

APPENDIX **A**

Thermocouple Tables for Type J (°F and °C)

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APPENDIX B

The Getting Started Guide for APS, Chapter 2 Control Basics (tutorial on using the file system, addressing, and ladder logic for the Allen-Bradley SLC 500 and MicroLogix 1000 PLCs) 568

Getting Results Guide for RS Logix 500, Chapters 1 and 5
(Instructions for using Windows based ladder logic programming for Allen-Bradley SLC 500 and MicroLogix 100 PLCs) 574

Getting Started Guide

Getting Started with RS Logix 500

APPENDIX C

Glossary

absolute optical encoder An optical rotary encoder that outputs a binary word representing the angular position.

absolute pressure The pressure difference between the measured value and an absolute vacuum.

AC servomotor A two-phase motor used in control applications; designed to have a near-linear torque-speed curve.

acceleration The process of increasing velocity; uniform acceleration is when the velocity is increasing at a constant rate.

accumulator A temporary, digital data-storage register in the microprocessor used in many math, logic, and data-moving operations. Used in a hydraulic system, a spring-loaded tank connected into the high-pressure side of the system; the accumulator can store some fluid to be used at peak-demand periods.

active filter A circuit that incorporates an op-amp.

actuator The source of energy or motion in a system; typical actuators would be electric motors or hydraulic cylinders.

adaptive controller A controller, such as a PID, with the ability to monitor and improve its own performance.

ADC *See* **analog-to-digital converter**.

address A number that represents the location of 1 byte of data in memory or a specific input/output port.

address bus A group of signals coming from the microprocessor to memory and I/O ports, specifying the address.

aftercooler Used in pneumatic systems, a device that removes moisture from the air supply by chilling and thereby condensing any water vapor.

air compressor Used in pneumatic systems, a device that creates the supply of high-pressure air.

aliasing The event that occurs when the wrong data are reconstructed from the sampled sensor data because the sample rate is too slow.

ALU *See* **arithmetic logic unit**.

analog drive A method of controlling an electric motor's speed by varying the DC supply voltage.

analog I/O module A module that plugs into the PLC and converts real-world analog signals to digital signals for the PLC and vice versa.

analog switch A solid-state device that performs the same function as a low-power mechanical switch.

analog-to-digital converter (ADC) A device (usually an IC) that can convert an analog voltage into its digital binary equivalent.

anode One of three terminals of an SCR and PUT.

arithmetic logic unit (ALU) The part of the CPU that performs arithmetic and logical operations.

armature The part of a motor that responds to the magnetic field; typically, the armature is the rotating assembly of an electric motor.

assembly language A computer program written in mnemonics, which are English-like abbreviations for machine-code instructions.

autotuning The ability of some digital controllers to continuously fine-tune themselves by making small changes in their gain constants, based on past performance.

axial piston pump A type of hydraulic pump that uses a number of small pistons to pump the fluid, this is a variable-displacement pump because the stroke of the pistons is determined by the adjustable angle of the swash plate.

backlash In a gear pass, the small amount of free play between gears so that the teeth don't bind on each other.

ballast resistor A resistor placed in series with the stepper motor coils to improve the torque at higher stepping rates by reducing the motor-time constant.

ball bearing screw A ball bearing type of a lead-screw, recirculating balls roll between the threaded shaft and the nut to

remove almost all friction.

band-pass filter A circuit that allows only a specified range of frequencies to pass and attenuates all others above and below the pass band.

base One of three terminals of a transistor.

batch process A process that has a beginning and an end and is usually preformed over and over.

baud The rate at which the signal states are changing; frequently used to mean "bits per second."

bias A value that is added to the output of the controller to compensate for a constant disturbing force, such as gravity.

biasing circuit The part of a transistor circuit that generates the forward bias voltage.

bidirectional control valve Used in hydraulic and pneumatic systems, it can direct the fluid into either end

of the actuator cylinder, allowing the piston to be moved in either direction.

bilevel drive A technique that uses two voltages to improve torque at higher stepping rates. A higher voltage is applied to the motor at the beginning of the step, and then a lower voltage is switched in.

bimetallic temperature sensor A strip made from two metals with different coefficients of thermal expansion; as the strip heats up, it bends.

bipolar junction transistor (BJT) Known as a *transistor*, a solid-state device that can be used as a switch or an amplifier.

bipolar motor A stepper motor that requires polarity reversals for some of the steps.

bit The smallest unit of digital data, which has a value of 1 or 0.

bit instruction The basic PLC instruction that logically represents a simple switch or relay coil; the state of each switch or coil occupies 1 bit in memory.

