Transducers, Mechanical Measurement and Industrial Instrumentation

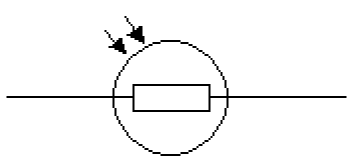
A **resistive transducer** is a device that senses a **change** to cause
a **change** in **resistance**. Transducers do NOT generate electricity. Examples include:

Device	*Action*	*Where used*
Light DependentResistor	Resistance falls with increasinglight level	Light operated switches
Thermistor	Resistance falls with increasedtemperature	Electronicthermometers
Strain gauge	Resistance changes with force	Sensor in an electronic balance
Moisturedetector	Resistance falls when wet	Damp meter

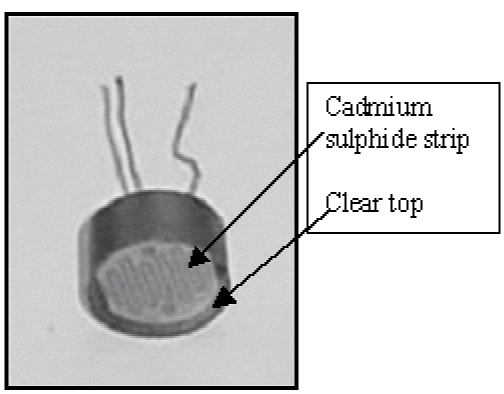
These are called **passive** devices. (**Active transducers** do generate electricity from other energy sources, or have a power supply.)

Light Dependent Resistors

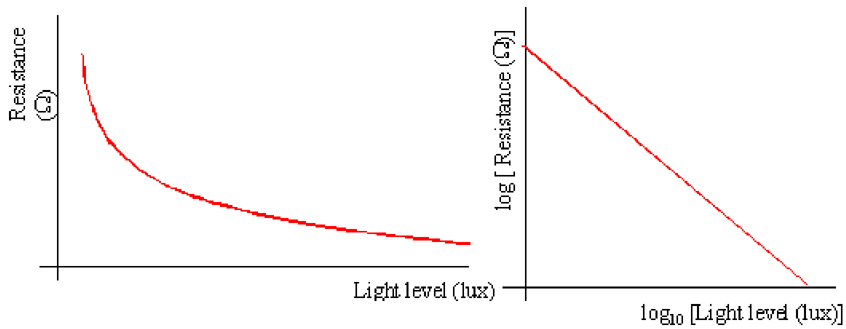
The **light dependent resistor** consists of a length of material (cadmium sulphide) whose resistance changes according to the light level. Therefore the brighter the light, the lower the resistance.



Symbol for LDR



We can show the way the resistance varies with light level as a graph:



LDRs are used for:

Smoke detection

Automatic lighting

Counting

Alarm systems.

Resistive components can get hot when excessive current is flowing through them, and this can impair their function, or damage them. This can be prevented by connecting a current limiting resistor in series, as shown in the picture below

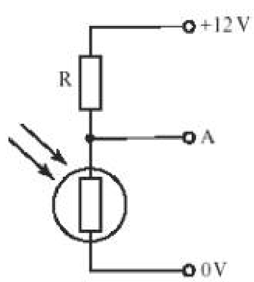


Figure 1

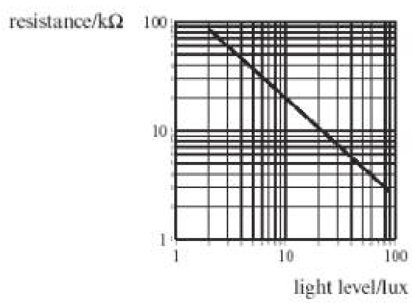
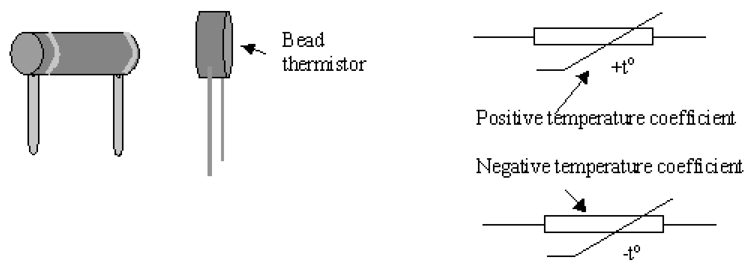


