,000, 2,048, 2,500, 3,600		
Output phases		Phases A, B, and Z*5		Phases A, A', B, B', Z, and Z'
Output configuration		Complementary outputs*2	Voltage output (NPN output)	Line driver output*3
Output capacity		Output voltage: $V_H = V_{CC} - 3 \text{ V min.}$ ($I_O = 30 \text{ mA}$) $V_L = 2 \text{ V max.}$ ($I_O = -30 \text{ mA}$) Output current: $\pm 30 \text{ mA}$	Output resistance: $2 \text{ k}\Omega$ Output current: 35 mA max. Residual voltage: 0.7 V max.	AM26LS31 equivalent Output current: High level: $I_O = -10 \text{ mA}$ Low level: $I_S = 10 \text{ mA}$ Output voltage: $V_O = 2.5 \text{ V min.}$ $V_S = 0.5 \text{ V max.}$
Maximum response frequency*4		125 kHz (65 kHz when using phase Z reset)		
Phase difference between outputs		$90^\circ \pm 45^\circ$ between A and B ($1/4 \text{ T} \pm 1/8 \text{ T}$)		
Rise and fall times of output		$1 \mu\text{s max.}$ (Cable length: 2 m, Output current: 30 mA)	$1 \mu\text{s max.}$ (Cable length: 2 m, Output current: 35 mA)	$1 \mu\text{s max.}$ (Cable length: 2 m, $I_O = -10 \text{ mA}$, $I_S = 10 \text{ mA}$)
Starting torque		10 mN·m max. at room temperature, 30 mN·m max. at low temperature		
Moment of inertia		$2.0 \times 10^{-6} \text{ kg m}^2 \text{ max.}$; $1.9 \times 10^{-6} \text{ kg m}^2 \text{ max.}$ at 500 P/R max.		
Shaft loading	Radial	80 N		
	Thrust	50 N		
Maximum permissible speed		5,000 r/min		
Protection circuits		Power supply reverse polarity protection, Output load short-circuit protection		---
Ambient temperature range		Operating: -10 to 70°C (with no icing), Storage: -25 to 85°C (with no icing)		
Ambient humidity range		Operating/Storage: 35% to 85% (with no condensation)		
Insulation resistance		20 M Ω min. (at 500 VDC) between current-carrying parts and case		
Dielectric strength		500 VAC, 50/60 Hz for 1 min between current-carrying parts and case		
Vibration resistance		Destruction: 10 to 500 Hz, 150 m/s ² or 2-mm double amplitude for 11 min 3 times each in X, Y, and Z directions		
Shock resistance		Destruction: 1,000 m/s ² 3 times each in X, Y, and Z directions		
Degree of protection		IEC 60529 IP65, in-house standards: oilproof		
Connection method		Pre-wired Models (Standard cable length: 1 m)		
Material		Case: Aluminum, Main unit: Aluminum, Shaft: SUS303		
Weight (packed state)		Approx. 300 g		
Accessories		Instruction manual Note: Coupling, mounting bracket and hex-head spanner are sold separately.		

*1. An inrush current of approximately 9 A will flow for approximately 0.1 ms when the power is turned ON.

*2. Complementary Output

The complementary output has two output transistors (NPN and PNP) as shown below. These two output transistors alternately turn ON and OFF depending on the high or low output signal. When using them, pull up to the positive power supply voltage level or pull down to 0 V. The complementary output allows flow-in or flow-out of the output current and thus the rising and falling speeds of signals are fast. This allows a long cable distance. They can be connected to open-collector input devices (NPN, PNP).



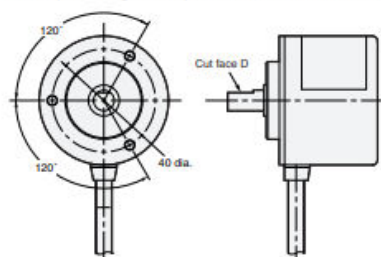
*3. The line driver output is a data transmission circuit compatible with RS-422A and long-distance transmission is possible with a twisted-pair cable. (AM26LS31 equivalent)

*4. The maximum electrical response speed is determined by the resolution and maximum response frequency as follows:

$$\text{Maximum electrical response speed (rpm)} = \frac{\text{Maximum response frequency}}{\text{Resolution}} \times 60$$

This means that the Rotary Encoder will not operate electrically if its speed exceeds the maximum electrical response speed.

*5. The phase Z signal is output when cut face D on the shaft and the cable connection direction are as shown in the following diagram (output position range: $\pm 15^\circ$).

