Industrial Automation Solutions

Programmable Logic Controller (PLC) Solutions

Overview

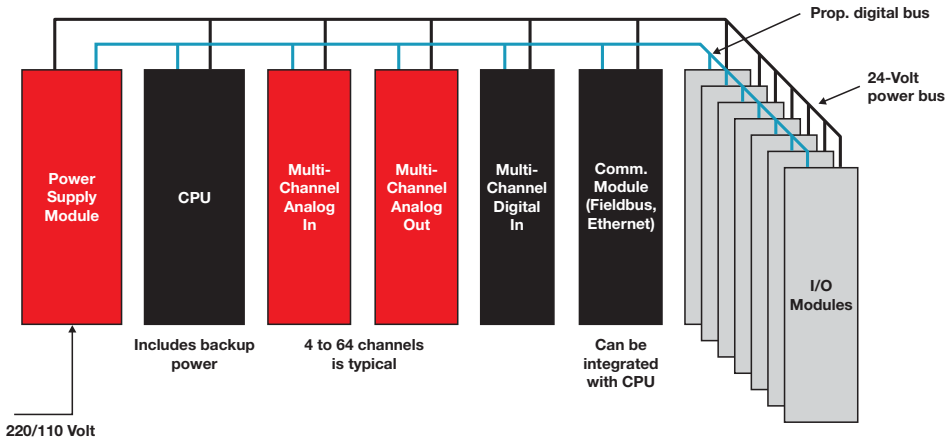
The Programmable Logic Controller (PLC) is the workhorse of Industrial Control systems. It uses digital and analog I/O modules to interface to sensors, actuators and other equipment. These I/O modules must meet stringent electrical specifications and designers face challenges in conditioning and converting these signals. In addition, increasing levels of embedded processing and connectivity can be seen on these modules. Variations of the PLC include the Programmable Automation Controller (PAC) which has more integration and processing functions to tackle more complex operations and the Distributed Control System (DCS) which is used extensively in process control. The DCS uses distributed controllers, each performing a specific task, connected together by networks for communication and monitoring. A central control room is typically used for an entire plant.

The PLC System

PLCs can be segmented by I/O count and scan rates. They can also be classified as brick type versus modular PLCs. A small or brick PLC has a fixed number of connections for inputs and outputs. Modular PLCs have a chassis (also called a rack) into which are placed modules with different functions. The processor and selection of I/O modules is customized to fit the application. A modular PLC consists of the Central Processing Unit (CPU), a power supply and various I/O modules. The CPU performs the main controller functions like scanning data and running control sequences. The power supply unit converts line power to 24 volts. The I/O modules are used to measure data from sensors and to control various actuators. Together, the input and output modules along with the central controller form a control loop.

I/O Module Types

I/O modules can be classified as analog input (AI), analog output (AO), digital input (DI) and digital output (DO). They are usually categorized into 2-, 4-, 8- and 16-channel modules. I/O modules need to meet stringent electrical specifications such as the IEC 61000-4 family of Electro Magnetic Compatibility (EMC) tests for surge, ESD (Electrostatic Discharge) and EFT (Electrically Fast Transients). They also need short-circuit and overload protection. All these modules include isolation between the control side and the field side via DC-DC converters and isolation on digital communication between the field devices and the digital backplane. Communication over the digital backplane is done by a variety of interfaces (RS-485, CAN, Ethernet, etc.) and industrial fieldbuses (PROFIBUS, DeviceNet, Modbus, Ethernet I/P, EtherCAT, PROFINET, etc.) On the following pages, we discuss solutions from TI for these various I/O types.