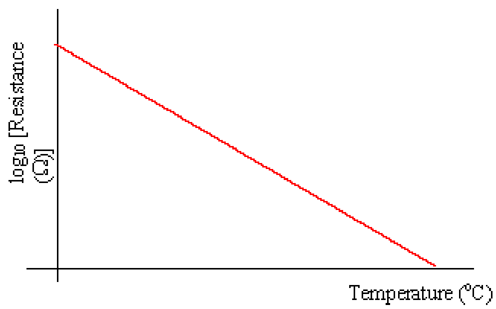
Figure 2

Thermistors

The most common type of **thermistor** that we use has a resistance that falls as the temperature rises. It is referred to as a negative temperature coefficient device. A positivetemperature coefficient device has a resistance that increases with temperature.



The graph of resistance against temperature is like this.



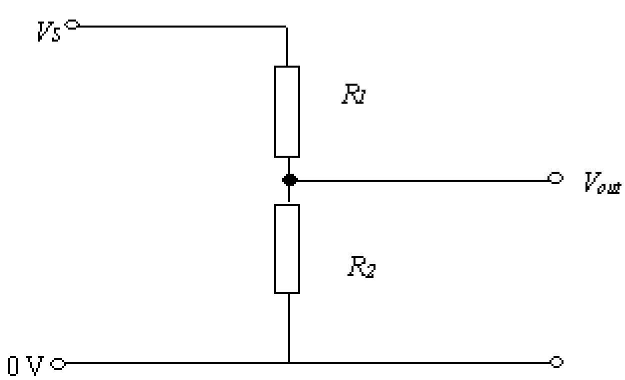
The resistance on this graph is on a logarithmic scale, as there is a large range of values.

The LDR is most commonly used in a potential divider circuit.

Potential Divider

- Although it is simple, the potential divider is a very useful circuit. In its simplest form it is two resistors in series with an input voltage Vs across the ends.
- An output voltage Vout is obtained from a junction between the two resistors.

The potential divider circuit looks like this:



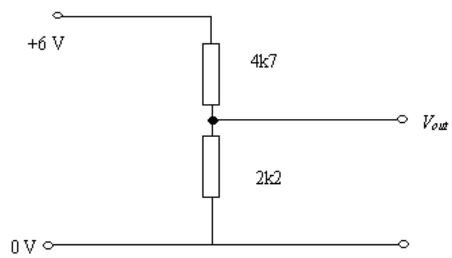
You need to learn this equation. It is very useful.

Learn this:

$$Vout = \frac{R_2}{R_1 + R_2} \times Vs$$

If you can't remember it, treat the circuit as a simple series circuit.

This result can be thought of as the output voltage being the same fraction of the input voltage as R2 is the fraction of the total resistance. Look at this circuit for the next example:

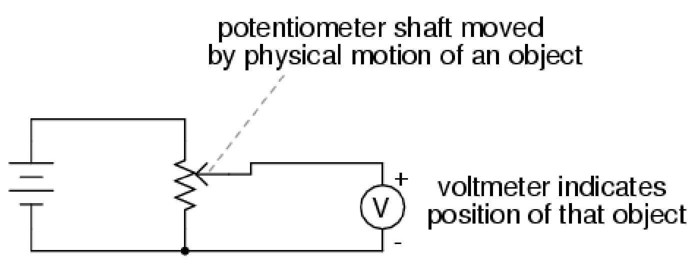


Capacitive Transducers

AC instrumentation transducers

Just as devices have been made to measure certain physical quantities and repeat that information in the form of DC electrical signals (thermocouples, strain gauges, pH probes, etc.), special devices have been made that do the same with AC.

