Филиал «Протвино» государственного университета «Дубна»
Евсиков
Александр
Александрович
я подтверждаю
этот документ
своей
удостоверяющей
подписью
2024-10-16 14:56:16

Государственное бюджетное образовательное учреждение высшего образования Московской области
«Университет «Дубна»
Филиал «Протвино»
Кафедра гуманитарных и социальных наук

Е.Э. Черкасова, М.Н. Чермных

Automation around us

ЭЛЕКТРОННОЕ МЕТОДИЧЕСКОЕ ПОСОБИЕ

Рекомендовано
кафедрой гуманитарных и социальных наук филиала «Протвино» государственного университета «Дубна» в качестве методического пособия для студентов, обучающихся по направлению «Автоматизация технологических процессов и производств»

Протвино 2017 г.

ББК 81.2 (англ)я73
Ч 48

Рецензент:
кандидат физико-математических наук, ведущий инженер – программист ЗАО ПРОТОМ,
Абрамов А.Г.

Черкасова Е.Э.
Ч 48 Automation around us : электронное методическое пособие / Черкасова Е.Э., Чермных М.Н. — Протвино, 2017. — 137 с.

Предназначено для студентов 3 курса направления «Автоматизация технологических процессов и производств», изучающих дисциплину «Иностранный язык. Терминология». Пособие разработано на основе руководства по эксплуатации электромеханического оборудования и автоматизированных систем управления компании «Siemens». Пособие состоит из 15 разделов и снабжено тематическим словарем.

ББК 81.2 (англ)я73

© Черкасова Е.Э., Чермных М.Н., 2017
© Государственное бюджетное образовательное учреждение высшего образования Московской области «Университет «Дубна», филиал «Протвино», 2017

Contents

Unit 1

Automation

Automation plays an increasingly important role in the global economy and in daily experience. Engineers strive to combine automated devices with mathematical and organizational tools to create complex systems for a rapidly expanding range of applications and human activities. **Automation** (is the use of control systems such as computers to control industrial machinery and processes, replacing human operators. In the scope of industrialization, it is a step beyond mechanization. Whereas *mechanization* ancient Greek: = *self dictated*), **roboticization** or **industrial automation** or numerical control provided human operators with machinery to assist them with the *physical* requirements of work, *automation* greatly reduces the need for human *sensory* and *mental* requirements as well.

There are still many jobs which are in no immediate danger of automation. No device has been invented which can match the human eye for accuracy and precision in many tasks; nor the human ear. Even the admittedly handicapped human is able to identify and distinguish among far more scents than any automated device. Human pattern recognition, language recognition, and language production ability is well beyond anything currently envisioned by automation engineers.

Specialised hardened computers, referred to as programmable logic controllers (PLCs), are frequently used to synchronize the flow of inputs from (physical) sensors and events with the flow of outputs to actuators and events. This leads to precisely controlled actions that permit a tight control of almost any industrial process. (It was these devices that were feared to be vulnerable to the "Y2K bug", with such potentially dire consequences, since they are now so ubiquitous throughout the industrial world.)

Human-machine interfaces (HMI) or computer human interfaces (CHI), formerly known as *man-machine interfaces*, are usually employed to communicate with PLCs and other computers, such as entering and monitoring temperatures or pressures for further automated control or emergency response. Service personnel who monitor and control these interfaces are often referred to as stationary engineers.

Another form of automation involving computers is test automation, where computer-controlled automated test equipment is programmed to simulate human testers in manually testing an application. This is often accomplished by using *test automation tools* to generate special scripts (written as computer

programs) that direct the automated test equipment in exactly what to do in order to accomplish the tests.
Finally, the last form of automation is software-automation, where a computer by means of macro recorder software records the sequence of user actions (mouse and keyboard) as a macro for playback at a later time.

Social issues of automation

Automation raises several important social issues. Among them is automation's impact on employment. Indeed, the Luddites were a social movement of English textile workers in the early 1800s who protested against Jacquard's automated weaving looms— often by destroying such textile machines— that they felt threatened their jobs. Since then, the term *luddite* has come to be applied freely to anyone who is against any advance of technology.
Some argue automation leads to *higher* employment. One author made the following case. When automation was first introduced, it caused widespread fear. It was thought that the displacement of human workers by computerized systems would lead to severe unemployment. In fact, the opposite has often been true, e.g., the freeing up of the labor force allowed more people to enter higher skilled jobs, which are typically higher paying. One odd side effect of this shift is that "unskilled labor" now benefits in many "first-world" nations, because fewer people are available to fill such jobs.
Some argue the reverse, at least in the long term. They argue that automation has only just begun and short-term conditions might partially obscure its long-term impact. Many manufacturing jobs left the United States during the early 1990s, but a one-time massive increase in IT jobs (which are only now being outsourced), at the same time, offset this.
It appears that automation does devalue labor through its replacement with less-expensive machines; however, the overall effect of this on the workforce as a whole remains unclear. Today automation of the workforce is quite advanced, and continues to advance increasingly more rapidly throughout the world and is encroaching on ever more skilled jobs, yet during the same period the general well-being of most people in the world (where political factors have not muddied the picture) has increased dramatically. What role automation has played in these changes has not been well studied.
One irony is that in recent years, outsourcing has been blamed for the loss of jobs in which automation is the more likely culprit . This argument is supported by the fact that in the U.S., the number of insourced jobs is increasing at a greater rate than those outsourced . Further, the rate of decline in U.S.

manufacturing employment is no greater than the worldwide average: 11 percent between 1995 and 2002 . In the same period, China, which has been frequently criticized for "stealing" American manufacturing jobs, lost 15 million manufacturing jobs of its own (about 15% of its total), compared with 2 million lost in the U.S.
Millions of human telephone operators and answerers, throughout the world, have been replaced wholly (or almost wholly) by automated telephone switchboards and answering machines (*not* by Indian or Chinese workers).
Thousands of medical researchers have been replaced in many medical tasks from 'primary' screeners in electrocardiography or radiography, to laboratory analyses of human genes, sera, cells, and tissues by *automated systems.* Even physicians have been partly replaced by remote, automated robots and by highly sophisticated surgical robots that allow them to perform remotely and at levels of accuracy and precision otherwise not normally possible for the average physician.

Current emphases in automation

Currently, for manufacturing companies, the purpose of automation has shifted from increasing productivity and reducing costs, to broader issues, such as increasing quality and flexibility in the manufacturing process.
The old focus on using automation simply to increase productivity and reduce costs was seen to be short-sighted, because it is also necessary to provide a skilled workforce who can make repairs and manage the machinery. Moreover, the initial costs of automation were high and often could not be recovered by the time entirely new manufacturing processes replaced the old. (Japan's "robot junkyards" were once world famous in the manufacturing industry.)
Automation is now often applied primarily to increase quality in the manufacturing process, where automation can increase quality substantially. For example, automobile and truck pistons used to be installed into engines manually. This is rapidly being transitioned to automated machine installation, because the error rate for manual installment was around 1-1.5%, but has been reduced to 0.00001% with automation. Hazardous operations, such as oil refining, the manufacturing of industrial chemicals, and all forms of metal working, were always early contenders for automation.
Another major shift in automation is the increased emphasis on flexibility and convertibility in the manufacturing process. Manufacturers are increasingly demanding the ability to easily switch from manufacturing Product A to

manufacturing Product B without having to completely rebuild the production lines.

Safety issues of automation

One safety issue with automation is that while it is often viewed as a way to *minimize* human error in a system, *increasing the degree and levels of automation also increases the consequences of error.* For example, The Three Mile Island nuclear event was largely due to over-reliance on "automated safety" systems. Unfortunately, in the event, the designers had never anticipated the actual failure mode which occurred, so both the "automated safety" systems and their human overseers were innundated with vast amounts of largely irrelevant information. With automation we have machines designed by (fallible) people with high levels of expertise, which operate at speeds well beyond human ability to react, being operated by people with relatively more limited education (or other failings, as in the Bhopal disaster or Chernobyl disaster). Ultimately, with increasing levels of automation over ever larger domains of activities, when something goes wrong the consequences rapidly approach the catastrophic. This is true for all complex systems however, and one of the major goals of safety engineering for nuclear reactors, for example, is to make safety mechanisms as simple and as foolproof as possible.

Automation Tools

Different types of automation tools:

- Simulation
- DCS - Distributed Control System
- PLC - Programmable Logic Controller
- PAC - Programmable automation controller
- ANN - Artificial neural network
- HMI - Human Machine Interface
- SCADA - Supervisory Control and Data Acquisition
- MES - Manufacturing Execution System
- LIMS - Laboratory Information Management System

Exercises

Answer the following questions on the text

1. What is the purpose of Automation?
2. Why is Automation so important in our daily life?
3. Why can't robots replace humans?
4. What are the main forms of Automaiton?
5. Where does the term 'luddite' come from and who can it be applied to nowadays?
6. What is characteristic of the modern world automation?
7. What negative impact does Automation have on employment?
8. Which way did the emphasis in Automation shift in the modern world?
9. Why can Automation, which is designed to serves safety purposes, lead to disasters?
10. How can engineers make Automation serve safety purposes?

Fill in the missing words:

1.When introduced automation caused ___________ fear.

2. There is no device that can be equal to the human eye in accuracy and _________.

3.Test Automation is one of the forms of Automation _________

computers.

4. Millions of human telephone operators and answerers, ________ the world, have been replaced wholly.

5. Increasing quality in the manufacturing process is the goal Automation is now applied ________ to.

throughout widespread involving primarily precision

Match part A with part B

A	B
ubiquitous	distinguish
dire	precision
permit (v)	achieve
vulnerable	stationary engineers
envision	influence
handicapped	disabled
service personnel	defenceless
accuracy	allow
identify	terrible
accomplish	general
impact	imagine

Discussion:

Form two groups , one of which expresses advantages of Automation and the other has opposite views. Try to bring your opponents round to your point of view. Support your arguments with examples.

Additional reading

Read the text and give a written summary of it.

Joined-up thinking

Social-networking sites are not just for teenagers. They have business uses too.

The most avid users of social-networking websites may be exhibitionist teenagers, but when it comes to more grown-up use by business people, such sites have a surprisingly long pedigree. Linked - In, an online network for professionals that signed up its ten-millionth user this week, was launched in 2003,a few months before My Space, the biggest of the social sites. Consumer adoption of social networking has grabbed most attention since then. But interest in the business uses of the technology is rising.

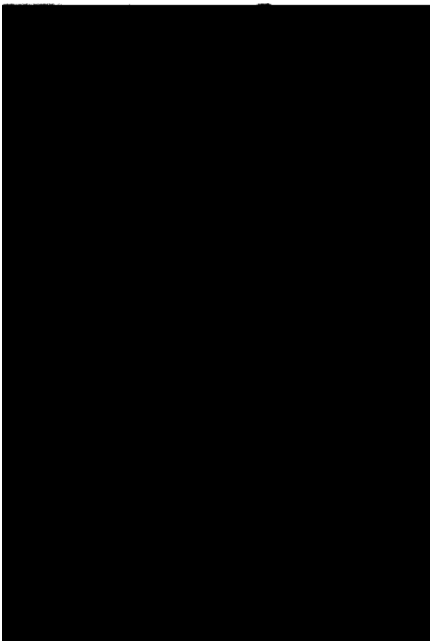
Many companies are attracted by the marketing opportunities offered by community sites. But the results can be painful. Pizza Hut has a profile on My Space devoted to a pizza-delivery driver called Ted, who helpfully lets friends in on the chain's latest promotional offers ("Dude, I just heard some scoop from the Hut," ran one recent post). Wal-Mart started up and rapidly closed down a much-derided teenage site called The Hub last year. Reuters hopes to do better with its forthcoming site for those in the financial-services industry. Social networking has proved to be of greatest value to companies in recruitment. Unlike a simple jobs board, social networks enable members to pass suitable vacancies on to people they know, and to offer potential candidates back to the recruiter. So employers reach not only active jobseekers but also a much larger pool of passive candidates through referrals. Linked - In has over 350 corporate customers which pay up to $250 000 each to advertise jobs to its expanding network. Having lots of people in a network increases its value in a "super-linear" fashion, says Reid Hoffman, Linked - ln's founder. He says corporate use of his service is now spreading beyond recruiters: hedge funds use it to identify and contact experts, for example.

Jobster, a Seattle-based social-networking site, is entirely devoted to recruitment. Jobseekers can post their own profiles and tag their skills; these tags are then used to match candidates against jobs posted by employers. Unlike on Linked In, companies can set up private networks to ensure that the right kinds of people are alerted to openings and that the data they post remain under their control. Information needs to stay behind when a user leaves the company, argues Jason Goldberg, Jobster's founder.

Where Linked In emphasizes scale and Jobster emphasizes specialization, Visible Path, a start-up based in New York, focuses on the strength of individual relationships. The firm analyses e-mail traffic, calendars and diary entries to identify the strongest relationships that exist inside and outside a company. An obvious application is to generate leads: a salesman can use the service to identify who within his network has the closest links to a prospect, and request an introduction.

Such techniques are also gathering momentum in "knowledge management". IBM recently unveiled a social-software platform called Lotus Connections, due out in the next few weeks, that lets company employees post detailed profiles of themselves, team up on projects and share bookmarks. One manufacturer testing the software is using it to put inexperienced members of its customer-services team in touch with the right engineers. It can also be used to identify in-house experts. Software firms will probably start bundling social features of this kind into all sorts of business software.

To work well in the business world, social networking has to clear some big hurdles. Incentives to participate in a network have to be symmetrical, for one thing. The interests of My Space members-and of jobseekers and employers-may be aligned, but it is not clear why commission-hungry salespeople would want to share their best leads with colleagues. Limiting the size of the network can reduce its value for companies, yet confidentiality is another obvious concern for companies that invite outsiders into their online communities. "Social networking sounds great in theory, but the business benefits are still unproven," says Paul Jackson of Forrester, a consultancy. But if who you know really does matter more than what you know, it has obvious potential.