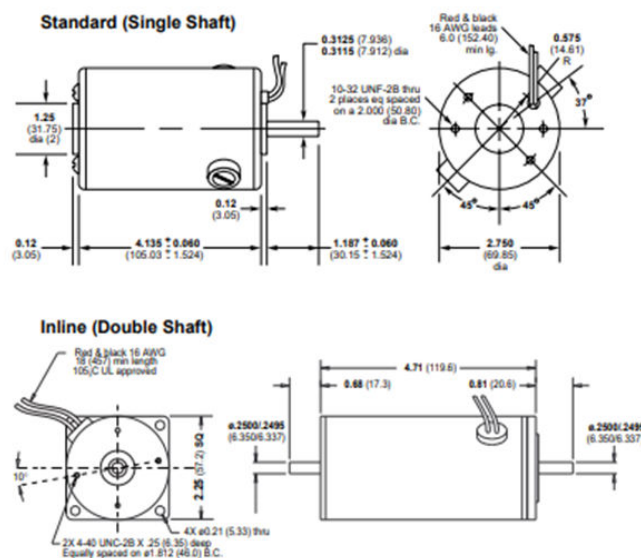


Datasheet for small D.C motor

This datasheet is for a 24V D.C motor

([https://www.kollmorgen.cn/sites/default/files/legacy%20-%20idc/documentation/%e2%80%93D 24VDC Brushed IDC Motor 810-101 Spec Drawing.pdf](https://www.kollmorgen.cn/sites/default/files/legacy%20-%20idc/documentation/%e2%80%93D%2024VDC%20Brushed%20IDC%20Motor%20810-101%20Spec%20Drawing.pdf))

D 24 Volt DC Motor Specifications



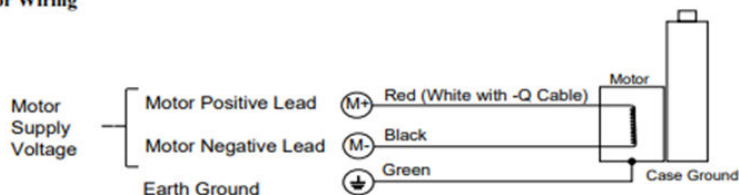
Electrical Data

Rated Voltage	V	24
Max. Continuous Current	A	4.5
Max. Operating Voltage	V	36
Inductance	mH	2.0
K _t Torque Constant (± 10%)	oz-in/A [N-m/A]	8.9 [0.062]
K _e Voltage Constant (± 10%)	V/kRPM	6.5
Winding Resistance @ Ambient	Ohms	1.0

Mechanical Data

Continuous Stall Torque	oz-in [N-m]	40 [0.28]
No-load Speed at Rated Voltage	RPM	3600
No-load Current	A	0.5
Rotor Inertia	oz-in-s ² [kg-cm ²]	0.018 [1.3]
Max. Winding Temperature	°F [°C]	180 [82]

Motor Wiring



Datasheet for 12 volt relay

This is a datasheet for a 12 volt omron relay.

(<https://www.parallax.com/sites/default/files/downloads/400-00052-Omron-12V-Relay-Datasheet.pdf>)

OMRON

Coils Ratings for High-sensitivity Models

Rated voltage	5 VDC	12 VDC	24 VDC
Rated current	50.0 mA	20.8 mA	10.42 mA
Coil resistance	100 Ω	576 Ω	2,304 Ω
Must operate voltage	75% max. of the rated voltage		
Must release voltage	10% min. of the rated voltage		
Max. voltage	180% of rated voltage (at 23°C)		
Power consumption	Approx. 250 mW		

Note: The rated current and coil resistance are measured at a coil temperature of 23°C with a tolerance of ±10%.

Contact Ratings

Item	General-purpose Models		High-capacity Models	High-sensitivity Models
Number of poles	1 pole	2 poles	1 pole	1 pole
Contact material	Ag Alloy (Cd free)			
Load	Resistive load (cosφ=1)			
Rated load	12 A at 250 VAC 12 A at 24 VDC (See note.)	8 A at 250 VAC 8 A at 30 VDC (See note.)	16 A at 250 VAC 16 A at 30 VDC (See note.)	10 A at 250 VAC 10 A at 24 VDC (See note.)
Rated carry current	12 A (See note.)	8 A (70°C)/5 A (85°C) (See note.)	16 A (See note.)	10 A (See note.)
Max. switching voltage	440 VAC, 300 VDC			
Max. switching current	12 A	8 A	16 A	10 A
Max. switching power	3,000 VA (4,000 VA)	2,000 VA	4,000 VA	2,500 VA

Note: Contact your OMRON representative for the ratings on fully sealed models.