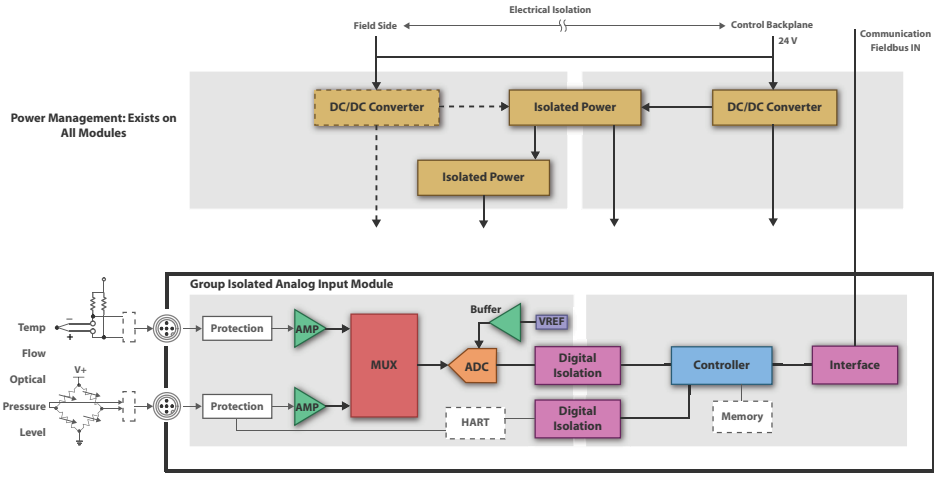


PLC: Analog Inputs

Analog input modules capture and measure signals such as temperature, pressure, flow, level, vibration and motion. These parameters are transmitted from equipment such as sensors and other field devices on the factory floor in the form of current or voltage. Current loops typically range from 4–20 mA while voltage inputs can be single ended or differential ranging from 0–5V, 0–10V, ±5V and ±10V.

The system accuracy is determined by the Analog to Digital Converter (ADC) resolution with thermocouple applications needing up to 24 bits. Delta sigma ADCs are a good choice with some products having a built-in PGA and MUX. Some products also offer ratio-metric measurement with built-in current sources for RTD excitation and voltage biases for ungrounded thermocouples. Slow changing variables like temperature, pressure, level and flow need lower sampling rates (up to 2 kSPS) while other applications and systems with higher channel counts need larger sampling speeds (several 100 kSPS). SAR ADCs are a good choice for these applications. Simultaneous sampling architectures are used for modules used in condition monitoring, motion control and power automation.

Signal conditioning considerations include high-input impedance when interfacing to sensors with low-source impedance which is achieved with input buffers and instrumentation amplifiers (INA). Other considerations are large common-mode voltage range and common-mode rejection of interference from motors, AC power lines and other sources which inject noise on the analog inputs. Since the inputs could be signals from thermocouples and other low-level sensors, low offset voltages as well as minimal drift of the offset voltage over temperature is needed to maintain accuracy. Precision bipolar op amps are used extensively. Differential amps can be used when the common mode range is greater than the power supply rails. Finally, Programmable Gain Amplifiers (PGA) can be used when the input voltage range can vary over multiple sensor types.



TI signal chain solutions for analog inputs

ADS1248 (temperature measurement and universal inputs)

- 4 differential or 7 single-ended inputs, 24-bit, single-cycle settling
- Low-noise PGA, temperature sensor, burnout detection
- 50-/60-Hz simultaneous rejection, up to 2kSPS
- Dual matched current sources for RTD excitation

PGA280 + ADS1259

- Zero drift high-voltage PGA + low-noise, 24-bit, 14-kSPS ADC
- Input signals from 10s of mV to ±15V
- Allows input signal diagnostics