The Economist, April 7th, 2007

Unit 2

Automation Control Systems

General descriptions:

WCB process equipment and systems can be supplied with a control system designed for virtually any level of automation, flexibility, sophistication and complexity. Even a "manual" system normally includes a limited amount of automatic operation (e.g. critical interlocks, recorders and discrete controllers.) The following comparison contrasts the major differences between the two control Concepts.

Manual (Semi Automatic) System Features:

- Based on buttons, switches, relays and individual indicators and controllers. Individual instruments may be microprocessor based.
- Utilizes process recorders for record generation.
- Minimal display of process parameters on control panel. Other parameters measured by gauges mounted in the process piping and equipment. Operator must interpret switch positions and other data to determine operation status.
- Operator initiates each individual sequence step and must do so in the correct order. Operator must be present to initiate most actions.
- Operator must set and verify flowpath for each function.
- Automatic timing and interlocks only for critical functions and sequences.
- Alarms for critical functions only. No automatic response/recovery.
- Individual process controllers. Interaction between controllers requires wiring. Advanced control schemes difficult to implement.
- Operator must be trustworthy and dependable as actions are not recorded or verified by the control system.
- Maintenance is normally limited to calibrating and troubleshooting hardware. Minimal interlock and alarm logic simplifies troubleshooting control system.
- Replacement components may be more readily available from various sources.
- Difficult to make changes due to hard-wired logic.

Fully Automatic System Features:

- Based on programmable microprocessors (PLC/ DCS/PC) and screen based operator interfaces (OIT's).
- Data logging and electronic records available. OIT can display information in graphical as well as numerical format. Displays can include system flow diagram with parameters, alarm history, equipment tuning, recipes, manual overrides, system status, etc.
- One button start/stop for normal operation. Control system runs the process sequences after initial operator command. Control system automatically responds to events such as running out of product.
- Control system automatically sets equipment for correct flowpath.
- Automatic timing and interlocks for all desired functions and sequences. Automatic alarm/fault response/recovery available.
- Extensive alarms, fault correction and troubleshooting information available.
- Process control integrated into programmable microprocessor. Advanced control (e.g., cascade, feed-forward) is easily implemented.
- Operator must be more technically sophisticated or have support that is more knowledgeable. Lack of hands on operation results in need for more in-depth understanding of process, equipment and control system.
- Less components to maintain and calibrate. System may be more difficult to trouble shoot due to the complexity of the control logic.
- Some components may require replacement with identical part. Availability may be limited.
- May be easily changed by someone familiar with process, programming language and programming style.

troubleshooting – диагностика
supplied with - снабженный
virtually - практически
sophistication - утонченность
interlocks – блокировка
gauges - индикатор, шкала
mount - монтировать
initiates – запускать, включать
sequence - последовательность
flowpath – направление потока

recovery - восстановление
wiring – проводка, монтаж
implement - внедрять
verify – контролировать, проверять
due to – благодаря, вследствие, в результате
interface – граница раздела
data logging – регистрация данных
tuning – регулировка, изменение конфигурации
manual override – ручная замена
extensive - обширный
maintain – поддерживать, соблюдать
familiar - привычный, хорошо знакомый

Exercises

Find English equivalents to the following phrases:

оснащенный системой контроля практического для любого уровня автоматизации; контроллер, имеющий кнопки управления, реле и индивидуальные индикаторы; минимум параметров на панели контроля; определять статус операции: сложность в применении более передовых схем контроля; оператор должен быть очень опытным и надежным; обладающий только калибровочным и диагностическим оборудованием.

Supply the following sentences with the linking devices: although, despite, whereas, however, so.

1. Semi-automatic systems include a limited amount of automatic operations, _______ fully automatic systems have control system which runs the process sequence after initial operator command.
2. _________ there are fewer components to maintain, the operator must be more technically sophisticated.
3. ________minor disadvantages, fully automatic systems are more reliable.
4. A semi – automatic system doesn’t have as many functions as a fully – automatic one, ________, replacement components for it may be more readily available from various sources.
5. A semi – automatic system is based on wire – connections, ____ it’s much more difficult to make changes on it.

True or false statements.
Put a tick √ next to a correct statement.

1. Fully – automatic systems require more components to maintain.
2. Minimal interlock and alarm logic in semi – automatic systems simplify troubleshooting control system.
3. Fault correction and troubleshooting information is available in semi – automatic systems.
4. Only a fully – automated system responds to events such as running out of product.
5. In fully automated systems there is need for more in-depth understanding of process, equipment and control system.

Additional reading

Fuel for friendship
America and its neighbors discover a common interest

As a pilot and the owner of an air-taxi service in Brazil's grain belt, Joel Rosado spends a lot of time thinking about fuel. So when the price of oil began rising a few years back, he ordered a new crop duster designed to run on ethanol instead of petrol. He found that the fuel bill for the new plane was a third that of each of his other nine, and so has decided to convert those to run on ethanol too. Brazilian divers learned a similar lesson long ago: 77% of new cars can run on ethanol, which accounts for half of all transport fuel consumed in the country. "At this rate," says Antonio Galvao, another pilot, who owns four ethanol-fuelled planes, "the gasoline engine is heading for extinction."

George Bush has also spent a lot of time thinking about fuel recently. Earlier this year he called for America to cut its projected petrol consumption by 20% over the next decade, largely by using more ethanol and other biofuels. Mr. Bush implied that most of the 35 billion gallons (i3o billion litres) required would be home-grown. At any rate, he has not tried to remove the 54cent tariff America levies on most imported ethanol in deference to its powerful farming lobby. Nonetheless, on March 8th Mr. Bush and Luiz Inacio Lula da Silva, Brazil's president is expected to strike a deal intended to boost biofuels. "Ethanol diplomacy" will be a focus of Mr. Bush's Latin American tour.

Firms around the world are trying to make biofuel out of everything from trees to cooking oil. To make ethanol from corn or wheat, as Americans and Europeans tend to do, distillers must first convert the starch in those crops into sugars. But Brazilian distillers dispense with this expensive step, as they use sugarcane as a feedstock. So Brazil can produce ethanol for 22 cents a litre, compared with 30 cents a litre for corn-based ethanol, according to 'cone, a Brazilian think-tank. That makes it cheaper than petrol, and therefore lucrative for farmers without subsidies.

For the past three decades, sugarcane plantations have been spreading north and west across Brazil's hinterlands, replacing coffee, citrus and pasture. Investors are planning to spend some $12.2 billion on 77 new ethanol plants over the next five years, as well as $2.4 billion to expand existing ones. By 2012, a total of 412 distilleries will be churning out 9.5 billion gallons of ethanol. Ultimately, Brazil would like to see ethanol traded as freely and widely as oil. In that case, it could potentially boost exports from the current 3 billion litres to as much as 200 billion litres by 2025, according to a study commissioned by the Ministry of Science and Technology. That would be enough to replace one-tenth of the world's petrol consumption.

Brazil is not the only country in Latin America that sees great promise in ethanol. Colombia now has five distilleries amid the sugarcane fields of the Cauca Valley, which produce 360m litres a year. Two more are under construction elsewhere. These producers are guaranteed a market, since regulations oblige fuel merchants to mix ethanol into petrol. By 2009the required blend will be10% ethanol and will gradually rise to 25% thereafter. Costa Rica has a similar policy, and Panama is contemplating one.

Indeed, since sugarcane is grown throughout the region, most Latin American countries could benefit. A recent study from the Inter-American Development Bank argued that replacing10% of Mexico's petrol consumption with locally refined ethanol would save $2 billion a year and create 400,000 jobs. Several Caribbean governments hope that the ethanol boom could help revive their ailing sugarcane farms.

The greatest lure would be access to the American market. Various Central American, Caribbean and Andean countries can already send ethanol to America tariff-free, thanks to concessionary trade agreements. Maple, an American energy investment group, plans to spend $i2om on an ethanol plant in Peru to take advantage of such a waiver. A pipeline running out into the nearby Pacific Ocean will deliver the plants output directly to tankers bound for America. Proponents of the project say it will create 3,200 jobs. If all goes well, exports could reach 120m litres a year by 2010, and perhaps as much as 400m in the more distant future.

The United States, for its part, has several reasons to encourage ethanol production in Latin America. For one thing, it will need seven times more of the stuff than it currently produces to meet Mr. Bush's 35 billion-gallon target. There simply is not enough spare land in America to grow adequate feedstock for such an amount, unless scientists find a way to make ethanol cheaply from abundant materials such as wood or grass. Although Mr. Bush's ultimate goal is energy independence, he would presumably prefer to be dependent on ethanol from friendly countries such as Brazil and Colombia than on oil from hostile places like Iran and Venezuela.

An ethanol boom in Latin America would also attract investment to rural areas and create lots of jobs. That might help to reduce the steady northward stream of illegal immigrants. It would certainly burnish America's image, and stem support for anti-American tub-thumpers such as Venezuela's Hugo Chavez. He has won friends throughout the region by selling oil cheaply. By sharing technology and promoting investment in ethanol, America would also be reducing Latin America's fuel bill. If it bought lots of ethanol from its neighbors, it would be providing them with a lucrative export of their own.

Mr. Bush's brother, Jeb, likes the idea. In December, just before stepping down as governor of Florida, he helped to set up a group called the Interamerican Ethanol Commission to promote ethanol in the region. He had written earlier to the president urging him to devise "a comprehensive ethanol strategy for our country and our hemisphere". The deal between Mr. Bush and Lula is even more ambitious, covering the world. It might prompt people to think a little harder about ethanol.

The Economist

Unit 3

Motion Control & Robotics

This unit will give you a basic understanding of how motion control and robotics can be used in applications

Introduction

Motion control is using power to control the movement of a mechanical system. Most motion control is now performed using electric motors, so that will be our primary focus.
Motors can be AC or DC, rotary or linear. Motion control can be as simple as applying power to the motor to using complex motion controllers for multi-axis contouring. Most of the motion control that we see falls into one of several categories

1. On / off control – quick and easy to implement.
2. Steppers – small and inexpensive, good positioning for small loads
3. Inverters / Variable speed drives – for controlling larger loads
4. Servos – expensive, very good positioning, fast acceleration
5. Multi-axis, 2D or 3D control, including CNC and robotics

There are typically three uses for motion control:

1. Positioning
2. Speed control
3. Torque control

Methods of Motion Control

Simple On / Off Control

Simple on / off control is the easiest type of motion control. For electric motors you have some sort of relay (starter) that simply applies power to the motor. Note you must also have fuses or circuit breakers, overload protection, and other safety mechanisms. We typically install some sort of feedback to indicate that the motor is actually running. For example a sensor will be placed on a conveyor to sense motion and provide confirmation to the system that the conveyor is in fact moving.
Feedback in automation systems is always a good idea. For example, suppose you have a machine dumping 20 parts per minute onto a moving conveyor. If the conveyor motor would fail then you have 20 parts per minute being dumped on top of each other (onto the floor, etc.).
I would also put reversing motors in this simple category. For example, a lift that goes up or down based on two inputs.
Let’s not forget that simple motion control can be performed with pneumatics (air powered). For a lot of simple movements, very large machines can be built based entirely on pneumatic cylinders. This reduces the total cost significantly.

Stepper Motors

Stepper motors are small motors where the magnetic field is rotated in small steps in order to make the motor rotate. A stepper motor usually requires a controller and a drive. The controller reads commands such as Acceleration 20 revolutions per second squared, Velocity 10 revolutions per second, Distance 2.3 inches, GO, and automatically generates the move profile that ramps the speed up to 10 RPS at an acceleration of 20 RPSS, maintains the 10 RPS speed and then decelerates the motor. Stepper motors and controllers are one of the least expensive ways to get accurate positioning but stepper motors only handle small loads. Contrary to what some people tell you, you can have encoders on stepping motors to reduce the effects of motor slip.

Inverters and Variable Speed Drives

This type of motion control is usually used for larger motors where the speed of the motor needs to be controlled. There are several ways to control the speed – varying voltage or frequency, vector, etc. From a programmer's view we are setting velocity, acceleration, and distance. Inverters and variable speed drives typically cost less than a servo system but do not offer the preciseness of control. Inverters are typically solid state.

Low-end inverters are becoming so inexpensive that it is starting to justify using them for even simple on / off control. Another advantage of using inverters / variable speed drives is the feedback that you get. The drive will tell you the voltage, current, and other data about the application. So not only are you getting control but monitoring capabilities as well.

Servo Motors

Servo motors have more torque and capabilities than stepping motors but also cost about twice as much as stepping motors. Years ago, servo motors were difficult to work with because you had to tune the motors and controllers. Most servo controllers now automatically tune the motors and their controller. It is important to tune motors after the load is attached so that the controller can see the effects of the load on the system. Servo motors are know as very accurate, fast, high torque, precise control.

CNC (Computer Numerically Control) is a multi servo axes system where they use a special G code language. The G code helps to make all controllers run the same program, although it usually is not that simple. Mechanical designers, with practice, can generate parts in AutoCAD, or similar software, run a program that generates G code, download it to the CNC controller, load metal stock into the machine, press the start button, and the machine will make the part.

Robotics

Robots are typically multi-axis servomotors with one controller that coordinates all of the axes. The robot controller also simplifies the programming by providing most of the calculations transparently. For example, you might tell the gripper to go from a certain point and orientation to another point and orientation. Determining the position of each axis takes a considerable amount of calculations, which the robot controller does transparently.

Robots are the most expensive form of motion control. However, robots are the most flexible and perform the most complex control. The robot controller simplifies that coordinated control. Therefore robots are typically reserved for special applications where maximum flexibility, 3 dimensional movement is required. Although expensive, in complex applications robots will save you money.