It is often necessary to be able to detect and transmit the physical position of mechanical parts via electrical signals. This is especially true in the fields of automated machine toolcontrol and robotics. A simple and easy way to do this is with a potentiometer: (Figure below)

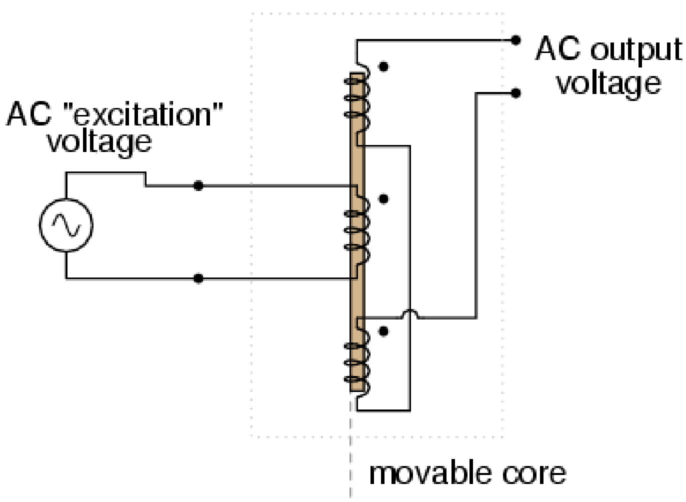


Potentiometer tap voltage indicates position of an object slaved to the shaft.

However, potentiometers have their own unique problems. For one, they rely on physical contact between the "wiper" and the resistance strip, which means they suffer the effectsof physical wear over time. As potentiometers wear, their proportional output versus shaft position becomes less and less certain. You might have already experienced this effect when adjusting the volume control on an old radio: when twisting the knob, you might hear "scratching" sounds coming out of the speakers. Those noises are the result of poor wiper contact in the volume control potentiometer.

Also, this physical contact between wiper and strip creates the possibility of arcing (sparking) between the two as the wiper is moved. With most potentiometer circuits, the current is so low that wiper arcing is negligible, but it is a possibility to beconsidered. If the potentiometer is to be operated in an environment where combustible vapor or dust is present, thispotential for arcing translates into a potential for an explosion!

Using AC instead of DC, we are able to completely avoid sliding contact between parts if we use a *variable transformer*instead of a potentiometer. Devices made for this purpose are called LVDT's, which stands for Linear VariableDifferential Transformers. The design of an LVDT looks like this: (Figure below)



AC output of linear variable differential transformer (LVDT) indicates core position.

Obviously, this device is a *transformer*: it has a single primary winding powered by an external source of AC voltage, and two secondary windings connected in series-bucking fashion. It is *variable* because the core is free to move between the windings. It is *differential* because of the way the two secondary windings are connected. Being arranged to oppose each other (180^o out of phase) means that the output of this device will be the *difference* between the voltage output of the two secondary windings. When the core is centered and both windings are outputting the same voltage, the net result at the output terminals will be zero volts. It is called *linear* because the core's freedom of motion is straight-line.

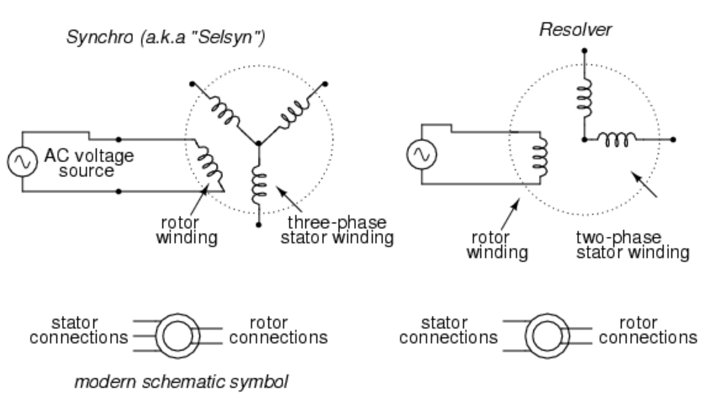
The AC voltage output by an LVDT indicates the position of the movable core. Zero volts means that the core is centered. The further away the core is from center position, the greater percentage of input ("excitation") voltage will be seen at the output. The phase of the output voltage relative to the excitation voltage indicates which direction from center the core is offset.