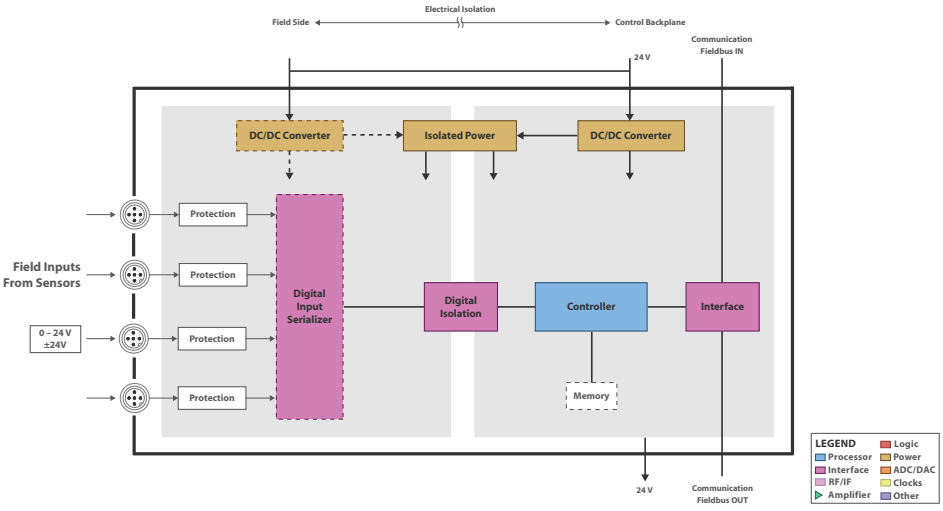
ADS8331/2 (low-power, 16-bit 500kSPS, 4-/8-channel SAR ADCs)

INA159 (precision, level translator diff amp to couple ±10V signals to single supply ADC)

PLC: Digital I/O

Design Considerations

Digital input modules capture and measure digital input signals from a wide variety of sensors like proximity switches, limit switches and push button switches. Inputs typically are 0–24V with tolerances up to 30V. The signals from DC sensors used in PLC digital input (DI) modules are typically of a higher voltage and are usually isolated through optocouplers before going into a shift register to be serialized. Instead, digital input serializers can be used to serialize a large number of digital inputs allowing higher channel densities in PLC I/O modules. The isolation is then limited to the SPI interface as a number of serializers can be daisy chained. They also provide the benefit of sensing higher voltages, adjustable current limits and programmable de-bounce times. Other functions that are integrated into these products are temperature sensing and voltage regulation.



TI solutions for Digital I/O

SN65HVS880 (18V – 30V industrial 8-channel digital input serializer)

SN65HVS881 (10V – 34V industrial 8-channel digital input serializer with parity)

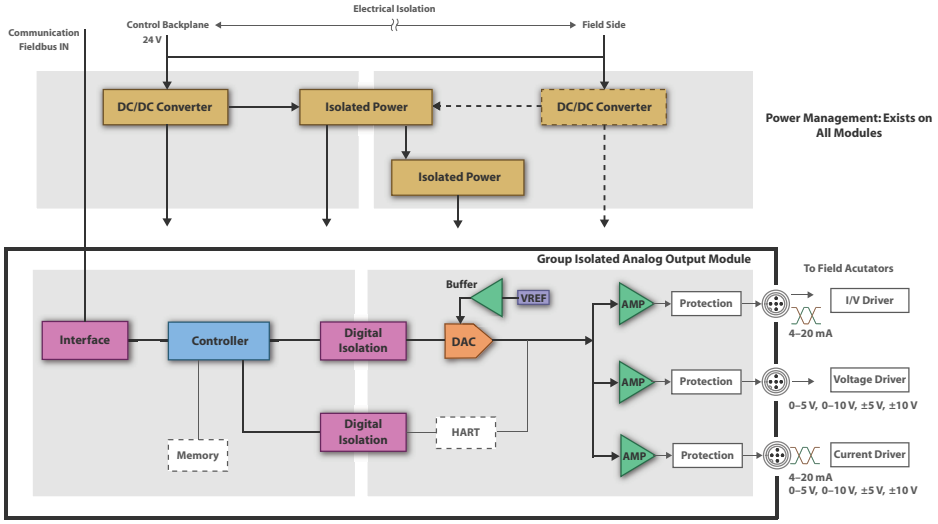
PLC: Analog Outputs

Design Considerations

Analog output modules are used to drive and control actuators and other machines and form part of an overall control system. Current-loop outputs typically range from 4–20 mA while voltage outputs range from 0–5V, 0–10V, ±5V and ±10V.