Motion Control Miscellaneous

Feedback

Note that motion systems do not behave exactly as you expect. For example, you can set up a motor and pump and then check what the flow rate is out of the pump. Let’s say it is 10 gallons per minute. You could then develop a control system to fill 55 gallon drums that turns on the motor (and pump) for 5.5 seconds to give you 55 gallons. What you will find in practice is that the voltage, frequency, viscosity, and other factors are all varying. So your accuracy for this example may only be +/– 20 percent. Your customers will not be happy with this large of a variance.

Therefore, for systems where accuracy is required some type of feedback is used. For example, if you are using a motor to drive a pump then you usually use a flow meter to tell you how much (total gallons) you have pumped and how fast you are pumping (gallons per minute). If you are using motion to move some distance then an encoder is required to tell you exactly how far you have moved and at what velocity you are moving. There are other types of feedback that control the motor such as pressure, temperature, etc.

If there is no feedback, the system is referred to as “open loop”. If there is feedback then the system is referred to as “closed loop”. There are several ways to achieve close loop control. The most common / best way is called PID (Proportional Integral Derivate) control. PID control gets rather complicated to explain so I'll let you research PID control strategies in other places. However, let me say that watching a second order PID controller operate is a thing of beauty.

Motor Protection & Safety

There are many things you must worry about with controlling electric motors:

1. Incoming power voltage fluctuations
2. Incoming power frequency fluctuations
3. Loss of just one or two phases of three phase power
4. Incoming surges and transients
5. Output short circuit
6. Output ground fault
7. Over temperature
8. Overload
9. Avoiding certain speeds / frequencies
10. Braking / stopping / holding torque

In most applications you have circuitry such as fuses or a circuit breaker, motor starter, and a motor overload. Safety circuits usually include an E-Stop (emergency stop) button or rope pull switch. Most motion controllers monitor voltage and current on each winding of the motor to detect problems and shutdown the system.

Feedback is also a good method for protecting the system. For example if you know that running a motor at 50% should generate a speed of 1000 rpm and the speed is significantly less than that, then you know that something is wrong and can shut down the system (or sound an alarm) for inspection.

Motors, especially variable speed drives, generate a tremendous amount of noise back onto the incoming AC power lines. Therefore, filters, reactors, or isolation transformers (or some combination of these three) are usually placed in series with all phases of the incoming AC power. Filters are the best but typically cost as much or more than the drive. Reactors are not as good but typically cost a fraction of filters. Using reactors or filters with variable speed drives is important since these disturbances can wreck havoc on the motion control system and other systems on the same power supply. We prefer to use reactors in-line with variable speed drives and use isolation transformers on the power for the control system.

If there is a long distance between the drive and motor then you may want reactors on the output side of the drive as well. Drives and motors can get very hot so make sure you provide adequate cooling.

Profiles

Normally you don’t just start a motor at 100%. You try to ramp the speed up over some time (for example 10 seconds). This reduces the wear and tear on the system. Other times you want to initially ramp the system up to some setpoint, run for a period of time, and then let the automatic control system take over. For example, if you start pumping into an empty pipe or system that will eventually fill and start to pressurize. In this case you may want to ramp up from 0 to 50%, wait until the pressure reaches 10 PSI, and then switch to automatic PID control. This initial ramp and hold eliminates wild fluctuations in the PID controller from ramping up to 100%, and then upon seeing flow, shutting down to near 0%, then ramping up, shutting down, etc.

Other profiles may want to take the position or speed through several different set points.

primary focus – главный фокус
rotary – вращательный
linear – линейный, прямолинейный
multi-axis – имеющий много осей вращения
load - груз, загрузка
acceleration - ускорение
torque – вращательный момент
fuse – плавкий предохранитель
circuit breaker - рубильник
feedback – обратная связь
confirmation - подтверждение
dump - сваливать
entirely – полностью, совершенно
significantly - многозначительно
ramp - быстрое изменение
fraction - доля
slip - ошибка
velocity - скорость
solid – твердый, сплошной
justify - выравнивать
capability – возможность, способность
servo motors – сервопривод, сервомотор
stock – комплект, комплектовать
provide - обеспечивать

transparently – очевидно, ясно
gripper – захват, зажим
drum – барабан, полый цилиндр
viscosity - вязкость
open loop – разомкнутый контур
surge – скачек напряжения
transient - переходное состояние, неустойчивое состояние
disturbance - нарушение
profile - параметры пользователя
wreck havoc – поломка, приводящая к разрушению
eliminate - устранять
fluctuation - колебание

Exercises

Put the word in brackets into a correct form to make the sentence sensible.

1. For electric motors you have some sort of relay (starter) that simply (application) ________ power to the motor.

2. For a lot of simple movements' pneumatic cylinders (reduction) ________ the total cost significantly.

3. Stepper motors are small motors where the magnetic field is (rotor)_______ in small steps.

4. It is important to tune motors after the load is (attachment) _________ so that the controller can see the effects of the load on the system.

5. (Vary) _________ speed drives, generate a tremendous amount of noise back onto the incoming AC power lines.

6. If you start pumping into an empty pipe or system that will eventually fill and start to (press) _________.

7. Using reactors or filters with variable speed drives is important since these (disturb) _________ can wreck havoc on the motion control system.

8. Reactors are not as good but (type) ________ cost a fraction of filters.

Find appropriate endings for the following sentences:

1. If there is a long distance between the drive and motor ….
2. If you are using a motor to drive a pump …..
3. Robots are the most expensive form of motion control,
4. Motors, especially variable speed drives…
5. What you will find in practice …….
6. There are other types of feedback ……
7. Filters are the best ….
8. Most motion controllers monitor voltage and current on each winding of the motor…

a. … but typically cost as much or more than the drive.
b. … that control the motor such as pressure, temperature, etc.
c. …to detect problems and shutdown the system.
d. …then you may want reactors on the output side of the drive as well.
e. …is that the voltage, frequency, viscosity, and other factors are all varying.
f...generate a tremendous amount of noise back onto the incoming AC power lines.
g. … then you usually use a flow meter.
h. …however, they are the most flexible and perform the most complex control.

Find 'if – clauses' in the text and define what type of conditional clauses they belong to.

Additional reading

Face value

Rocket Man Elon Musk is part playboy, part space cowboy

It is midnight at the Playboy mansion and Elon Musk is in the cigar alcove with a couple of friends, holding forth. His vantage point gives him panoramic views of the goings-on at the party and easy access to the poolside bunnywalks. He seems like just another wealthy playboy. After all, when he is not partying with Playmates, Mr Musk likes to entertain in style at his pricey Bel Air home and speed around Los Angeles in his million-dollar McLaren racer.

But Mr Musk has no sense of occasion. He is talking expansively about saving the planet and conquering space. Moreover, unlike other silicon Valley "thrillionaires" who throw money earned in the internet boom into voguish new hobbies, he is proving to be just as original in his thinking about his new pursuits as he was about his old ones.

On March loth the Falcon, a two-stage rocket owned by Mr Musk's Space Exploration Technologies (Spacex), lifted off from the Marshall Islands and climbed to an altitude of some goo miles. Although the second stage failed to reach its intended orbit, the Falcon can claim to be the first rocket designed, developed and financed by the private sector that is anywhere near carrying a payload into space. Mr Musk founded spacex five years ago and designed much of the rocket himself.

Though he is only 35, Mr Musk has already made surprising progress toward the three modest goals he set for himself when at college: to transform the internet, make a breakthrough in clean energy and propel mankind towards interplanetary travel. He arrived at Stanford University intending to do a doctorate on batteries for electric cars, but dropped out to jump on the internet bandwagon. He struck gold when he sold PayPal, the online payments firm, to eBay for $1.5 billion in 2002. Rather than retire comfortably, he says he "doubled down" his proceeds into his two other passions: clean energy and space.

The first bet was Tesla Motors, an electric-car company that is the first new American automobile firm in decades. Many consumers associate electric cars with golf carts and fear they will have only limited range; the motor industry refused to make them after a failed effort in the 1990s. Mr Musk may prove the nay-sayers wrong. In July Tesla unveiled its first model: a sports car which is faster than a Ferrari, more environmentally friendly than a Toyota Prius and can travel 250 miles after charging overnight through an ordinary household socket. The first few have been pre-sold, but the concept will be properly tested only when they start rolling off the production line in August.

Taking on Detroit hardly counts as easy-except if you compare it with conquering space. Giant defence contractors close to the Pentagon and wasa, America's space agency, have long dominated the business of launching satellites. "Launch vehicles today are little changed from those of 40 years ago," Mr Musk complained during a recent tour of his manufacturing facilities near Los Angeles airport. So he set about redesigning rockets from the bottom up.

Just near the entrance of a "clean room" on his shop floor, there is a large display of mechanical parts, engine components and other tired-looking bits and bobs. "That's all the stuff that didn't work," he explains. The display highlights one of Spacex's strengths: a culture of experimentation. His firm is stocked with experts poached from Northrop Grumman, Boeing and other aerospace giants. "These guys used to get frustrated at the old bureaucracies," he says. "Here, it's more Google-ish."

Breaking the space oligopoly

Because it was designed from scratch, the Falcon is much simpler than most rockets and thus free of some of the risks and costs of complexity. The version launched this week cost under $gym: Spacex's competitors charge four or more times that for a launch. If Mr Musk's rockets can be recovered and recycled (he has designed them to be "used over and over like jet engines"), then the cost would fall even further.

In time, he believes his rockets will costs a tenth as much as his competitors' while lifting payloads much larger than they can. That matters, because the really big money is in the market for launching heavy payloads. But Mr Musk alleges that the industry has unfairly tried to keep him out. When the American air force recently awarded some two dozen future rocket launches to a consortium formed by Boeing and Lockheed Martin, the sector's dominant firms, Spacex cried foul. It has sued them on the ground that they are colluding to keep low-cost competitors out-a charge both firms deny. Spacex lost the initial case, but is appealing.

Entrenched incumbents are the least of Spacex's problems. Mr Musk may fail simply because rocket science is, well, rocket science. He compares designing one to writing computer code that can be tested only in parts and which, when run for the first time, must be perfectly bug-free. The Falcon's first test a year ago ended in tears when a fuel leak after launch destroyed the rocket. Mr Musk sees this week's glitch as less serious. The launch, he says, "retired almost all of the significant development risk", in that both lift-off and the separation of the two stages went smoothly. That has greatly encouraged the customers waiting for Spacex to launch their satellites, including an arm of the Pentagon and the Malaysian government.

Falcon's progress has convinced Mr Mush that his dream of interplanetary travel may yet come true. "If normal humans ever travel beyond Earth, it will be because of Spacex or companies like it," he says. He reckons Mars is amenable to civilisation, and ought to be colonised as a "life-insurance policy" that guarantees the continuity of humanity. When mankind eventually gets to the red planet, the cars people will drive, Mr Musk fully expects, will be made by Tesla Motors.

The Economist,

Unit 4

Safety Information

Definition of qualified personnel

Qualified personnel are those who are familiar with the installation, mounting, start-up and operation of the equipment and the hazards involved. He or she must have the following qualifications:

- Trained and authorized to energize, de-energize, ground and tag circuits and equipment in accordance with established safety procedures.
- Trained in the proper care and use of protective equipment in accordance with established safety procedures.
- Trained in rendering first aid.

Caution

- SIMODRIVE units with motor spindles are subject to a voltage test corresponding to EN 50178 as part of the routine test. While the electrical equipment of industrial machines is being subject to a voltage test in accordance with EN 60204 –1, Section 19.4, all SIMODRIVE unit connections must be disconnected/withdrawn in order to avoid damaging the SIMODRIVE drive units.
- It is not permissible to directly connect the motor spindles to the three-phase line supply as this will destroy the motor spindles.

Electrostatic Discharge Sensitive devices (ESDS) are individual components, integrated circuits or boards which, when handled, tested or transported, could be destroyed by electrostatic fields of electrostatic discharge.

Handling ESDS boards:

- When handling components which can be destroyed by electrostatic discharge, it must be ensured that personnel, the workstation and packaging are well grounded!
- Electronic boards may only be touched by personnel in ESDS areas with conductive flooring if
  - they are grounded through ESDS bracelet
  - they are wearing ESDS shoes or ESDS shoe grounding strips.

Electronic boards should only be touched when absolutely necessary.

Electronic boards will not be brought into contact with plastics and articles of clothing manufactured from man-made fibers.

Electronic boards may only be placed on conductive surfaces (desk with ESDS surface, conductive ESDS foam rubber, ESDS packing bag, ESDS transport containers).
Electronic boards may not be brought close to data terminals, monitors or television sets. (Minimum clearance
10 >cm).
Measuring work may only be carried out on the electronic boards, if

- the measuring unit is grounded (e.g. via a protective conductor) or
- for floating measuring equipment, the probe is briefly discharged before making measurements (e.g. a bare-metal control housing is touched).

Products from third-party manufacturers

The products from third-party manufacturers described in this document are products which we know to be essentially suitable. It goes without saying that similar products from other manufacturers can also be used.
Our recommendations should be considered as such. We cannot accept any liability for the quality and properties/features of third-party products.

Protection against potentially hazardous motion

Depending on the operating mode (e.g. setting-up, production) of the machine, motor spindles, just like feed drives, represent a specific, potential hazard. This must be taken into account when designing and engineering the machine.
The protective goals of the EEC Machinery Directive must be fulfilled by applying suitable protective measures. It is important that the machine is correctly used. In order to implement these protective goals, in addition to being knowledgeable about the applicable standards and Directives, it is also necessary to carefully observe the information and instructions concerning the Machine designer and the company operating the machine.
The designer must carry out a risk analysis, draw-up a safety concept, provide the necessary safety equipment on the machine, instruct the operating company about the “correct use” of the machine and spindle.
The Company operating the machine should inform or train employees about the “correct use” of the spindle and the application of the safety functions and how they work.
The potentially hazardous motion for the motor spindle is when the maximum permissible speed for the spindle and/or the tool is exceeded.