The primary advantage of an LVDT over a potentiometer for position sensing is the absence of physical contact between the moving and stationary parts. The core does not contact the wire windings, but slides in and out within a nonconducting tube. Thus, the LVDT does not "wear" like a potentiometer, nor is there the possibility of creating an arc.

Excitation of the LVDT is typically 10 volts RMS or less, at frequencies ranging from power line to the high audio (20 kHz) range. One potential disadvantage of the LVDT is its response time, which is mostly dependent on the frequency of the AC voltage source. If very quick response times are desired, the frequency must be higher to allow whatever voltage-sensing circuits enough cycles of AC to determine voltage level as the core is moved. To illustrate the potentialproblem here, imagine this exaggerated scenario: an LVDT powered by a 60 Hz voltage source, with the core being moved in and out hundreds of times per second. The output of this LVDT wouldn't even look like a sine wave because the core would be moved throughout its range of motion before the AC source voltage could complete a single cycle! It would be almost impossible to determine instantaneous core position if it moves faster than the instantaneous source voltage does.

A variation on the LVDT is the RVDT, or Rotary VariableDifferential Transformer. This device works on almost the same principle, except that the core revolves on a shaft instead of moving in a straight line. RVDT's can be constructed for limited motion of 360^o (full-circle) motion.

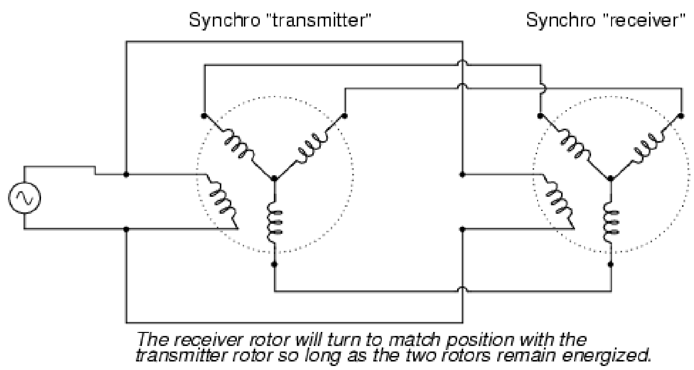
Continuing with this principle, we have what is known as a*Synchro* or *Selsyn*, which is a device constructed a lot like a wound-rotor polyphase AC motor or generator. The rotor is free to revolve a full 360^o, just like a motor. On the rotor is a single winding connected to a source of AC voltage, much like the primary winding of an LVDT. The stator windings are usually in the form of a three-phase Y, although synchros with more than three phases have been built. (Figure below) A device with a two-phase stator is known as a *resolver*. A resolver produces sine and cosine outputs which indicate shaft position.



A synchro is wound with a three-phase stator winding, and a rotating field. A resolver has a two-phase stator.

Voltages induced in the stator windings from the rotor's AC excitation are *not* phase-shifted by 120^o as in a real three-phase generator. If the rotor were energized with DC current rather than AC and the shaft spun continuously, then the voltages would be true three-phase. But this is not how a synchro is designed to be operated. Rather, this is a *position-sensing* device much like an RVDT, except that its output signal is much more definite. With the rotor energized by AC, the stator winding voltages will be proportional in magnitude to the angular position of the rotor, phase either 0^o or 180^oshifted, like a regular LVDT or RVDT. You could think of it as a transformer with one primary winding and three secondary windings, each secondary winding oriented at a unique angle. As the rotor is slowly turned, each winding in turn will line up directly with the rotor, producing full voltage, while the other windings will produce something less than full voltage.

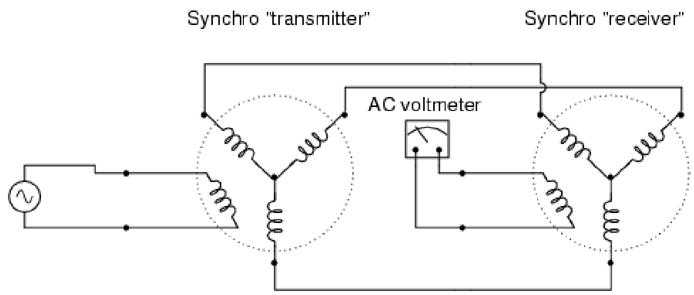
Synchros are often used in pairs. With their rotors connected in parallel and energized by the same AC voltage source, their shafts will match position to a high degree of accuracy: (Figure below)



Synchro shafts are slaved to each other. Rotating one moves the other.