The linearity, settling time, response and accuracy is determined by the DAC used. Resistor string-based DACs are small, inexpensive and inherently monotonic. For higher resolution and for applications requiring higher linearity like open-loop valve control, R-2R DACs are a good choice. Finally for achieving the fastest settling times and speeds, R-2R multiplying DACs should be used. Selecting the right reference and pairing it with the right buffer can impact system performance. Considerations for references include initial accuracy, temperature drift and source/sink current capability.

The output amplifier must be picked based on speed, output voltage level and power. TI's XTR family of industrial drivers is a good choice to implement 4–20 mA current loops. Some products allow the designer to make the output programmable to be either a voltage or current. Newer products integrate the DAC and XTR together to minimize board space and optimize power.



TI signal chain solutions for analog outputs

DAC8718 family

- 16-/14-/12-bit family of 8-channel bipolar ±16.5V DACs
- Wide voltage range of ±16.5V with up to 6× gain eliminates need for external gain circuitry
- 10-µs settling time, 4 nV-s glitch energy
- 12- and 14-bit serial and parallel options provide flexible upgrade / downgrade path

DAC8562 family

- 16-bit family of dual-channel, low-power and low-voltage DACs
- Integrated precision reference (4 ppm/°C drift), ultra-small package (3×3 mm)
- Wide temperature range (-40°C to 125°C)

XTR300

- Industrial analog current/voltage output driver
- User-selectable: voltage or current output – Design flexibility
- Separate driver and receiver channels
- Digital output selection, error flags, and monitor pins

OPA140 (11 MHz, precision, low-noise, RRO, JFET op amp)

REF5020 + OPA350 (precision voltage reference + high-speed, single-supply rail-to-rail op amp)

PLC: Processor

Processor

To support the processor, development platforms and software tools in addition to support which quickens time to market are highly desired. Connectivity options ranging from Ethernet ports to UARTs to simple SPI ports are required. Ethernet enables integration of field devices to the corporate enterprise network. Most industrial control applications need simple, low-cost PLCs with lots of digital I/O and integrated functions. These include fault diagnostics, watchdog timers, low power, multiple SPI ports, UARTs, integrated analog peripherals like ADCs and PWM outputs which perform similar functions to DACs. MCUs (Micro Controller Units) are a good choice for these applications. For applications which push capabilities and need higher loop rates along with advanced control algorithms to handle multiple functional domains like logic, PID control and motion, higher-performance MPUs (Micro Processing Units) are needed. TI provides solutions to address all these needs.

Description	Device Series	Key Benefits
C2000™ 32-bit real-time MCUs up to 300 MHz and 512 kB Flash	Delfino™ floating-point series	• IEC61131-3 programming with CoDeSys • Integrated real-time control peripherals
Stellaris® ARM® Cortex™-M3-based MCUs up to 80 MHz, up to 256 kB Flash	LM3Sx	• Fully integrated 10/100 Ethernet MAC and PHY • Hardware-assisted IEEE 1588 precision time protocol • Integrated CAN controllers • Integrated USB On-the-Go / host / device
MSP430™ 16-bit ultra-low-power microcontroller, 120 kB Flash, 4 KB RAM, ADC12, 16-bit timer, USCI	MSP430F2419	• Simple PLC implementation • Versatile connectivity options • Optimized system power budget • Temperature monitoring on-board
TMS570 ARM Cortex-R4F-based microcontroller for safety-critical applications up to 160 MHz and 2 MB Flash	TMS570LS2x	• Support for safety-critical applications up to IEC 61508 SIL-3 • Three integrated CAN controllers • Powerful Cortex™-R4F floating-point CPU • Up to 2 MB of integrated Flash memory