Speed monitoring

When using a tool spindle, the machinery construction company is always responsible in applying measures to detect and prevent speeds which are not permissible and the ensuing effects. The machinery construction company is also responsible in instructing and training the company operation the machine about the various measures which have been applied.

When an inadmissible speed occurs, then the spindle must be shut down and stopped. In this case, the limit value is interpreted as that value where the maximum permissible speed is exceeded. This limit value depends on the following factors:

- Operating state (setting-up or automatic mode)
- Tool which is currently being used
- Maximum permissible spindle speed.

In order to prevent the speed being exceeded, some safety measures have to be taken: monitoring the spindle speed, activation tool-specific limit values, monitoring operational and cutting parameters as well as monitoring the tool condition. To control the effect when the speed is exceeded, it's necessary to provide machine panels, which can withstand the maximum impact of pieces which are thrown off at the maximum energy that can be assumed. Another important feature is ensuring that these machine panels can only be opened at a defined low spindle speed. There also should be automatic shutdown and stopping when fault or error occurs.

Future – oriented strategies, which are applied to limit risks, distinguish themselves by the fact that they are measures which are practical and safe and which are designed to avoid faults and errors. This means that the machinery construction company has a certain degree of flexibility inappropriately reducing the costs involved to control faults and errors.

Safety Integrated as a measure to avoid faults

Safety Integrated is an efficient measure, which is optionally available at the fault prevention level. It can be used to monitor the drive functions.

The basic Safety Integrated principle is based on a two-channel monitoring function. This means that the requirements from the EEC Machinery Directive can be simply and cost-effectively fulfilled.

Example of Safety Integrated:

The maximum energy of broken tool pieces, flung-out, can be safely limited using Safely Integrated by activating the tool specific- limit value. This means that the costs and resources, which would otherwise be incurred for providing the appropriate machine panels with the corresponding strength, can be significantly reduced.

Speed limits

The spindle is designed for a maximum operating speed. This is specified as “maximum speed”. The operating company can use this speed in operation. The **maximum operating speed** is the highest speed, which may be saved in the control system and part programs.

Shutdown speed is the speed limit, where the system is shut down if this value is exceeded.

The machinery construction manufacturer defines this taking into account the secondary conditions and limitations, which apply to the spindle and tool. The shutdown speed should be defined so that shutdown does not occur during the normal operation and, on the other hand, the spindle system and tool are not overloaded due to speed peaks, which are permitted. The spindle must be shutdown if erroneous functions occur and the speed is exceeded. Standard technology of also safety-related technology can be used to monitor the speed.

Control-related speed peaks

The spindle speed is obtained as a result of a control (close-loop) process. Depending on a particular controller setting and the load condition, it oscillates around the programmed set point. When the spindle is operated, it is therefore normal that the spindle shaft assumes speeds which briefly lie above the programmed operating speed. However, even if mechanical critical speeds are even briefly exceeded, this can result in excessive material stressing and in turn damage. This means that tools and spindle systems must be able to withstand normal speed peaks as a result of control operations.

In order to guarantee safety at all of the speeds, permitted in operation, **the speed peaks** must be taken into account when designing the machine (e.g. natural resonance frequency of the spindle holder) and also when selecting the tool. This is the reason why the subjects related to natural resonance and centrifugal force strength do not refer to the speed programmed for normal operation, but always refer to the shutdown speed, which is higher.

Adapting the shutdown speed to various tools

If the maximum speed, permitted for the tool currently being used, lies below the maximum operating speed of the spindle, then the speed monitoring and the shutdown speed must be adapted for the particular tool.

Warning

The shutdown speed may only be set at a maximum of 15% above the maximum operating speed of the spindle. The shutdown speed may not be set higher than permitted maximum speed of the tool.

Exercises

Find different parts of speech for the following words

NOUN	VERB	ADJECTIVE
Caution		
Warning		
Error		
Fault		
Implementation		
Employee, employer, employment		
Application		
Reference		
Existence		
Operation		
Protection		
Permission		
Flexibility		
Liability		
Hazard		

1. The shutdown speed is usually higher then the speed programmed for normal ___________________ (operate).

2. The spindle must be shut down if the ____________________(error) functions occur and the speed is exceeded.
3. This means that the ____________________(require) from EEC Machinery Directive can be simply and cost-efficiently fulfilled.
4. The limit value is interpreted as that value where the maximum ____________(permit) speed is exceeded.
5. Only trained ___________________(employ) can be allowed to deal with the equipment and hazards involved.
6. Special _____________________(protect) measures should be taken to avoid malfunction of the spindle.

Turn the following sentences into Passive.

1. They install new equipment at our plant every year.
2. They train personnel in accordance with safety requirements.
3. They have read this manual three times.
4. The manufacturer and the user seem to have reached an agreement.
5. We require some technical support.
6. One must adapt the speed monitoring and the shutdown speed for the practical tool.
7. They have instructed the personnel about the hazards connected with the dismounting of the equipment.
8. People have to take certain safety measures to ensure normal functioning of the equipment.

Find English equivalents for the following phrases:

Использование защитного оборудования; в соответствии с установленными процедурами безопасности; сборка и установка оборудования; подлежать тесту на соответствие напряжению; избегать повреждения; не допускается прямое подсоединение; электронных плат можно касаться только в случае крайней необходимости; принимать на себя ответственность; потенциальная опасность; тщательно изучить информацию; меры безопасности.

Additional reading

Give a short summary of the text

New MEMS microphones enable thinner phone designs

Micro-Electro-Mechanical Systems (MEMS) technology is radically changing the microphones in cell phone designs. Because MEMS-based microphones are inherently smaller than traditional microphones and can be reflowed with other components, they provide the flexibility needed by engineers who must design smaller, thinner phones today.

As designers continue to integrate new features into sleek new cell phone designs, there continues to be a drive for integrated components and for size reductions of each individual component.

In clamshell or similar types of designs where each half contributes to the overall thickness of the phone, component height is the limiting factor that determines the thickness of the phone. Thin phone designs have proven to be very popular with consumers, as demonstrated by the popularity of recent phone models launched in the market.

One standalone component that is subject to these design pressures is the microphone. In some cell phone designs the microphone is the limiting component that determines the thickness of the design, and requires special modification of the phone case to accommodate the microphone height. Traditional electret condenser microphones (ECMs) have reached the 4x1.5mm size (without acoustic boot) but are approaching the limits of the technology and are unlikely to shrink much further.

The future technology in microphones is MEMS (Micro-Electro-Mechanical Systems). MEMS is a technology that enables the manufacturing of small mechanical components on the surface of a silicon wafer. In the case of a microphone, a back plate and diaphragm are built on the surface of a wafer along with the necessary electrical connections. The diaphragm is then ‘released’ through chemical etching so it can vibrate freely with incoming sound. The changing capacitance of the charged capacitor formed by the back plate and diaphragm transduces sound into an electrical signal.

MEMS microphones take advantage of semiconductor processing and have inherent advantages over ECMs. For example, the MEMS microphone produced by Knowles Acoustics (SiSonic) utilizes a charge pump to produce a constant charge on the diaphragm, resulting in better isolation from power supply noise.

In addition, the MEMS can recover from moisture condensation since the charge on the diaphragm is renewed by the charge pump once the condensation dries. A MEMS microphone is not susceptible to charge decay over the life of the phone or to sensitivity shifts due to supply voltage changes. It is inherently less susceptible to vibration because of the smaller diaphragm mass. MEMS microphones are also perfect candidates for chip-scale packaging since integration with amplifiers, A/D converters, and other IC devices is a relatively straightforward packaging task.

MEMS microphones have two main characteristics that make them particularly suitable for thin phone designs: small size and the ability to withstand reflow temperatures.

One of the most notable differences between a MEMS microphone and an ECM is size. The back plate and diaphragm in a MEMS microphone are approximately 10x smaller than those in the smallest ECM. This inherent small size allows packaged MEMS microphones to start at approximately the same size as the smallest ECMs, with the potential to shrink much further as MEMS microphone technology matures. A smaller microphone consumes less PCB space and requires smaller height allowances, making it ideal for a thin phone designs.

The other main characteristic that distinguishes MEMS microphones is their ability to withstand standard solder reflow temperatures. The ability of microphones to withstand reflow temperatures without impacting performance is so unique that many engineers simply refer to MEMS microphones as ‘reflow mics’ to distinguish them from traditional ECMs. There are obvious manufacturing benefits from using auto pick-and-place tools and solder reflow to install the microphone, but reflow mics also enable a new approach to acoustic path design that make them attractive for thin phone designs.

A typical cell phone design incorporates the primary microphone somewhere near the bottom of the keypad, ideally with the acoustic hole in the front case of the phone near the speaker’s mouth. Since the acoustic path length from the outside world to the microphone must be kept as short as possible to maintain optimum performance, the microphone must be on the front of the PCB near the acoustic hole in the case.

However, in a thin phone design virtually all components need to reside on the back side of the PCB, opposite the keypads. This creates a height issue that is a barrier to creating a thin design. With a MEMS microphone, the mic can be reflowed onto the back side of the phone PCB with other components, while utilizing an acoustic path that goes directly through the PCB to the acoustic hole in the front case of the phone.

To achieve this, the microphone package is designed with an acoustic port hole in the bottom along with the signal solder pads. The mic port hole aligns with a corresponding hole in the PCB, and a solder pad around the port hole provides an acoustic seal between the microphone and the main phone PCB. A simple gasket on the front side of the PCB provides a seal to the phone case, and a hole in the case completes the acoustic path to the outside world. In many designs, the gasket between the PCB and the phone case can be implemented by a simple extension of the rubber seal between the keypads and case.

A short, elegant acoustic path like this allows speech to travel through the phone case, gasket, and PCB and directly into the microphone, while allowing the microphone to reside on the back side of the PCB with the other components. This approach to acoustic path design puts virtually zero height requirements on the front side of the PCB and allows for tighter height tolerances on backside components for thinner overall phone designs.

enable – давать возможность
inherently – в действительности
reflow - менять
electret - электрет
boot - загрузка
shrink - уменьшаться
manufacturing - изготовление
wafer - подложка
etching - травление
capacitance – емкость, емкостное сопротивление
transduce - преобразовывать
take advantage – иметь преимущество
utilize – использовать, употреблять
charge pump – генератор подкачки заряда
power supply - электроснабжение
recover - восстанавливаться
moisture condensation – конденсация влаги
susceptible - восприимчивый
decay - разрушение

sensitivity - чувствительность
chip-scale – размер чипа
amplifier - усилитель
straightforward - простой
withstand - выдержать
notable differences – ощутимые отличия
approximately - приблизительно
distinguish – отличать, характеризовать
solder - припой
impact - оказывать влияние
obvious - очевидный
pick-and-place tools – устройство для установки деталей
attractive - привлекательный
incorporate – включать (в состав)
primary - основной
maintain – поддерживать, сохранять
virtually – фактически, в сущности
reside - находиться
height issue - проблема высоты
achieve - достигать
solder pad – соединительная прокладка
corresponding - соответствующий
seal – уплотняющая прокладка
gasket - прокладка
implement - осуществлять
extension - расширение
rubber seal – резиновая прокладка
tight - компактный
tolerance - допуск
overall – в целом

Unit 5
Function of the Spindle

Applications

The ECO motor is a high-speed directly driven tool spindle for milling and drilling operations.

Features

The ECO motor spindle is integrated into the SIMODRIVE drive system just like the feed and main spindle motors.
The drive motor and the tool interface of the spindle form a mechanical unit, which has a common bearing system. This eliminates all of the generally used mechanical transmission elements, such as belts or toothed couplings. With the ECO spindle, the user has many advantages over conventional spindles with mechanical transmission elements. Further, directly - driven ECO motor spindles are very compact:

- **High speeds** because there are no mechanical transmission elements
- **Smooth running properties** as a result of the stable balancing arrangement
- **Good speed stability,** good closed-loop speed control
- **High accuracy of the closed-loop position control**
- **Lower mechanical design costs,** as all of the functions are integrated
- **Lower weight,** more compact dimensions
- **Essentially compatible to the electrical drive system** as a spindle, drive amplifier and NC are engineered and supplied from a single source.

Functionality overview

The ECO motor spindle is ready to be installed-and the functions, which are required to operate a milling spindle, are already completely integrated in the system. This guarantees perfect interaction of individual function elements and minimizes the mechanical design costs for the machinery construction company.

Drive motor

The ECO motor spindle is driven by an integrated build-in motor with a high torque. The motor rotor is mounted directly on the tool spindle. The electric is only feed to the stationary, outer section of the motor. The inner rotating part of the motor does not require any electric power.

The motor are available both as synchronous and induction motor. When designing the machine, in order to graduate the power requirement, either a long or a short drive package type can be selected.

The motors are available in various speed classes. The induction (asynchronous) motor version is prepared so that the torque can be adapted to the machining situation, for both the star and delta connection type as required

The motors are designed for dynamic load operations and quickly following changing torque requirements. In conjunction with the integrated, precision rotary angle encoder, they are admirably suited for speed and position controlled operation.

Cooling concept

The ECO motor spindle has integrated ducts for the liquid cooling of the stationary drive motor stator. The stator, which draws the electric drive power, represents the main source of power loss of the spindle unit. This is the reason that the cooling duct system is closely and thermally coupled to the drive motor stator. However, even sources of power loss (thermal energy), which are located further away, are sufficiently cooled as a result of the integrated cooling ducts.