Such “transmitter/receiver” pairs have been used on ships to relay rudder position, or to relay navigational gyro position over fairly long distances. The only difference between the “transmitter” and the “receiver” is which one gets turned by an outside force. The “receiver” can just as easily be used as the “transmitter” by forcing its shaft to turn and letting the synchro on the left match position.

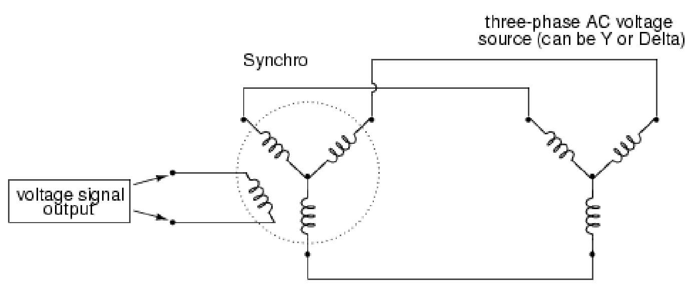
If the receiver's rotor is left unpowered, it will act as a position-error detector, generating an AC voltage at the rotor if the shaft is anything other than 90^o or 270^o shifted from the shaft position of the transmitter. The receiver rotor will no longer generate any torque and consequently will no longer automatically match position with the transmitter's: (Figure below)



AC voltmeter registers voltage if the receiver rotor is not rotated exactly 90 or 270 degrees from the transmitter rotor.

This can be thought of almost as a sort of bridge circuit that achieves balance only if the receiver shaft is brought to one of two (matching) positions with the transmitter shaft.

One rather ingenious application of the synchro is in the creation of a phase-shifting device, provided that the stator is energized by three-phase AC: (Figure below)

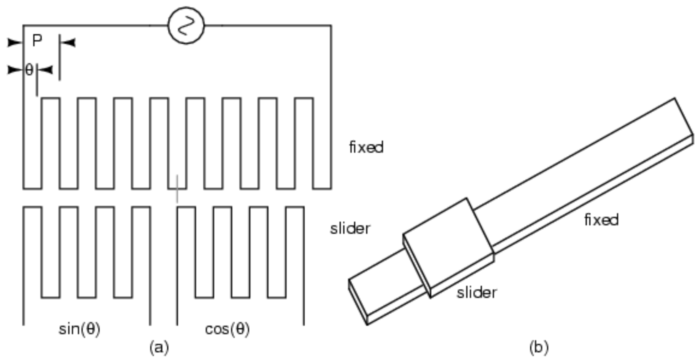


Full rotation of the rotor will smoothly shift the phase from 0^o all the way to 360^o (back to 0^o).

As the synchro's rotor is turned, the rotor coil will progressively align with each stator coil, their respective magnetic fields being 120^o phase-shifted from one another. In between those positions, these phase-shifted fields will mix to produce a rotor voltage somewhere between 0^o, 120^o, or 240^o shift. The practical result is a device capable of providing an infinitely variable-phase AC voltage with the twist of a knob (attached to the rotor shaft).

A synchro or a resolver may measure linear motion if geared with a rack and pinion mechanism. A linear movement of a few inches (or cm) resulting in multiple revolutions of the synchro (resolver) generates a train of sinewaves. An*Inductosyn*® is a linear version of the resolver. It outputs signals like a resolver; though, it bears slight resemblance.

The Inductosyn consists of two parts: a fixed serpentine winding having a 0.1 in or 2 mm pitch, and a movable winding known as a *slider*. (Figure below) The slider has a pair of windings having the same pitch as the fixed winding. The slider windings are offset by a quarter pitch so both sine and cosine waves are produced by movement. One slider winding is adequate for counting pulses, but provides no direction information. The 2-phase windings provide direction information in the phasing of the sine and cosine waves. Movement by one pitch produces a cycle of sine and cosine waves; multiple pitches produce a train of waves.