BJT

See

bipolar junction

n

transist

or.

BLDC

See

brushle

ss DC

motor.

Bode plot A graph that plots system gain and phase shift versus frequency; it can be used to determine system stability.

bonded-wire strain gauge A force sensor consisting of a small pattern of thin wires attached to some structural member; when the member is stressed, the stretched wires slightly increase the resistance.

Bourdon tube A type of pressure sensor consisting of a short bent tube closed at one end; pressure inside the tube tends to straighten it.

brake A device used to slow down or stop a shaft, or to prevent a stopped shaft from moving.

brush A stationary conductive rod that rubs on the rotating commutator and conducts current into the armature windings.

brushless DC motor (BLDC)

The newest type of DC motor; it does not use a commutator or brushes; instead, the field windings are turned on and off in sequence, and the permanent magnet rotor (armature) is pulled around by the apparently rotating magnetic field.

bus topology A type of network wherein all the nodes tap into a single cable at different places, and the cable has a beginning and an end (that is, the cable is not in a ring).

byte An 8-bit digital word.

CAD *See*

computer-aided design.

CAM *See*

computer-

aided

manufacturin

g.

capacitor start motor

A single-phase AC induction motor that uses a capacitor to phase-shift the AC for the start windings.

cathode One of three terminals of an SCR and PUT.

CEMF *See counter-EMF.*

central processing unit (CPU)

The central part of a computer, the CPU performs all calculations and handles the control

functions of the computer.

change-of-state system

A method of communicating on a network wherein a device sends a message only when something changes.

chatter the condition that occurs when the output of a comparator oscillates when the input voltage is near the threshold voltage.

CIM *See computer-integrated manufacturing.*

circular pitch The distance along the pitch circle of a gear of one tooth and valley.

class A operation

The event when a transistor is biased so the collector current is approximately half of its maximum value.

class B operation

The event when a transistor is biased so that the collector current is just turning on.

class C operation

The event when a transistor is biased below cutoff and used as an on-off switch.

closed-loop control system

A control system that uses feedback. A sensor continually monitors the output of the system and sends a signal to the controller, which makes adjustments to keep the output within specification.

closed-loop gain The gain of an amplifier when feedback is being used. The value of closed-loop gain is less than open-loop gain (for negative feedback).

closed-loop control system

A control system that uses feedback. A sensor continually monitors the output of the system and sends a signal to the controller, which makes adjustments to keep the output within specification.

clutch A device used to connect or disconnect rotating shafts "on the fly"; usually a clutch acts by pressing two friction disks together.

coefficient of friction

A constant that is arrived at experimentally for different materials and can be used to calculate the force needed to overcome friction.

cogging The jerky motion of electric linear motors, especially at low speeds.

cold junction One of two temperature-

sensitive junctions of the thermocouple temperature sensor. The cold junction is usually kept at a reference temperature.

collector One of the three terminals of a transistor.

common mode rejection

System whereby a common voltage in both wires of a differential signal is canceled out. This system is used to advantage to reduce noise that is usually common to both wires.

commutator The part of an armature that makes contact with the brushes.

comparator (1) A type of op-amp that is used open-loop to determine if one voltage is higher or lower than another voltage. (2) Part of the control system that subtracts the feedback signal (as reported by the sensor) from the set point, to determine the error.

comparison

instruction Compares two words and yields a single bit as a result.

compensating gauge

A nonactive strain gauge that is used solely for the purpose of canceling out temperature effects.

compound motor A motor that has both shunt and series field windings.

computer-aided design

A computer system that makes engineering drawings.

computer-aided manufacturing

A computer system that allows CAD drawings to be converted for use by a numerical control (NC) machine tool.