The spindle unit should be supplied with the cooling medium through a feed return line. The cooling medium absorbs the power loss of the spindle, which means that the cooling medium temperature appropriately increases. The cooling medium is cooled down to the original intake temperature using an external cooling or heat - exchanger system mounted outside the spindle. This is the responsibility of the machinery construction company. A pump must be used to provide the necessary cooling medium pressure in the intake line. This external pump is also the responsibility of the machinery construction company.

ECO motor spindle have integrated function elements to operate and control the various operations and sequences. The following medium must be provided for the spindle, either through suitable cables or hoses:

- **Electric power** for the **drive motor (**the consumption depends on the power drawn)
- **Cooling liquid** (continuous flow; load depends on the power level)
- **Compressed air** to actuate the tool clamping system (this air is only used when releasing and ejecting the tool)
- **Cone purge air** to clean the tool cone (this air is only used when releasing and ejecting the tool)
- **Sealing air** to protect the bearings from dirt accumulating (this air is continually used)
- **Optional cooling-lubricating medium supply** of the tool (consumption depends on the particular process)
- **Electric** 24V **supply** for the sensors to monitor the tool clamping state (continuous consumption)
- **Power supply** for the **rotary encoder** (for SIMENS drive converters, this is integrated in the encoder interface)

Internal tool cooling using the cooling-lubricating medium (option)

ECO motor spindles are optionally available with an internal tool cooling function. In this case, cooling-lubricating medium is fed through a rotary gland from the rear of the shaft through the spindle to the tool. In order to guarantee the lifetime of this rotary gland, the user (operating company) must appropriately condition the cooling -lubricating mediums.

Exercises

Match English words and expressions with their Russian equivalents.

1. Milling	a. Крутящий момент
2. Drilling	b. Подшипник
3. Tool interface	c. Вращающаяся часть
4. Transmission	d. Охлаждающая среда
5. Amplifier	e. Взаимодействие

6. Install	f. Усилитель
7. Interaction	g.Трансмиссия
8. Internal	h. Устанавливать
9. Tool cooling	i. Потеря мощности
10. Bearing	j. Сверление
11. Torque	k. Фрезерование
12. Inner	l. Насос
13. Rotating part	m. Поверхность инструмента
14. Synchronous motor	n. Охлаждение инструмента
15. Induction motor	o. Система теплообмена
16. Duct	p. Давление
17. Power loss	q. Синхронный мотор
18. Cooling medium	r. Индукционный мотор
19. Heat-exchanger system	s. Впускная линия
20. Pump	t. Канал
21. Pressure	u. Встроенная
22. Intake line	v. Смазочная
23. Lubricating	w. Ответственность
24. Responsibility	x. Внутренняя

One word in each sentence is out of place. Take it away.

1. The ECO motor spindle is driven mounted by an integrated build-in motor with high torque. 2. The motor rotor is mounted installed directly on the tool spindle. 3. The electronic power is only feed toque to the stationary outer section of the motor. 4. The motors are designed available both as synchronous and induction motor. 5. The inner interaction rotating part of the motor does not require any electric power. 6. The ECO motor spindle has integrated duct lines for the liquid cooling of the starter. 7. This is the reason that the cooling medium duct system is closely coupled. 8. This is the responsibility transmission of the machinery construction company. 9. A pump must be used in use to provide necessary cooling medium pressure in the intake line. 10. ECO motor spindle an optional available drilling with an internal tool cooling function.

Additional reading

Read the text and give its main idea.

Model Plane Flies the Atlantic

When Maynard Hill decided he wanted to fly a model airplane across the Atlantic Ocean, no one took him seriously.

TAM-5, the model airplane that crossed the Atlantic Ocean, rests at its landing spot in Ireland.
Ronan Coyne

"To be perfectly honest, most of us thought he was crazy," says Dave Brown, president of the Academy of Model Aeronautics and an old friend of Hill's. "We didn't think it could be done."

Sometimes, daring to be crazy pays off. Last summer, one of Hill's creations became the first model airplane to cross the Atlantic.

Named TAM-5, the 11-pound plane flew 1,888 miles from Canada to Ireland in 38 hours, 53 minutes. It set world records for longest distance and longest time ever flown by a model airplane.

The achievement came at a symbolic time in the history of flight. One hundred years ago, on Dec. 17, 1903, the Wright brothers made the first powered, sustained, and controlled flight in a heavier-than-air flying machine at Kitty Hawk, N.C. Their plane covered a grand distance of 120 feet in about 12 seconds.

TAM-5's route also had historical significance. The model airplane followed the same path as the first nonstop, manned flight across the Atlantic in 1919. And Amelia Earhart left from a nearby spot in Newfoundland when she became the first woman to cross the Atlantic in 1928.

August launch

Hill, who is 77, legally blind, and mostly deaf, began his project 10 years ago. With the help of a support team, he made his first three attempts in August, 2002. He figured August would be the best time to launch because that's the month with fewest storms, and wind conditions are usually favorable.

None of the planes flew more than 500 miles, less than one-third of the way to Ireland. "As we put it," Brown says, "we fed them to the Atlantic." The first plane the team sent up this past summer flew about 700 miles before plunging into the sea.

At about 8 p.m. on Aug. 9, 2003, Hill went for attempt number five. He had traveled from his home in Silver Spring, Md., to Cape Spear, Newfoundland, to toss TAM-5 into the air. Once the plane was airborne, a pilot on the ground used a remote control to steer the plane until it reached a cruising altitude of 300 meters. Then, a computerized autopilot took over.

For the next day and a half, everyone on the crew held his or her breath. "We were very much on pins and needles," says Brown, who went to Ireland to land the plane.

They had plenty of reasons to feel nervous. To qualify for flight records, a model airplane has to weigh less than 11 pounds, including fuel. So, TAM-5 had room to carry just under 3 quarts of gas. This meant that the plane had to get the equivalent of about 3,000 miles per gallon of fuel, Brown says. By comparison, a commercial jet can burn more than 3 gallons of fuel every mile.

The biggest challenge in building the model, Brown says, was figuring out how to make TAM-5's engine efficient enough to cross the ocean. Most model airplanes use alcohol-based fuels. Instead, Hill used Coleman lantern fuel because, he says, it's more pure and performs better. He tweaked a regular model airplane engine to make the valves smaller and more efficient.

The plane also carried an impressive set of electronics. Every hour during the flight, crewmembers were able to get information about the plane's location from a Global Positioning System (GPS) device on board. The GPS device communicated with a satellite orbiting Earth to determine the plane's exact latitude, longitude, and speed.

The route was programmed into the computerized autopilot, which automatically adjusted the plane's direction to stay on course. There was also a transmitter on board that sent signals directly to crewmembers on the ground when the plane was within 70 miles of its launch and landing sites.

Rough spots

Everything went smoothly until about 3 a.m. on the second day of flight. Then, suddenly the GPS unit stopped sending information. Everyone assumed the worst—until data started pouring in again 3 hours later. The satellite had just been busy for a while.

Even then, the model's arrival was never a sure thing. TAM-5's flight plan was programmed to use 2.2 ounces of fuel per hour. Crewmembers estimated that burning fuel at this rate would give the plane between 36 and 37 hours of flying time. They counted on having a good tailwind to push the plane to a cruising speed of about 55 miles per hour. When data came streaming back in at 6 a.m., though, the plane was moving at only 42 miles per hour. Apparently, there was no wind at all.

TAM-5 had already been flying for more than 38 hours when it finally came into view in Ireland. Brown was sure it was running on fumes. "The whole crew had visions of seeing the thing appear on the horizon," Brown says, "then quit and fall in the ocean."

With a remote control, he took over the plane's flight in stages: first steering, then altitude. At a few minutes after 2 p.m. on Aug. 11, TAM-5 landed safely just 88 meters from the chosen spot on Mannin Bay, Galway. Cheers went up among the crowd of 50 or so people who had gathered to watch it land. "It was absolutely euphoric to see it arrive," Brown says.

Brown's wife was on the phone with Hill in Canada at the time. His reaction was even more emotional. "When the plane landed in Ireland," Hill says, "I was so overjoyed I hugged my wife and cried."

Nothing fancy

Amidst the celebration, Brown took the model apart to check how much fuel was left. He found just 1.8 ounces, almost nothing. Later, the team realized that the flight plan had been set to burn 2.01 ounces of fuel per hour instead of 2.2. The plane had wobbled up and down as a result, but the mistake was probably the secret of its success.

While Brown was working, he overheard one boy say to another, "That model isn't very fancy." This was quite true. TAM-5 was made of balsa wood and fiberglass, and it was covered with a plastic film, just like any ordinary model airplane. At 74 inches long and with a 72-inch wingspan, it used the same principles of flight as any other airplane, model or life-sized. "Yeah," the other boy said. "I bet I could build one that good."

The conversation forced Brown to reflect on the importance of TAM-5's record-setting flight. "I realized later that the most important significance wasn't the accomplishment itself but what it will challenge someone else to do," he says. "Perhaps even that kid, or some adult down the road, will build one that's better, or one that goes higher, faster, farther. That kind of challenge is what setting records is all about."

For Hill, the accomplishment holds a lesson in persistence. Keep trying, no matter what kind of handicaps you have, he says.

"Kids can learn that it's often necessary to try and try again to achieve a goal," Hill says. "Don't give up! I have worked on model airplane records for 40 years. This particular goal required 5 years of building and testing—and crashing!"

It's impossible to know what TAM-5's flight will lead to next. If a small model airplane can fly across the ocean, maybe someday jets will be able to carry cargo the same distance without a single human on board, Brown says.

Other consequences may emerge that nobody has dreamed of yet, Brown says. "When the Wright brothers finished their first flight," he says, "if you had asked them what this means for the future, I don't think they would have told you that some day a 747 would fly across the country. They wouldn't have foreseen a flight to the moon."

So, it's onward and upward!

Unit 6
Mechanical Data

The ECO motor spindle allows operating companies to fully utilize the benefits of high-speed machining. At high speeds, the components involved in the machining operation are subject to significant stress levels. This means that the machine must be mechanically designed to withstand the high speeds and the user must harmonize and align the tools and the process conditions to the load capability of the spindle.

Observing the shutdown speed

Even if the critical speed is exceeded, the following can occur

- Vibration of the spindle carrier (support structure)
- The centrifugal strength of the tools can be exceeded and excessive mechanical stress can cause damage.

Caution

The shutdown speed should be used as basis for assuming load level and strength requirements. It is not permissible to use the speed, which can be programmed for operation.

Installation conditions

The spindle is integrated into the machine assembly as a complete unit. The static and especially the dynamic are obtained from the interaction between the spindle and the spindle carrier.

Degree of protection

The degree of protection refers to the ingress of water. Cooling-lubricating mediums which contain oil, can creep and are aggressive, and can penetrate more than water. The spindle support design must guarantee suitable protection behind the mounting flange against the effects from the machining area.

Installing the spindle

The spindle must be installed in the machine so that liquids and dust-type dirt from the machining area cannot be permanently deposited on the spindle. The jet of cooling-lubricating medium may not be directly aimed at the labyrinth seal located at the nose of the spindle (refer to Fig.3-2).

Notice

Horizontal mounting:

When the spindle is mounted horizontally, the relief opening for the sealing air, located at the spindle nose, must face downwards.

Orientation help: The position of the ring bolt thread M12, located on the mounting flange, when viewed from the front, must be inclined 20º towards the right (refer to Fig. 3-3).

The spindle must be mounted so that the motor spindle is not subject to any compulsive forces. If the housing is subject to tension, this can result in a slight deformation and increased stressing on the roller bearings. This will have a neg-

ative impact on the smooth running characteristics, operating temperature and therefore the lifetime.
Axial tapped holes (on the rear bearing cover) and radial tapped holes (on the flange and at the rear bearing cover) are provided on the spindle for lifting lugs. These are used when the spindle is mounted.

Vibrational characteristics: Mechanical design requirements placed on the spindle support

The spindle support must have a stiff design so that no natural resonance points of the appropriate vibration types can be generated over the complete speed range up to the shutdown speed. The lowest resonance frequency must lie above the rotating frequency of the shutdown
speed which can be excited by an imbalance condition. In this frequency range, the spindle support must be able to absorb the tilting and lateral forces caused by the residual imbalance, without being deformed.
The spindle is mounted to the machine assembly at the drive end (front end) using the mounting flange. This must be taken into account in the mechanical design of the spindle support, especially when it comes to suppressing the tilting vibration of the rear (non-drive end) of the spindle, which is relatively far away from the mounting flange.

Information regarding the design of the spindle support

The following points should be carefully observed when designing the spindle support to accept the motor spindle:

- **Material strength**
  The fit area around the mounting flange is extremely important due to the high force density to counteract the tilting vibration. The material thickness and strength must be adequately dimensioned.
- **Lateral stability of the flange plane.**
  The plane of the mounting flange must be stiffly embedded in the machine so that in the frequency range up to the shutdown speed, vibration with lateral motion of the mounting flange is not possible. Specific designs, where the plane of the mounting flange is located far in front of the guide element plane of the spindle side are critical with regards to the flange plane being shifted due to the spindle support being torsionally moved and deformed.
- **Carefully observe the fit and tolerance**
  The spindle mounting flange must be attached to the spindle support so that it is geometrically precise and is as dynamically stiff as possible.

The mechanical design and the tolerances, which are documented in the drawings to accept the mounting flange, must be carefully maintained.

- **Supporting the spindle support using the guide elements**
  The guide elements (linear guides) which support the spindle support with respect to the machine bed, should provide an appropriately wide basis to withstand tilting vibration (refer to Fig. 3-4).
- **Short length between the spindle mounting flange and where the spindle support is retained**
  If the spindle mounting flange extends in front of where the spindle support is retained, then this can undesirably reduce the resonant frequency of tilting vibration (refer to Fig.3-5). This means that the length which extends between the spindle mounting flange and the point where the spindle support is retained at the machine bed should be kept as short assembly stiff.
- **Stiffening non-supported long distances**
  Longer non-supported distances should be avoided. If the spindle mounting flange is extended, then appropriate ribs and transverse reinforcing elements should be used. These reinforcing measures should be designed so that they counteract tilting vibrations.
- **No additional components mounted directly on the spindle**

In order that the natural frequency of the tilting vibration is not undesirable reduced, it is not permissible to mount or anchor any components directly on the spindle. For example, connecting the strain relief for drag cables.