Transducers

Pressure transducers, ultrasonic transducer, strain gaugetransducer, ultrasound transducer, i p transducer, currenttransducer, torque transducer, force transducer, differentialpressure transducer, power transducer, piezo transducer,velocity transducer, sensor temperature, oxygen sensor,pressure sensor, sensor torque, speed, driveway sensor

Transducers and Signal Conditioning

- Pressure transducers - A pressure transducer is atransducer that converts pressure into an analog electrical signal - This page speaks about Millivolt Output Pressure Transducers, Voltage Output PressureTransducers, 4-20 mA Output Pressure Transducers
- Pressure Transducer Basics - A Primer put together by Transtronics to help people understand pressuretransducers.
- Ultrasonic Transducers - Ultrasonic transducers forapplications as diverse as flaw detection, thickness gaging, materials research and medical diagnostics.
- Ultrasonic Transducers on GlobalSpec - Ultrasonictransducers send and receive waves for many types ofsensing. Examples include distance, proximity, level, nondestructive evaluation, web break detection, counting, and security applications.
- Principle of action of solid state strain gaugetransducer - Outline of Wheatstone bridgeconfiguration with excitation by regulated supply followed by stable, fixed gain amplification. Description of errors, overdamping, overshoot, causes & remedial actions
- Philips Ultrasound Transducers - All Philips Ultrasound systems benefit from the clinically versatile family of HDI and SONOS transducers.
- I P Transducer - Fairchild precision I/P, E/P, D/P & P/I converters

- Current transducer, Current transformer - Current transformers, voltage transformers, powertransducers, current transducers and hall effect devices for alternating and direct current.
- Current Transducers Accessories - Current transducerconverts the AC Current into a 4-20 DC ... The currenttransducer requires a power supply of 24VDC
- Torque Transducers and Torque Sensors - Torque meters provide extremely accurate torque and speedmeasurement over a very broad range.
- Principles of a force transducer - What is the general principle of a force transducer?
- Differential Pressure Transducers - PressureTransducer Product Finder
- Technical Notes / Ultrasonic Transducers - Ultrasonictransducer - an extremely important and critical part of any ultrasonic test

- KPSI Pressure Transducers - Application Notes
- Air Velocity Transducers Application Notes - Notes, References
- Process/Industrial Instruments and Controls Handbook (5th Edition) - This updated, expanded, and revised handbook brings you the latest methods for increasing process efficiency, production rate, and quality - plus all the background you need to approach any key decision with confidence.
- What is Signal Conditioning? - From Natinal Instruments
- Power Transducers from CR Magnetics - A wide selection of power transducers including digital and analog versions!
- Signal Conditioning - Requirements for A-D converters, Voltage to Voltage, Current to Voltage, Resistance to Voltage, Capacitance to Voltage, SignalConditioning Circuits
- Introduction To PIEZO Transducers - Transducersconvert one form of energy to another. Piezo motors (actuators) convert electrical energy to mechanical energy, and piezo generators (sensors) convert mechanical energy into electrical energy.
- Rotary Torque Transducer Installation Guide - Installation guide for transducers
- Transducers for Physiological Measurement -Transducers are designed for general use in data acquisition and recording instruments and systems.

- Linear Velocity Transducers - The Series 100 LinearVelocity Transducers are inductive, instantaneousvelocity transducers.
- Sensors and Transducers Links - Very good Pointers on Web to transducer manufacturing comapnies
- Temperature Sensor - Find temperature sensors ortemperature measurement devices, learn abouttemperature sensors and their uses in temperaturemeasurement, a free web guide to temperaturesensors, temperature measurement devices andtemperature measurement.
- Oxygen Sensor - When the oxygen sensor in your car goes bad, your car runs differently. This is a story of author's experiences ....
- How does the oxygen sensor in a car work? - Every new car, and most cars produced after 1980, have an oxygen sensor....HowStuffWorks.com explains the details
- Torque Sensors - Rotary - Reaction - from Honeywell Sensotec - Reaction and Rotary Torque Sensors
- Hall Effect - The Hall effect can be used to measure magnetic fields with a Hall probe