computer-integrated manufacturing

A computer system that oversees every step in the manufacturing process, from customer order to delivery of finished parts.

constant current chopper drive

A drive circuit for stepper motors that uses PWM techniques to maintain a constant average current at all speeds.

contactor A heavy-duty relay that switches power directly to motors and machinery.

continuous-cycle method

A method of tuning a PID controller that involves driving the controller into

oscillations and measuring the response; the PID constants are computed based on these data.

continuous-level detector

A sensor that can determine the fluid level in a container.

continuous process

A process wherein there is a continuous flow of product—for example, a steam boiler where water is continuously pumped in and steam continuously comes out.

control bus A group of timing and control signals coming from the microprocessor to memory and I/O ports.

control instruction

Allows for such things as jumps and subroutines (in a computer program).

control strategy The set of rules that the controller follows to determine its output to the actuator.

control system A system that may include electronic and mechanical components, where some type of machine intelligence controls a physical process.

control valve Used to control the flow of fluids. A valve that has a built-in valve-operating mechanism, allowing it to be controlled remotely by a signal from the controller.

control winding One of two windings in an AC servomotor.

controlled variable

The ultimate output of the process; the actual parameter of the process that is being controlled, such as temperature in a heating system.

controller The machine intelligence of the control system.

counter-EMF (CEMF)

A voltage that is generated inside an electric motor when running under its own power; the polarity of the CEMF is always opposite to the applied voltage.

CPU See **central processing unit**.

creep The property that explains why two pulleys

connected with a belt will not stay exactly synchronized.

critically damped A system that is damped just enough to prevent overshoot.

cumulative

compound motor A compound motor where the magnetic fields of the shunt and series fields aid each other.

cumulative error Error that accumulates; for example, a cumulative error of 1° per revolution means that the measurement error would be 5° after 5° revolutions.

current loop In a signal transmission system, a single loop of wire that goes from the transmitter to the receiver and back to the transmitter. The signal intelligence is conveyed by the current level instead of the

voltage. This system is immune to voltage drops caused by wire resistance.

current-to-voltage converter An op-amp based circuit used as a receiver for a current-loop system.

cutoff frequency The frequency at which a filter circuit starts to attenuate.

DAC *See* **digital-to-analog converter**.

damping A drag force on a system from sliding or viscous friction, which acts to slow movement (make it sluggish).

data bus A group of signals going to and from the microprocessor, memory, and I/O ports. The data bus carries the actual data that are being processed.

data communication equipment (DCE) One of two units specified by the RS-232 standard (for serial data transfer); the DCE is usually a modem.

data file The collection of data in a PLC that represents the present condition of switches, counters, relays, and the like.

data memory The section of RAM memory in a PLC where the data file is stored.

data terminal

equipment (DTE) One of two units specified by the RS-232 standard (for serial data transfer). The DTE is usually the computer.

data packet A message transmitted on a network; usually includes the address of where it's going, the address of where it came from, and the message itself.

DCC *See*

distributed

computer

control. DCE

See **data**

communication

in equipment.

DC link converter A circuit that converts line voltage at 60 Hz to AC power at different voltage and frequencies, for the purpose of controlling the speed of AC motors.

DC offset voltage The small voltage that may occur on the output of an op-amp, even when the inputs are

equal; DC offset can be eliminated with a resistor adjustment.

DDC *See* **direct digital control**.

dead band The small range, on either side of the set point (of the controlled variable), where the error cannot be corrected by the controller because of friction, mechanical backlash, and the like.

dead time The interval of time between the correcting signal sent by the controller and the response of the system.

dead zone *See* **dead band**.

decibel Gain expressed in a logarithmic scale.

delta-connection One of two ways in which to connect three-phase motor or generator coils. With the delta-connection, each of the three coils is connected between two phase wires; there is no neutral.

derivative control A feedback control strategy where the restoring force is proportional to the rate that the error is changing (increasing or decreasing); derivative control tends to quicken the response and reduce overshoot.

desiccant dryer Used in pneumatic systems, a device that dries the air supply by passing the air

through a water-absorbing chemical.

detent torque A magnetic tug that keeps a stepper motor rotor from turning even when the power is off; also called *residual torque*.

deterministic network A network able to assign priority to a message and to guarantee that it will arrive in a given time.

device-level network A network used to connect low-level devices such as sensors and actuators to a PLC.