Numerical techniques, such as the FEM-based modal analyses have proven themselves to be helpful when evaluating a mechanical design regarding its Vibrational characteristics. For additional support please contact your local Siemens office.

- **Support at the non-drive-end**

ECO motor spindles are available in several power classes. For the high-speed versions with high torques, an additional direct mechanical support is required between the non-drive end of the spindle and the spindle support.

Function of the support

The direct support between the non-drive end of the spindle and the spindle support has the function to stabilize the spindle against tilting vibrations **so that the lowest resonance frequency lies above the rotational frequency of the shutdown speed.**

Properties and characteristics of the support

This is the reason that the support design must be as stiff as possible to counter the lateral vibration shown in Fig.3-2. Further, this support must have a low mass close to the non-drive end. This is because the increase in the effective spindle mass at the non-drive end increases the moment of inertia of the tilting vibration and in so doing undesirably lowers the resonant frequency. Also in this case, FEM-supported modal analyses can be effectively used when evaluating the mechanical design.

Spindle bearings

The shaft of the ECO motor spindle is located in high-precision spindle bearings. They offer excellent precision and are designed to withstand loads at high speeds. Hybrid bearings are used for spindle versions which rotate at even higher speeds. Special significance was placed on the ruggedness of the bearings. They have proven themselves over many years in applications ranging from job shops up to three-shift series production.

Features and operating conditions

The high precision spindle bearings absorb the radial and axis forces from the machining process without and play. Thermal stressing of the spindle shaft does not influence the mechanical tension. The bearings have excellent balance quality and extremely low roughness. The balance quality specifications at the tool interface of the individual types can be taken from the data sheets.

The spindle's own sealing air system

The bearings are equipped with an integrated seal. The seal to the machining space at the spindle drive end is backed-up by the spindle's own sealing air system.

Note

In order to achieve the specified bearing lifetime, the sealing air system must be correctly used. The machinery construction company is responsible for explaining this to the company operating the spindle.

ECO motor spindles have permanently lubricated bearings. This is the reason why they do not require any maintenance. A re-lubrication device is not required. The permanent grease lubrication may not be negatively influenced or polluted by other materials and substances.

Warm-up phase

When starting to machine a workpiece, the motor spindle may not be immediately operated at its maximum speed. The following motor spindle warm-up phase is required.

25% maximum speed	2 min operating time
50% maximum speed	2 min operating time
75% maximum speed	2 min operating time
	ready

The machine construction company can include a spindle warm-up cycle in the control software.

Longer non-operating times (running-in the spindle)

A new spindle must be run-in if it has not been used for more than one week. This must be carried out according to the following guidelines:

25% maximum speed	5 min run time
50% maximum speed	5 min run time
75% maximum speed	5 min run time
	ready for operation

Note

If the spindle has been stored for longer periods of time, the procedure for storing ECO motor spindles must be carefully observed.

Exercises

Use the following phrases in the sentences.

utilize the benefits of high-speed machining – использовать преимущества высоко - скоростных машин

the components involved in the machining operation_– компоненты, участвующие в работе машины

withstand the high speeds – выдерживать высокие скорости

if the critical speed is exceeded – если критическая скорость превышена

can cause damage - привести к поломке

interaction between the spindle and the spindle carrier - взаимодействие между шпинделем и кронштейном, на котором установлен шпиндель

mediums which contain oil_- среда, содержащая масло

can penetrate more than water –_имеет большую проникающую способность, чем вода

permanently deposited on the spindle_- постоянно оседающая на шпинделе

when viewed from the front – при фронтальном обзоре

the motor spindle is not subject to any compulsive forces – шпиндель не должен подвергаться никаким насильственным силам
smooth running characteristics – характеристики плавной работы
the spindle is mounted to assembly the machine– шпиндель вмонтирован в машинный агрегат
this must be taken into account_– это должно быть принято во внимание
relatively far away_– относительно далеко
due to the high force density – из-за высокой концентрации силы
must be attached to the spindle support – должна быть прикреплена к основанию шпинделя
longer non-supported distances should be avoided – нужно избегать больших расстояний, не снабженных опорой
counteract tilting vibrations – препятствовать раскачивающим вибрациям
it is not permissible to mount or anchor any components directly on the spindle – не допускается монтаж или присоединение любых компонентов непосредственно на шпиндель
have proven themselves to be helpful – сами доказали свою полезность
spindles are available in several power classes – шпиндели доступны в нескольких классах мощности
and in so doing undesirably lowers the resonant frequency – и при этом невольно понижает резонансную частоту
can be effectively used when evaluating the mechanical design_ - может эффективно использоваться при оценке механического дизайна
absorb the radial and axis forces – поглощать радиальные и осевые силы
the balance quality specifications – технические условия качества соотношения сил
is backed-up by the spindle’s own sealing air system – поддерживается запорной системой шпинделя
in order to achieve the specified bearing lifetime – чтобы достичь определенного для опоры срока эксплуатации
they do not require any maintenance – они не требуют какого – либо обслуживания
may not be negatively influenced – не могут подвергаться негативному влиянию

Write a short summary of the text using the phrases above.

Exercises

Fill in the correct tense of the verb in brackets.

1. Please be quiet! I…………. (try) to concentrate.
2. They made a big mistake. They should……… (not get/involve) in that affair.
3. The number of people without jobs…………….. (increase) at the moment.
4. What time…….the banks……… (close) in Britain?
5. We………. (have) a party next Saturday. Would you like to come?
6. – I've got a terrible headache.
- Have you? Wait over there and I……… (get) an aspirin for you.
7. If I only…… (know) you …..(go) to London yesterday, I …… (ask) you to bring me back some of my favorite books.
8. Before you ……. (leave), don't forget to shut the windows.
9. Ann……… (spend) a lot of money yesterday. She……. (buy) a dress which……. (cost) £50.
10. You...…….. (might/tell) me you ……… (not/want) to go to the cinema. I …….. (not need/bother) to book tickets yesterday.
11. George …… (fall) off the ladder while he ……… (paint) the ceiling.
12. "……you….. (go) to the bank?" "No, I …….already…..to the bank."
13. I….. (lose) my key. Can you help me look for it?
14. …..you….. (see) my dog? I can't find him anywhere.
15. I……. (hate/queue up) in the cold to get into a cinema.
16. You're out of breath. …….you……. (run)?
17. If I ……… (know) that you ……. (be) ill last week, I …….. (go) to see you.
18. The road through the city center ……… (repair) at the moment, so if I …… (be) you, I ……… (avoid/go) that way.
19. Jane is hot and tired. She ……… (play) tennis.
20. The house was very quiet when I got home. Everybody ……. (go) to bed.

Additional reading

ERASERS

Rubber 'graphite grabbers' are simple but indispensable tools for home and office

STEVE RITTER

Some of life's greatest treasures are simple ones. Take erasers, for example. These small pieces of molded rubber are underappreciated but handy tools when it comes to a quick fix of something written in pencil or even in pen.

I had not given a thought to the chemistry behind erasers until a couple of years ago when my family and I stumbled across Claes Oldenburg and Coosje van Bruggen's giant typewriter eraser sculpture. The 14-foot-tall eraser wheel with attached brush, which sits on a patch of lawn in the National Gallery of Art's Sculpture Garden in Washington, D.C., is more than a reminder of the bygone days of typewriters.

For Oldenburg, it was a reminder of the simplicity of youth growing up around his father's office desk. For me, there was something hidden to explore in the giant wheel. Although the sculpture is made from stainless steel and fiberglass, the symbolic rubber wheel was begging the question, "What is an eraser?"

Although there are felt-pad chalkboard and white board erasers, the essence of an eraser is a plain piece of rubber--"graphite grabbers," some people in the industry like to call them. Even so, there are many types of these erasers, including handheld flat rectangles, cylindrical plugs attached to a pencil, or caps that fit over the end of a pencil. There are also all sorts of colorful novelty erasers in various geometric shapes with holiday, animal, sports, and other motifs.

THE STORY of the chemistry behind erasers is really a historical tale about rubber. It begins with the development of the pencil. Graphite began to be used as a writing device by the 1560s, and the first crude pencils were fashioned shortly thereafter. At first, unwanted pencil marks were rubbed off with a ball of moist bread and probably other similar materials.

In 1752, the proceedings of the French Academy of Sciences noted that caoutchouc (condensed latex) obtained from the *Hevea brasiliensis* rubber tree could be used to erase pencil marks. The first scientific description of caoutchouc had come during a French geographic expedition to South America in 1735. The name rubber was given to caoutchouc in 1770, and is attributed to none other than British-American chemist Joseph Priestley. He noted that caoutchouc was useful to "rub out" pencil marks; hence the name rubber was born. In most parts of the world, erasers are still called rubbers.

There was a drawback to the early erasers--and all materials made from rubber--since the rubber softened during warm weather, became hard in cold weather, and was stinky as it started to degrade. Enter hardware merchant-turned-chemical engineer Charles Goodyear, who, after several years of work, developed the vulcanization process to cure rubber in 1839. During vulcanization, sulfur is added to rubber and the mixture is heated under pressure to form sulfur cross-links between the rubber's polymer chains. The cross-links increase the strength, stability, and elasticity of the rubber.

After Goodyear's discovery, rubber became broadly used for many common items, including erasers. The first patent on a combined pencil and rubber eraser was granted in the U.S. in 1858. Most pencils made for use outside the U.S. still don't have attached erasers.

Natural rubber was chemically identified in the 1880s as *cis*-polyisoprene, $–[CH_2C(CH_3)=CHCH_2]_n–$. It is biosynthesized in the rubber tree from 3-methyl-3-butenyl pyrophosphate, an important building block for many natural compounds. About 30% of the milky white latex obtained from a cut on the rubber tree is *cis*-polyisoprene. The polymer is recovered from the liquid by using formic acid to coagulate the polymer into curds, which are then pressed into sheets.

Synthetic production of rubber wasn't initially successful, since radical polymerization of isoprene leads to random cis and trans arrangements, giving a sticky and useless product. With the development of Ziegler-Natta catalysts in the 1950s, however, 100% *cis*-polyisoprene could be manufactured. *Trans*-polyisoprene, also known as gutta-percha, is a harder material.

Several synthetic rubber compounds have been used to make erasers. These include isoprene-isobutylene (butyl rubber), styrene-butadiene, and ethylene-propylene copolymers. Synthetic rubber began to replace natural rubber in erasers by the 1960s. Since the mid-1990s, erasers have been made nearly exclusively with synthetic rubber, primarily polyvinyl chloride. The driving force to complete the changeover was to help prevent allergic reactions to latex, mainly in schoolchildren.

Erasers and other rubber products are prepared by masticating the natural or synthetic rubber, followed by mixing at low heat to obtain the desired consistency. During mixing, a variety of additives may be introduced: a small amount of petroleum-based oil to aid mixing, sulfur and other reagents for vulcanization (if needed), plasticizers to control firmness, amine or phenol antioxidants, and pigments. For erasers, high-silica pumice or other abrasives may be added, especially if natural rubber is used.

Following mixing, the rubber is shaped by extrusion or by placement in a mold. At this point, the rubber is cured under pressure and elevated temperature. Afterward, the erasers are cut into the final shape or removed from the mold, ready to be used.

For pencil erasers, cylindrical ribbons of rubber are cut into short pieces called plugs. The plugs are placed in a rotating hopper that lines the plugs up on a conveyer belt that carries them to be married up with a pencil. A band of metal called a ferrule is glued onto the end of the pencil where a recess has been cut, while at the same time a plunger presses an eraser plug into the ferrule. When the glue dries, everything is bliss.

Unit 7

Electrical Data

1. **Definitions**

Mechanical limiting speed n/max

The maximum permissible speed n/max is the max. programmable speed

S1 duty (continuous duty)

S1 duty is operation with a constant load condition, whose duration is sufficient that the machine goes into thermal steady-state condition.

S6 duty (intermittent load)

S6 duty is operation with comprises a sequence of similar load duty cycles; each of these load duty cycles comprises a time with constant motor load and a no-load time. If not otherwise specified, the power-on time refers to a load duty cycle of 2 min.

S6-40% : 40% load
60% no-load time

Thermal time constant Tth

The thermal time constant defines the increase in the motor winding temperature when the motor load is suddenly increased (step function) to its permissible S1 torque. After time Tth the motor has reached 63% of its final S1 temperature.

Maximum torque Mmax

Torque which briefly available for dynamic operations (e.g. when accelerating).The following calculation is used to calculate this:

$$M_{max} \approx 2 \cdot M_n$$

At higher speeds, i.e. in the constant power range, the maximum available torque at a specific speed n is approximated according to the following formula:

$$ØØM_{max}\,[Nm] \approx 9.6 \cdot \frac{P_{max}[W]}{N[RPM]}$$

2. Motor

The drive motor of the ECO motor spindle is integrated on the spindle shaft between the two spindle bearings. The rotor is electrically passive and doesn’t require any power to fed to it. The electric power is conditioned by a drive converter and fed to the stator winding. The losses associated with converting the electric power into the mechanical power, which are unavoidable, mainly occur in the motor stator. This means that the stator is equipped with a cooling system, which ensures the necessary cooling thus preventing the machine assembly from reaching excessively high, damaging temperatures.