Instrumentation

Process Instrumentation and Measurement

On-off control, time proportional control, proportional control, integral control, derivative control, typical PID controller characteristics and related terminology. Parameteradjustments, pneumatic PID controllers, electronic controllersand hydraulic controllers, Radio control systems, split range control, cascade control, feed forward control. Feedback and connecting elements in the loop flow, pressure level and temperature control loops, pneumatic transmission, electrictransmission, thermal element lag, pressure element lag.

Instrumentation is defined as "the art and science ofmeasurement and control". Instrumentation can be used to refer to the field in which Instrument technicians and engineers work, or it can refer to the available methods ofmeasurement and control and the instruments which facillitate this. - wikipedia

- Measurement
- Output
- Control
- Related professions

- External links
- Further reading

Process Instrumentation and Measurement

- Instrumentation and Process Control - Syllabus from University of Colorado in PDF Format
- Process Control Chart - in PDF format
- Instrumentation Links - Do visit
- Instrumentation Laboratory - Amplifiers, Attenuators, Emulators, Filters, Transmitters & Receivers, Switches etc.
- Mass Spectrometry Instrumentation Links - Resources on The Web Chemistry and Mass Spectrometry

- Scientific Computing & Instrumentation - Online magazine promoting scientific computing,instrumentation, and automation technology.
- IEEE Instrumentation and Measurement Society - ... measuring is the key to know!
- Instrumentation Laboratory World Wide - Home Page
- ON-OFF Control - Alternating ON-OFF Switch
- Introduction to Closed-Loop Control - Most control systems utilize feedback in some manner. Here's a look at several fundamental feedback mechanisms, culminating in a description of a basic PID controller.
- Feedback and Temperature Control - Types ofFeedback Control
- Radio Control Systems - ServoCity - Radio Control Systems
- DIMENSION III Process and Instrumentation Diagrams - P and I diagram Drwaing Tool
- Instrumentation & Process Control - Applied Math ForInstrumentation, DC Electronics, AC Electronics, Semiconductors, Digital Electronics, Electronic Test Equipment, Computer Aided Circuit Analysis, Pneumatic Test Equipment
- Instrumentation and Automation News - Product News for the Instrumentation, Control, and Automation Engineer

- Instrumentation Projects - Projects like Inamori Magellan Areal Camera and Spectrograph (IMACS), Low Dispersion Survey Spectrograph (LDSS2), Raymond and Beverly Sackler Magellan Instant Camera (MagIC),Persson's Auxilliary Nasmyth Infrared Camera (PANIC), Wide Field Infared Camera (WIRC)

System Design Process

Instrumentation System Design

Signal processing circuits: Relay ladder diagrams, design of bridge circuits/amplifiers, cold junction compensation for thermocouple, linearisation of thermistor; design of chargeamplifier,, design of transmitters, Pneumatic and electroniccontrollers, annunciation, Control Valves, Piping and Instrumentation PID diagrams, ISA symbols, PI diagrams of typical process plants, Project evaluation. Microprocessor based Instrumentation systems, Data acquisition systems

Instrumentation System Design

- Modeling, Evaluation, and Testing of Paradyn Instrumentation System - modeling- and simulation-based evaluation to provide feedback to the tool

- Electronic System Design Group - Electronic Systems
- Relay Ladder Logic - Ladder diagrams, or Relay Ladder Logic (RLL), are the primary programming language for programmable logic controllers (PLCs). Ladder logic programming is a graphical representation of the program designed to look like relay logic.
- Implementing Cold Junction Compensation in Thermocouple Applications - by Michelle Youn, Maxim Integrated Products
- charge amplifier design on GlobalSpec - Site Search Results/ charge amplifier design
- Pneumatic and electronic controllers - Important information on how to make best use
- ISA symbols - ISA Symbol Library