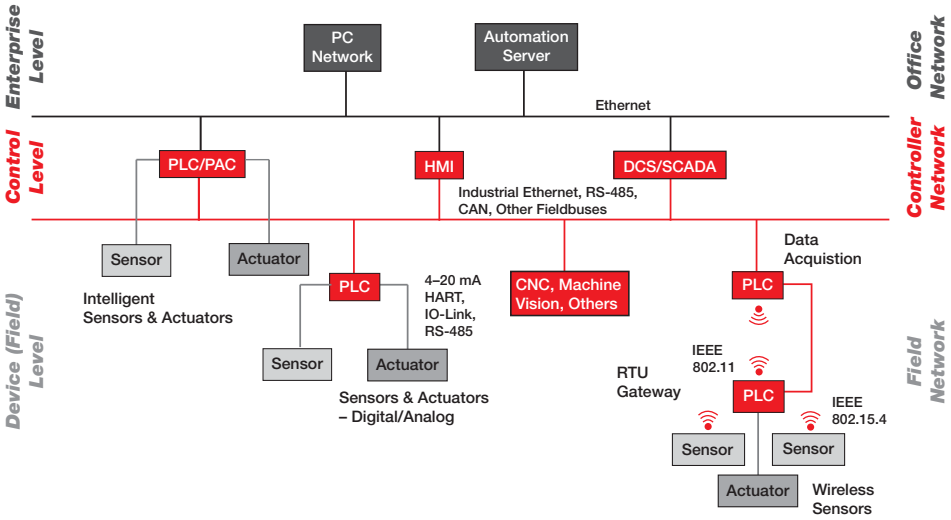
TI processors for PLC

- AM1810 Sitara™ ARM9™ MPU
  - Integrated PROFIBUS with application processor
  - PROFIBUS Fieldbus Data Link Layer (FDL) implemented on PRU subsystem
  - ARM9 runs PROFIBUS stack and user application
  - AM1810EVM available with AM1810 + ISO1176T
- Includes parts listed to the left

PLC: Connectivity

Interface

There are a number of fieldbus options – both serial (RS-485, DeviceNet, PROFIBUS, CAN, etc.) and Ethernet based. Extended cable reach and diagnostics to debug wire breaks provides system designers significant value. Integrated digital isolation on the interface transceivers is highly desirable to reduce board space. In addition, the interface between the DAC and the controller can be digitally isolated either by using optocouplers or TI isolators built with capacitive technology.



TI interface products for PLC

ISO1176 (isolated PROFIBUS RS-485 transceiver)

- Fully compliant to PROFIBUS and RS-485
- Hot pluggable without data corruption
- High-speed operation

TLK100 (industrial Ethernet PHY)

- Low and deterministic latency
- Extended cable reach (up to 200 m)
- Flexible supply options
- Cable diagnostics

ISO1050 (isolated 5-V CAN transceiver)

- Integrated CAN and isolation
- Reduced loop time
- Lower power than using optocouplers

ISO7421E (low-power dual-channel, 50-Mbps digital isolator)

- Life span > 25 years
- High immunity for noisy environments
- Flexibility with power supplies

PLC: Power

Power

To protect against transients and ground loops, the field side which interfaces to sensors is electrically isolated from the control side. This is done on a per channel basis or by isolating groups of channels from each other and from the control side. The design can be customized for performance and cost by using a DC-DC converter and discrete components or pre-built isolated DC-DC converter modules can be used. Other considerations include high efficiency and integration along with smaller packages. Picking a DC-DC converter with a large input range will protect against supply transients. Finally, using LDOs with good PSRR (power supply rejection ratio) to supply the precision analog circuitry will reduce the power supply ripple and preserve system accuracy and resolution.

TI power management for PLC

Description	Device Series	Key Benefits
3.5-V to 60-V input, 0.5/1.5/2.5-A, DC-DC converters	TPS54060/ 160/260	• Small form factor with 10 SON package • 12-/24-V support plus transients • Easy design with SwitcherPro software tool
Cost-optimized 200-mA linear regulator	TLV700xx	• Saves board space • Saves energy with 31µA quiescent current • Saves an RC filter through high PSRR of 68 dB at 1 kHz
2W, 3.3/5Vin isolated DC/DC converter	TPS55010	• No optocoupler required • Primary side feedback allows input/output voltage combinations with the same transformer
±36-V, 150-mA high voltage, ultra-low-noise LDOs	TPS7A4901/ TPS7A30xx	• Stable with ≥ 2.2µF ceramic capacitor • Low noise with 15.4µV_{rms} and 72dB PSRR • Reduces noise from switchers generating ± Vout

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