Advantages of a direct drive

The drive motor does not have its own bearings. Its rotor also the spindle shaft and located in the bearings of the spindle shaft. This type of drive is also known as direct drive. The reason for this name is that there are no mechanical couplings between the motor shaft and the spindle shaft with the associated weak points.

When compared to mechanically-coupled drives, direct drives have the following advantages:

- Ruggedness even at high speeds
- The spindle rotor does not have any play with respect to the drive motor and high precision in C axis operation
- Low noise emission and high smooth running qualities
- Stable balancing

The torque is contactlessly transmitted to the rotor which means that there is not mechanical wear. The high availability and raggedness thus achieved mean that the drive motor does not require any maintenance therefore counteracting the potential disadvantage associated with the fact that this type of motor is not quite so accessible.

Synchronous and induction motor versions

The ECO motor spindle is, as standard, equipped with a synchronous motor; an induction motor is available as option. Both of these motor versions have their own specific strengths and place certain requirements on the AC drive converter. The machinery construction company (OEM) should be aware of this when designing his machine.

Selecting the motor versions

As far as power and torque are concerned, the synchronous motor is superior to the induction motor. It is more powerful and has noticeably less power than an induction motor. For synchronous motors, the motor shaft is subject to a lower thermal stressing which is important as it is more difficult to cool motor shafts.

The synchronous motor field weakening function is already included in the standard functional scope of the SIMODRIVE System 611 digital/universal. A well-tested and favorably- priced overvoltage protection module is available in the form of the VP module.

General motor characteristics

Field weakening

In addition to reducing the counter voltage, field weakening also reduces the maximum torque. When field weakening is used, there is a constant torque range and a constant power range.

Power limiting using reactive power drawn

As the speed increases, the reactive power (electrical) drawn by the motor increases. This reactive power demand in turn reduces the mechanical spindle power. This means, in the uppermost speed range, the constant spindle power can no longer be maintained, but decrease with increasing speed. The power limiting is defined in the power diagrams using the "limiting characteristic". The level of the power limiting depends very heavily on the operating mode (star/delta) and the motor type (synchronous or induction motor). For synchronous motors, the spindle power always remains constant up to the maximum speed.

- **Constant maximum torque:**

Field weakening is not activated in the lower speed range and the RMS magnetic flux is constant as long as the required voltage, which is proportional to the speed, does not exceed the maximum drive converter output voltage. This means that a constant torque is available in this range.

- **Constant maximum power:**

The motor voltage reaches the maximum drive converter output voltage in the upper speed range of field weakening. This means that the magnetic flux must be reduced linearly with the speed. For induction motors, this is realized by reducing the flux-generating current, and for synchronous motors, by impressing a current or magnetic field which opposes the permanent magnet field. This means that the permanent magnet field is "weakened". The torque also decreases proportionally with the flux which decreases with the speed. The mechanical power, as product of speed and torque, remains constant.

- **Limited maximum power (only for induction motors):**

The reactive power, which increases with the speed, can, depending on the motor type mean that the maximum power has to be reduced in the uppermost speed range.

The speed at the start of field weakening and the power limiting depend on the magnitude of the DC link voltage.

For synchronous motors, the spindle power always remains constant up to the maximum speed.

Suitable drive converter/system environment

Drive converter

The ECO motor spindle is harmonized to the SIMODRIVE system with the 611 Digital and 611 universal drive converter. The angular data of the sin-cos encoder is multiplied in the encoder interface of the drive converter. 611 digital/universal with various multiplication factors are available.

Supply

SIMODRIVE 611 drive converters can be operated from non-regulated and regulated rectifier (infeed) modules. The engineering and performance data refer to operation with a regulated infeed/regenerative feedback module and a 600 V DC link voltage. It may be necessary to correct this data if the equipment is operated from non-regulated infeed modules with different DC link voltage.

Overvoltage protection (only for synchronous motors)

For synchronous motors, overvoltage protection must be used to prevent the drive converter from being damaged due to overvoltage when a fault occurs. The VPM (Voltage Protection Module) fulfills this particular task in the SIMODRIVE system. If the power module fails at high spindle speeds, then the synchronous motor feeds back a high voltage into the DC link. The VP module detects a motor voltage which is too high and then short-circuits the three motor feeder cables. The rotational energy of the spindle is then converted into heat.

Star-delta mode (only for induction motors)

When induction motors are used, it is possible to select one of the following operating modes:

- Star circuit configuration
- Delta circuit configuration

Circuit to implement a star-delta changeover

For induction motors, all six connections leads of the three winding phases are fed out to be able to select the various operating modes.

Switching equipment, which is located external to the spindle, is used to change between the star and delta configuration. This switching equipment is not included with the spindle.

Using the star circuit configuration

The star circuit configuration offers advantages at low speeds. The maximum torque in the star circuit configuration is approximately twice as high as in delta circuit configuration. However, due to the higher reactive power requirement of the star circuit configuration, the available torque in the uppermost speed range is significantly restricted. This means that the star circuit configuration should only be activated when machining which requires a high torque in the lower speed range. An example of such a machining operation is roughing.

Using the delta circuit configuration

Although the delta circuit configuration provides, in the lower speed range< a lower maximum torque than the star circuit configuration, the torque remains available up to high speeds. This means that the delta circuit configuration should be activated for all machining operations which are carried-out in the average and high speed ranges.

Exercises

Answer the following questions.

1. What does the thermal time define?
2. How to define that the stator is equipped with a cooling system?
3. What do high availability and ruggedness mean?
4. What are the advantages of synchronous motors?
5. What is operating mode?

Make up sentences using the following words.

1. in this/ is available/ range/ a constant torque/ this/ that/ means.
2. the induction motor/ are concerned/ is superior/ the synchronous motor/ to/ torque/ power/ as far as/ and.
3. type/ is/ of drive/ this/ also/ known as/ direct drive/ a.
4. should be aware/ his machine/ company/ of this/ machinery/ when designing/ construction.
5. cooling system/ this/ that/ the stator/ with/ means/ is equipped.
6. the ECO motor/ as standard/ is/ spindle/ equipped/ motor/ a/ synchronous/ with.
7. drive/ bearings/ does not/ own/ its/ motor/ the.
8. very heavily/ the level/ depends/ limiting/ of the power/ mode/ on the/ operating.
9. converted/ into heat/ is/ the/ energy/ of/ rotational/ the spindle.
10. configurations/ between/ is used/ to change/ equipment/ switching.

Write the correct form of the verbs in brackets to complete the conditional sentences in this article. Use modal verbs if you think they are appropriate.

No pain, no gain?

It's January 1st. You're on the bathroom scales, groaning. If you (1)………. (eat) that last piece of Christmas pud, perhaps you wouldn't have put on extra kilo. Never mind, you can lose it and get fit at the gym!

Or is that the right thing to do? If you're unfit, you (2)…………….. (stand) a huge chance of injuring yourself in the gym or on the squash court. You must take care before launching yourself into a vigorous exercise routine: if you don't treat your body with respect, it (3)………… (not/function) as you want it to. The knee, in particular, can cause untold problems. We (4)……………. (not/have) problems with our knees if we still (5)………….. (walk) on all fours, but they are not up to a vertical pounding on the treadmill for an hour a day. All of our joints can cause problems; if you (6)…………… (want) to play football safely, make sure you wear the right boots to protect your ankles. Decent coaching (7)…………… (be) essential if you're going to take up a racket sport: something as simple as a wrong – size grip can cause tennis elbow.

Many sports injuries are caused by insufficient warm-ups. If everyone spent a few minutes stretching their muscles before exercising, they (8)……………… (experience) much less pain during exercise itself. But people can be stubborn about pain when exercising. The phrase 'no pain, no gain' is rubbish. Should you feel pain when you're exercising, you (9)…………………. (stop) at once!

Sport has so many other hazards, though. Golf, you would think, is relatively harmless. Not so for Anthony Phua, a Malaysian golfer who was killed by getting in the way of his partner's swing. Now, if he hadn't taken up that particular form of exercise in the first place, it (10)……………. (happen).

What can you do if you (11)………………………… (not/want) to risk sport, but you still want to lose weight? Well, it's not all bad news for couch potatoes. If you're happy to lose calories steadily but slowly, just (12)…………………… (stay) at home: sleeping burns 60 calories an hour, ironing 132 and cooking 190. Just don't eat what you cook!

Additional reading

Read and translate the following text

Higher mathematics
Truth and Lies.

Mapping the most complex known mathematical object

FOR more than a century mathematicians have known about Lie groups. These are families of shapes named after Sophus Lie, a Norwegian mathematician who discovered them. There are four "simple" Lie groups and five-this being mathematics-that are not quite so simple.

The simplest member of the simplest Lie group is the circle, which looks the same however it is rotated. Its higher-dimensional cousin, the sphere, has the same properties, only more so, and is thus the second-simplest of the same family. The five non-simple groups-dubbed "exceptional" in their complexity and symmetry-are harder to envisage and, for almost 120 years, the details of the most intricate of these have lain beyond reach. This week a group of mathematicians led by Jeffrey Adams of the University of Maryland announced that they had completed a map of the largest and most complicated one, a structure known to mathematicians as E_8.

Lie groups have two defining features: surface and symmetry. A sphere has two surface dimensions. In other words, any place on its surface is defined by just two numbers, the longitude and the latitude. But it has three dimensions when it comes to symmetries. A sphere can spin on an axis that runs, say, from north to south, or on each of two axes placed at right angles to this. E_8 is rather more difficult to visualize. Its "surface" has 57 dimensions-that is, it takes 57 co-ordinates to define a point on it, and it has 248 axes of symmetry.

Grappling with such a structure is as tricky as it sounds. But Dr Adams's team decided to have a go. They want to create an atlas of maps of the Lie groups. This involves making a description in the form of a matrix for each structure. (A matrix is a multi-dimensional array of numbers, such as that found in a sudoku puzzle.)

Dr Adams and his colleagues began by writing a computer program that would generate such matrices, a task that took them more than three years. It transpired that they needed 453,060 points to describe E_8 but that they also needed to express the relationship between each of these points. That meant they had to devise a matrix with 453>06o rows and the same number of columns. In total this gives 205 billion entries. To complicate things further, many of these entries were not merely numbers but polynomials-sequences in which a given number is raised to a series of different powers, for example its square and its cube.

Processing such a vast quantity of data was beyond the capacity of even modern supercomputers, so the team was forced to tinker with the problem to make it tractable. This tinkering led them to a piece of ancient maths known as the Chinese remainder theorem.

This theorem is contained in a book written in the late third-century an by a mathematician called sun Tzu (not to be confused with the military strategist of the same name). It is used to simplify large calculations by breaking them down into many smaller ones, the results of which can then be recombined to generate the answer to the original question.

One problem addressed in the original book concerns counting soldiers. Sun Tzu's solution was that the soldiers should first split into groups of three, then groups of five, then groups of seven, with the number unable to join a group (in other words, the remainder) being noted each time. The three remainders can then be used to calculate how many soldiers are present. For example, if two were left over from the groups of three, three left over from the groups of five and two left over from the groups of seven, there would have been **2**3 soldiers in the unit (or possibly 233, but the difference should be obvious to even the stupidest commanding officer).

The researchers worked out how to use the remainder theorem to bring their calculation within the capacity of a supercomputer called sage, which spent more than three days crunching the numbers to generate the map of $\mathbf{E}_8$. Not content with letting the supercomputer do all the arithmetic, the mathematicians simultaneously jotted down some calculations of their own on the back of an envelope. They worked out that if each entry in the matrix were written on paper that was one inch square, the answer would cover an area the size of Manhattan.

And the point is

Apart from the satisfaction of mapping $\mathbf{E}_\$$ at long last, mathematicians are pleased because the structure keeps popping up in another branch of intellectual endeavor: string theory. This purports to be the best explanation of the universe beyond the standard Model of physics that describes all known particles and forces, but which is generally acknowledged to be incomplete. String theory requires that the universe has many more dimensions than those that are obvious, but that most of these extra dimensions are too small to be discerned with today's equipment. One of the ways in which they can be hidden involves $\mathbf{E}_a$, so having a mathematical map of its structure could be handy. Cheaper, too, than building a particle accelerator the size of the solar system. ■

The Economist **March**, 24th, 2007

Unit 8
Feedback

Feedback is (generally) information about actions.
In cybernetics and control theory, feedback is a process whereby some proportion or in general, function, of the output signal of a system is passed (fed back) to the input. Often this is done intentionally, in order to control the dynamic behavior of the system. Feedback is observed or used in various areas dealing with complex systems, such as engineering, architecture, economics, and biology.
Continuous feedback in a system is a feedback loop.

Types of feedback

Feedback may be negative, which tends to reduce output (but in amplifiers, stabilizes and linearises operation), positive, which tends to increase output, or bipolar, which can either increase or decrease output. Systems which include feedback are prone to hunting, which is oscillation of output resulting from improperly tuned inputs of first positive then negative feedback. Audio feedback typifies this form of oscillation.

In electronic engineering

The processing and control of feedback is engineered into many electronic devices and may also be embedded in other technologies.
The most common general-purpose controller is a proportional-integral-derivative (PID) controller. Each term of the PID controller copes with time. The proportional term handles the present state of the system, the integral term handles its past, and the derivative or slope term tries to predict and handle the future.
If the signal is inverted on its way round the control loop, the system is said to have negative feedback; otherwise, the feedback is said to be positive. Negative feedback is often deliberately introduced to increase the stability and accuracy of a system, as in the feedback amplifier invented by Harold Stephen Black. This scheme can fail if the input changes faster than the system can respond to it. When this happens, the negative feedback signal begins to act as positive feedback, causing the output to oscillate or hunt. Positive feedback is usually an unwanted consequence of system behavior.
With mechanical devices, hunting can be severe enough to destroy the device. Harry Nyquist was an electrical engineer who contributed the Nyquist plot for determining the stability of feedback systems.