Characteristics

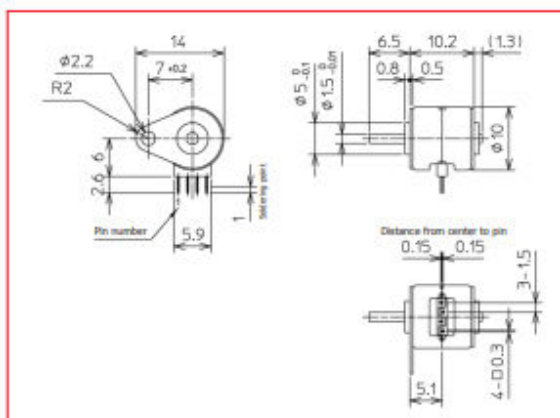
Item	General-purpose (High-capacity) Models	General-purpose Models	High-sensitivity Models
Number of poles	1 pole	2 pole	1 pole
Contact resistance	100 mΩ max.		
Operate (set) time	15 ms max.		
Release (reset) time	5 ms max.		
Max. operating frequency	Mechanical: 18,000 operation/hr Electrical: 1,800 operation/hr at rated load		
Insulation resistance	1,000 MΩ min. (at 500 VDC)		
Dielectric strength	5,000 VAC, 1 min between coil and contacts 1,000 VAC, 1 min between contacts of same polarity	5,000 VAC, 1 min between coil and contacts 2,500 VAC, 1 min between contacts of different polarity 1,000 VAC, 1 min between contacts of same polarity	5,000 VAC, 1 min between coil and contacts 1,000 VAC, 1 min between contacts of same polarity
Impulse withstand voltage	10 kV (1.2×50 μs) between coil and contact		
Vibration resistance	Destruction: 10 to 55 to 10 Hz, 0.75 mm single amplitude (1.5 mm double amplitude) Malfunction: 10 to 55 to 10 Hz, 0.75 mm single amplitude (1.5 mm double amplitude)		
Shock resistance	Destruction: 1,000 m/s ² (approx. 100 G) Malfunction: 100 m/s ² (approx. 10 G)		
Endurance (Mechanical)	20,000,000 operations (at 18,000 operations/hr)		
Ambient temperature	Operating: -40°C to 85°C (with no icing) Storage: -40°C to 85°C (with no icing)		
Ambient humidity	5% to 85%		
Weight	Approx. 12 g		

Note: Values in the above table are the initial values.

Datasheet for stepper motor

This is a datasheet from dynetics for a stepper motor

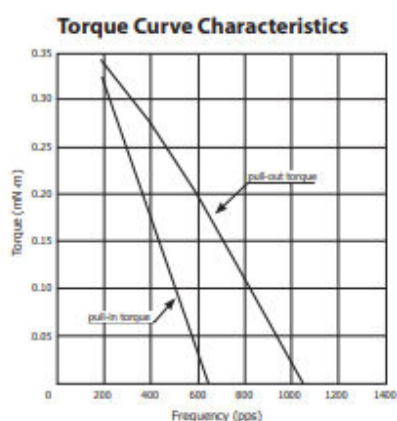
(<http://www.dynetics.eu/media/2678/stepper-motors.pdf>)



Specifications

Specification	Unit	PFC10-20R6
Type of Winding		Bipolar
Excitation Mode*		Full step (2-2)
Steps/Revolution		20
Step Angle	°	18
Holding Torque	mN·m	1.0
Rated Voltage	V	2.7
Rated Current	mA/phase	135
Resistance	Ω / ϕ	20
Inductance	mH / ϕ	3.2
Coil		R
Starting Pulse Rate	pps	960
Slewing Pulse Rate	pps	1600
Rotor Inertia	kg·m ²	0.03×10^{-3}
Operating Temp. Range	°C	-10 to +50
Storage Temp. Range	°C	-30 to +80
Insulation Class		E
Temperature Rise	K	70
RoHS Compliant		Yes
Weight	g	5

All tin-can motor specifications are based on full-step constant voltage operation. When the rated voltage is 5V, the terminal voltage is 4V. Do not use this product over maximum operating temperature (100°C).