DeviceNet A type of device-level network developed by Allen-Bradley. *See* **device-level network**.

diac A bistable, two-terminal, solid-state device that is used to trigger the triac.

diametral pitch The ratio of the number of gear teeth per inch of pitch diameter; in practice, the number that describes the tooth size when specifying gears.

differential amplifier A circuit that produces an output voltage that is proportional to the instantaneous voltage difference between two input signals. Op-amps by themselves are difference amplifiers; however, a practical differential amplifier incorporates additional components.

differential compound motor A compound motor where the magnetic fields of the shunt and series windings oppose each other.

differential pressure The difference between two pressures where neither may be ambient.

differential voltage A signal voltage carried on two wires, where neither wire is at ground potential.

differentiator An op-amp circuit that has an output voltage proportional to the instantaneous rate of change of the input voltage.

digital control system

A control system where the controller is a digital circuit, typically a computer.

Digital-signal processor (DSP) A type of digital processor that is designed to support high-performance, repetitive, numerically intensive tasks.

digital-to-analog converter (DAC) A circuit that translates digital data into an analog voltage.

DIP switch A set of SPST switches built into the shape of an IC (DIP stands for dual in-line package).

direct current tachometer Essentially, a DC generator that gives an output voltage proportional to angular velocity.

direct digital control An approach to process control where all controllers in a large process are simulated by a single computer.

discrete I/O I/O that deals with on-off devices. Discrete input modules are used to connect real-world switches to the PLC, and discrete output modules are used to turn on lamps, relays, motors, and so on.

discrete-level detector A sensor that can determine if the fluid in a container has reached a certain level.

distributed computer control An approach to process control where each process has its own local controller, but all individual controllers are connected to a single computer for programming and monitoring.

double-acting cylinder A hydraulic or pneumatic cylinder and piston assembly in which the piston can be driven in either direction.

double-pole/double-throw switch (DPDT) A switch contact configuration.

download To transfer a computer program or data into a computer (from another computer).

DPDT See

double-pole/double-throw switch.

drain One of

three terminals in an FET.

dryer Used in pneumatic systems, a dryer removes the moisture from the air supply.

DTE See **data terminal equipment.**

duty cycle The percentage of cycle time that the PWM pulse is high—that is, a true square wave has a duty cycle of 50%.

dv/dt effect The event when the SCR turns on if the anode-cathode voltage rises too quickly.

dynamic braking A method of braking the motor by switching the armature windings to a resistor. The coasting motor generates current that is dissipated in the resistor, thus removing energy from the system.

dynamic torque The motor torque available to rotate the load under normal conditions.

earth ground The voltage at (or connection to) the surface of the earth at some particular place.

efficiency When describing energy conversions, the percentage of input energy that is converted to useful output energy.

eight-step drive A two- or four-phase stepper motor being driven in half-steps; the sequencing pattern has eight steps.

electric field A condition that exists in the space between two objects that are at a different voltage potential. A wire in this space will assume a “noise” voltage proportional to the field strength.

electromechanical counter A device that counts events. Each time it receives a pulse, it increments a mechanical counter, which can then be read by an operator or used to activate some other process.

electromechanical relay (EMR) A device that uses an electromagnet to close (or open) switch contacts—in other words, an electrically powered switch.

electromechanical sequencer A device that provides sequential activation signals; it works by rotating a drum with cams, which activates switches.

embedded controller

A small microprocessor-based controller that is permanently installed within the machine it is controlling.

emitter One of three terminals of a transistor.

EMR See **electromechanical relay**.

energy The amount of work it takes to do a job; energy has different units for chemical, thermal, mechanical, and electrical systems.

enhancement mode Property of some MOSFETs where the gate voltage can always be positive (for N-channel).

error (E) In a control system, the difference between where the controlled variable should be (set point) and where it actually is ($E = SP - PV$).

Ethernet The type of network used to interconnect PCs and mainframe computers for the purpose of exchanging data and data files.

event control system

A control system that cycles through a predetermined series of steps.

event-driven operation In a sequentially controlled system, an action that is allowed to start or continue based on some parameter changes. This is an example of closed-loop control.

expansion card/slot An expansion card is a printed circuit card that plugs into an expansion slot on the motherboard of a personal computer (PC). The expansion card usually interfaces the PC to the outside world.

extension rate The rate at which a linear actuator can extend or retract; the term is usually applied to electrical linear actuators.

feedback The signal from the sensor, which is fed back to the controller.

feedforward The concept of letting the controller know in advance that a change is coming.

fetch-execute cycle

A computer cycle where the CPU fetches an instruction and then executes it.

FET See **field effect transistor**.

field The part of an electric motor that

provides a magnetic field; typically, it is the stationary part.

Fieldbus A type of device-level network. See **device-level network**

field effect transistor (FET) A three-terminal solid-state amplifying device that uses voltage as its input signal.

field-oriented control drive A class of AC-motor-control units that provides very precise control of speed. A type of vector drive. See **vector drives**.

field winding A stationary electromagnet used to provide the magnetic field needed by the armature.

flow sensor A sensor that measures the quantity of fluid flowing in a pipe or channel.

flow-control valve Used to control the flow of fluids. A valve that has a built-in valve-operating mechanism,

allowing it to be controlled remotely by a signal from the controller.

flux vector drive A class of AC-motor-control units that requires a position sensor and maintains better control than the sensorless drive can (but not as good control as the field-oriented drive). A type of vector drive. See **vector drives**.

follow-up system A control system where the output follows a specified path.

forced commutation The process of turning off an SCR by momentarily forcing the anode-cathode voltage to 0 V (or below).

forward bias voltage The DC offset base voltage required to start the transistor conducting.

forward breakover voltage The voltage across a thyristor that causes it to switch into its conduction state.

forward conduction region The operating range of a thyristor when it is conducting.

forward current gain (h_{FE}) The gain of a transistor; the collector current divided by the base current.

forward path The signal-flow direction of the controller to the actuator.

four-phase stepper

motor A motor with four separate field circuits; this motor does not require polarity reversals to operate and hence is unipolar.

four-step drive The standard operating mode for two- or four-phase stepper motors taking full steps; the sequencing pattern has four states.

fractional horsepower (hp) motor A motor with less than 1 hp.

frame A basic part of an AC motor, an overall case that supports the stator and the rotor bearings.

fuzzy logic A new control strategy, modeled originally on human thought processes, where decisions are made based on a number of factors and each fac-

tor can have such qualities as *maybe* and *almost*, to name only two.

fuzzy predicates Linguistic terms of degree, used in describing actual variables—for example, *warm*, *very warm*, *not so warm*, and so on.

fuzzy set The range of one fuzzy predicate in a system—that is, all values of temperature that correspond to *very warm*.

gain A multiplication factor; the steady-state relationship between input and output of a component. (In this text, *gain* and *transfer function* are used interchangeably, although this is a simplification.) The term *system gain* refers to the proportional gain factor (K_P).

gain-bandwidth product (f_T) A constant for an amplifier that is the product of the open-loop gain and the frequency at that gain; can be read as the frequency when a transistor's gain has been reduced to 1.

gain margin A form of a safety margin. When the phase lag is 180° , the gain margin is the amount the gain could be increased before the system becomes unstable.

gate One of three terminals in an SCR, PUT, FET, or triac.

gauge pressure The difference between measured and ambient pressure (ambient is 14.7 psi or 101.3 kPa).

gearhead In smaller motors, a gear train attached or built-in to the motor assembly, which effectively gives the motor more torque at less rpm.

gear motor A simple hydraulic motor in which fluid pushes on the teeth of a set of constantly meshed gears (in a housing), causing them to rotate.

gear pass Two gears in mesh.

gear pump A simple positive-displacement hydraulic fluid pump that uses two constantly meshed gears (in a housing).

gear ratio The ratio of the number of teeth of two gears in mesh. (Also the ratio of pitch diameters.)