Pin	Coil Phase
1	4φ B̄
2	1φ A
3	2φ B
4	3φ Ā

Datasheet for transistor

This datasheet is for a 2N4401 transistor, this is a type of transistor that could be used instead of a relay.

<http://www.farnell.com/datasheets/661741.pdf>

2N4401

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (Note 1) ($I_C = 1.0\text{ mAdc}$, $I_E = 0$)	$V_{(BR)CEO}$	40	—	Vdc
Collector-Base Breakdown Voltage ($I_C = 0.1\text{ mAdc}$, $I_E = 0$)	$V_{(BR)CBO}$	60	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 0.1\text{ mAdc}$, $I_C = 0$)	$V_{(BR)EBO}$	6.0	—	Vdc
Base Cutoff Current ($V_{CE} = 35\text{ Vdc}$, $V_{EB} = 0.4\text{ Vdc}$)	I_{BEV}	—	0.1	μAdc
Collector Cutoff Current ($V_{CE} = 35\text{ Vdc}$, $V_{EB} = 0.4\text{ Vdc}$)	I_{CEX}	—	0.1	μAdc

ON CHARACTERISTICS (Note 1)

DC Current Gain ($I_C = 0.1\text{ mAdc}$, $V_{CE} = 1.0\text{ Vdc}$) ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 1.0\text{ Vdc}$) ($I_C = 10\text{ mAdc}$, $V_{CE} = 1.0\text{ Vdc}$) ($I_C = 150\text{ mAdc}$, $V_{CE} = 1.0\text{ Vdc}$) ($I_C = 500\text{ mAdc}$, $V_{CE} = 2.0\text{ Vdc}$)	h_{FE}	20 40 80 100 40	— — — 300 —	—
Collector-Emitter Saturation Voltage ($I_C = 150\text{ mAdc}$, $I_B = 15\text{ mAdc}$) ($I_C = 500\text{ mAdc}$, $I_B = 50\text{ mAdc}$)	$V_{CE(sat)}$	— —	0.4 0.75	Vdc
Base-Emitter Saturation Voltage ($I_C = 150\text{ mAdc}$, $I_B = 15\text{ mAdc}$) ($I_C = 500\text{ mAdc}$, $I_B = 50\text{ mAdc}$)	$V_{BE(sat)}$	0.75 —	0.95 1.2	Vdc

SMALL-SIGNAL CHARACTERISTICS

Current-Gain-Bandwidth Product ($I_C = 20\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 100\text{ MHz}$)	f_T	250	—	MHz
Collector-Base Capacitance ($V_{CB} = 5.0\text{ Vdc}$, $I_E = 0$, $f = 1.0\text{ MHz}$)	C_{cb}	—	6.5	pF
Emitter-Base Capacitance ($V_{EB} = 0.5\text{ Vdc}$, $I_C = 0$, $f = 1.0\text{ MHz}$)	C_{eb}	—	30	pF
Input Impedance ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{ie}	1.0	15	k Ω
Voltage Feedback Ratio ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{re}	0.1	8.0	$\times 10^{-4}$
Small-Signal Current Gain ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{fe}	40	500	—
Output Admittance ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{oe}	1.0	30	μmhos

SWITCHING CHARACTERISTICS

Delay Time	$V_{CC} = 30\text{ Vdc}$, $V_{BE} = 2.0\text{ Vdc}$, $I_C = 150\text{ mAdc}$, $I_{B1} = 15\text{ mAdc}$	t_d	—	15	ns
Rise Time		t_r	—	20	ns
Storage Time	$V_{CC} = 30\text{ Vdc}$, $I_C = 150\text{ mAdc}$, $I_{B1} = I_{B2} = 15\text{ mAdc}$	t_s	—	225	ns
Fall Time		t_f	—	30	ns

1. Pulse Test: Pulse Width $\leq 300\text{ }\mu\text{s}$, Duty Cycle $\leq 2.0\%$.

ORDERING INFORMATION

Device	Package	Shipping†
2N4401	TO-92	5000 Units / Bulk
2N4401G	TO-92 (Pb-Free)	5000 Units / Bulk
2N4401RLRA	TO-92	2000 / Tape & Reel
2N4401RLRAG	TO-92 (Pb-Free)	2000 / Tape & Reel
2N4401RLRMG	TO-92 (Pb-Free)	2000 / Tape & Ammo Box
2N4401RLRPP	TO-92	2000 / Tape & Ammo Box
2N4401RLRPG	TO-92 (Pb-Free)	2000 / Tape & Ammo Box

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

Bibliography