In mechanical engineering

In ancient times, the float valve was used to regulate the flow of water in Greek and Roman water clocks; similar float valves are used to regulate fuel in a carburetor and also used to regulate tank water level in the flush toilet.
The windmill was enhanced in 1745 by blacksmith Edmund Lee who added a fantail to keep the face of the windmill pointing into the wind. In 1787 Thomas Mead regulated the speed of rotation of a windmill by using a centrifugal pendulum to adjust the distance between the bedstone and the runner stone (i.e. to adjust the load).
The use of the centrifugal governor by James Watt in 1788 to regulate the speed of his steam engine was one factor leading to the Industrial Revolution. Steam engines also use float valves and pressure release valves as mechanical

regulation devices. A mathematical analysis of Watt's governor was done by James Clerk Maxwell in 1868.
The Great Eastern was one of the largest steamships of its time and employed a steam powered rudder with feedback mechanism designed in 1866 by J.McFarlane Gray. Joseph Farcot coined the word servo in 1873 to describe steam powered steering systems. Hydraulic servos were later used to position guns. Elmer Ambrose Sperry of the Sperry Corporation designed the first auto-pilot in 1912.
Nicolas Minorsky published a theoretical analysis of automatic ship steering in 1922 and described the PID controller.
Internal combustion engines of the late 20th century employed mechanical feedback mechanisms such as vacuum advance but mechanical feedback was replaced by electronic engine management systems once small, robust and powerful single-chip microcontrollers became affordable.

In economics and finance

A system prone to hunting (oscillating) is the stock market, which has both positive and negative feedback mechanisms. This is due to cognitive and emotional factors belonging to the field of behavioral finance. For example, When stocks are rising (a bull market), the belief that further rises are probable gives investors an incentive to buy (positive feedback); but the increased price of the shares, and the knowledge that there must be a peak after which the market will fall, ends up deterring buyers (negative feedback).
Once the market begins to fall regularly (a bear market), some investors may expect further losing days and refrain from buying (positive feedback), but others may buy because stocks become more and more of a bargain (negative feedback).
George Soros used the word "reflexism" to describe feedback in the financial markets and developed an investment theory based on this principle.
The conventional economic equilibrium model of supply and demand supports only ideal linear negative feedback and was heavily criticized by Paul Ormerod in his book "The Death of Economics" which in turn was criticized by traditional economists. This book was part of a change of perspective as economists started to recognize that Chaos Theory applied to nonlinear feedback systems including financial markets.

In nature

Bipolar feedback is present in many natural and human systems. Feedback is usually bipolar that is, positive and negative in natural environments, which, in their diversity, furnish synergic and antagonistic responses to the output of

any system .
In biological systems such as organisms, ecosystems, or the biosphere, most parameters must stay under control within a narrow range around a certain optimal level under certain environmental conditions. The deviation of the optimal value of the controlled parameter can result from the changes in internal and external environments. A change of some of the environmental conditions may also require change of that range to change for the system to function. The value of the parameter to maintain is recorded by a reception system and conveyed to a regulation module via an information channel.
Biological systems contain many types of regulatory circuits, among which positive and negative feedbacks. Positive and negative don't imply consequences of the feedback have positive or negative final effect. The negative feedback loop tends to slow down a process, while the positive feedback loop tends to accelerate it.
Feedback and regulation are self related. The negative feedback helps to maintain stability in a system in spite of external changes. It is related to homeostasis. Positive feedback amplifies possibilities of divergences (evolution, change of goals); it is the condition to change, evolution, growth; it gives the system the ability to access new points of equilibrium.
For example, in an organism, most positive feedbacks provide for fast autoexcitation of elements of endocrine and nervous systems (in particular, in stress responses conditions) and play a key role in regulation of morphogenesis, growth, and development of organs, all processes which are in essence a rapid escape from the initial state. Homeostasis is especially visible in the nervous and endocrine systems when considered at organism level.
Feedback is also central to the operations of genes and gene regulatory networks. repressor (see Lac repressor) and activator proteins are used to create genetic operons, which were identified by Francois Jacob and Jacques Monod in 1961 as feedback loops.
Any self-regulating natural process involves feedback and is prone to hunting. A well known example in ecology is the oscillation of the population of snowshoe hares due to predation from lynxes.
In zymology, feedback serves as regulation of activity of an enzyme by its direct product(s) or downstream metabolite(s) in the metabolic pathway.
There is an ice-albedo positive feedback loop whereby melting snow exposes more dark ground (of lower albedo), which in turn absorbs heat and causes more snow to melt. This is part of the evidence of the danger of global warming.

In organizations

As an organization seeks to improve its performance, feedback helps it to make required adjustments.

Examples of feedback in organizations:

Financial audit

performance appraisal

shareholder meetings

customer surveys

360-degree feedback

In gaming

In computer games, feedback is an important and heavily exploited mechanism for controlling resources. Both positive and negative feedback loops can be used to alter the pacing, challenge, and sense of accomplishment in a game. For example, Unreal Tournament's practice mode offers an auto-adjust setting that causes the bots to attempt to match the player's skill level, keeping a more consistent level of challenge for different players; this is negative feedback. On the other hand, in StarCraft, a player who has a small advantage in resources will be able to build more units, enabling them to seize more resource-rich territory and so gain a much larger advantage in resources; this is positive feedback.

Exercises

1. Match the names with the dates and say what these people are famous for:

James Watt	1866
Joseph Farcot	1922
James Clerk Maxwell	1788
J.McFarlane Gray	1961
Elmer Ambrose Sperry	1745
Nicolas Minorsky	1873
Edmund Lee	1912
Francois Jacob and Jacques Monod	1868

Give Russian equivalents to the following phrases:

float valves, often this is done intentionally, improperly tuned inputs, unwanted consequence of system behavior, the largest steamships of its time, steam powered steering systems, to regulate the speed of rotation of a windmill by using a centrifugal pendulum, steam powered rudder with feedback mechanism, to give investors an incentive to buy, conveyed to a regulation module via an information channel, stability in a system in spite of external changes, when considered at organism level possibilities of divergences.

Translate the following phrases into English:

1. Обратная связь наблюдается в различных областях, имеющих отношение к сложным системам.
2.

Additional reading

Information technology
The skinny on IT
The human body as a computer bus
IT SOUNDS like an April Fool's Day joke, but it isn't. Microsoft, that imperialist of the information-technology world, has actually succeeded in patenting the human body as a computer network. US Patent 6,754,472, issued to the company on June 22nd, is for a "method and apparatus for transmitting power and data using the human body".
At the moment, ubergeeks who want to create a so-called personal area network **(PAN)** have to link their personal electronic devices-mobile phones, pagers, personal data assistants (PDAs) and so on-using infra-red or radio signals. What Microsoft is proposing is to use the skin's own conductive properties to transmit the data needed to create such a network. And the firm does not stop at people. A "wide variety of living animals", it says, could be used to create computer buses, as they are known technically, in this manner.

Many people today carry a range of portable electronic devices, each with its own keypad, speaker, display, processing unit and power supply. The idea behind the patent is to get rid of some of these items. If such gizmos were networked, it would be possible to have, say, just one keypad for a mobile phone, an MP3 music player and a PDA. The keypad might even be a person's forearm. As the patent puts it, "The physical resistance offered by the human body can be used in implementing a keypad or other input device as well as estimating distances between devices and device locations. In accordance with the present invention, by varying the distance on the skin between the contacts corresponding to different keys, different signal values can be generated representing different inputs." In other words you can, in theory, type on your skin.

Microsoft suggests using the body to generate power for the network, too. **A** "kinetic power converter" in the wearer's shoe or wristwatch would produce electricity in the same way that an old-fashioned self-winding watch extracted energy from its owner's normal movements.

The patent points out that networked portable devices which employ infra-red or radio-frequency communication have limitations. Radio devices use a lot of power, and are prone to interference from others operating on similar frequencies. There are also fears that people might be able to hack into them or, at the least, listen in. Infra-red communication suffers the same problems, but has the additional limitation of requiring a direct line of sight between objects-as anyone who has tried to operate a television remote control with someone else standing between him and the television will know. Microsoft claims that its approach of "near field intrabody communication" does not suffer from these problems, and provides a secure way to transfer data between devices.

It a11 sounds very revolutionary, but Microsoft is not (as is often the case with the firm's "innovations") actually the pioneer in the field. The Massachusetts Institute of Technology's Media Laboratory and **IBM** jointly developed the idea of using the human body as a personal network nearly a decade ago. The first prototype **PAN,** which was demonstrated at the Comdex trade show in **1996,** showed how two people could transmit business-card details to each other electronically, via a handshake. Little has been done since then to take the technology forward, and most people seem satisfied with the capabilities provided by radio-frequency
PANs such as Bluetooth.

Microsoft is keeping its cards close to its chest, and has declined to comment on how, exactly, it intends to develop its patent into something that people will actually want to buy. Some of the features of Microsoft's **PAN** would put off even the most avid technophile-the most obvious being the problem of how the electronic devices it links up are themselves to be attached to the body. The patent suggests a pair of electrodes, attached to the skin, for each device. The trade-off between eliminating redundant input/output devices and the inconvenience of having to attach dozens of electrodes to your skin does not obviously favour the latter. Still, you have to admire them for trying.

.

Unit 9
Supply with Cooling Medium and Compressed Air

Compressed medium.

The spindle is designed for water cooling. The Spindle housing is equipped with cooling ducts, which transfer the stator power loss (heat) into the cooling water. The temperature of the cooling water increases when it flows through the spindle corresponding to the flow rate and the thermal power that it absorbs.

In order to guarantee the necessary thermal transition in the cooling ducts, the minimum cooling water flow should be maintained.

Higher cooling water flow rates are permissible as long as the permissible hydrostatic pressure in the system is not exceeded.

Cooling water connections

	Value	Comment
Connection fitting	G ½ (inner thread)	On the spindle side
Connection coding	I = motor cooling ON II = motor cooling OFF	On the spindle side
Perm. Tightening torque [Nm]	Max. 100 Nm	When tightening

The feeder lines and hoses to the connections must be flexible and strain relieved. Rigid pipe connections are not permissible.

Conditioning the cooling water
The cooling water must be conditioned in order to maintain the correct functioning of the cooling system on the spindle side (refer to Table 5-2)

	Value	Comment
Min. incoming temperature	No moisture condensation	
Max. incoming temperature	25˚C 45˚C	Without de-rating With de-rating, refer to table 5-3
Max. hydrostatic pressure	5 bar	
Max. particle size	100µm	
Recommended anti-corrosion agents	Max. 25% Clariant, Antifrogen or Tyfocor	

Caution
Cooling

- It is not permissible to use ware from the drinking water supply, or
- With cooling – lubricating medium

The cooling water temperature must be set corresponding to the ambient temperature so that moisture condensation does not occur.

The S1 power (continuous duty) of the spindle depends on the intake temperature of the cooling water. For intake temperatures of up to 25˚C the S1 power, specified in the data sheet, is achieved. The S1 power rating is reduced above the cooling water intake temperature of 25˚C (refer to table 5 – 3)

Table 5 – 3 Reduced S1 power as a function of the cooling water temperature

Intake temperature [˚C]	Reduction factor
25	1
35	0.95
45	0.90

Cooling water additives

Additives must be added to the cooling water to protect against corrosion and living organism. These additives must be compatible with the materials used for the cooling water feed system on the side of the spindle. Further, they must also be compatible with the materials used in the cooling water feed system on the machine side. Electro-chemical incompatibilities between the materials of the cooling water feed and the spindle side and on the machine side are not permissible. The machine-side cooling water feed system must be appropriately designed.

List of material for the cooling water feed on the spindle side:

- Steel, grey cast iron
- Brass
- Viton

Cooling systems

The cooling water, which is withdrawn from the spindle, must be cooled using an external cooling system. The external cooling system is not included in the spindle.

External cooling system versions

Version	Characteristics

The existing cooling system is used	- The existing cooling system must be increased by the spindle power loss - The compatibility of the materials must be carefully checked - The pump must be able to provide the additional flow at the required pressure
Air/water heat exchanger cooling system	- Favorable investment and operating costs such as a compressor do not have to be used - The heat exchanger must be dimensioned so that the intake temperature for the spindle is max. 5K above the ambient temperature - Higher space requirement of the heat exchanger that for the cooling unit
Stand-alone cooling system	- The intake temperature for the Spindle is independent of the ambient temperature

Exercises

Find Russian equivalents to the underlined words.

In your text find synonyms to the following words: happen, external, outer, adequate, moreover, revoke, refrigerant, dampness, autonomous, demands

Translate the following phrases into English:

1. Шпиндель устроен так, что ему необходимо водяное охлаждение.
2. Охлаждающие каналы передают тепло (или потерю мощности статора) в охлаждающую воду.
3. Температура охлаждающей воды возрастает соответственно интенсивности потока воды и термической мощности, которую она поглощает.

4. Необходимо поддерживать минимальный поток воды, чтобы гарантировать передачу тепла в охлаждающие каналы.
5. Допускается усиленный поток воды при том, что допустимое гидростатическое давление в системе не превышается.
6. Шланги и транспортная линия (подающая линия) должны быть гибкими, а не жесткими.
7. Температура охлаждающей воды должна быть установлено соответственно внешней температуре, чтобы не образовывался конденсат.
8. Длительная эксплуатация шпинделя зависит от температуры охлаждающей жидкости.
9. Чтобы защитить оборудование от коррозии и бактерий, необходимы специальные добавки к охлаждающей воде.
10. Далее. Добавки должны быть совместимы с материалами, используемыми для подающей системы, установленной на боковой части машины.

]

Additional reading

Metro. The fully automatic control system

The Metro's fully automatic control system works as the Metro's brain. The control system monitors and controls the Metro.

Among other things the fully automatic control system makes it possible to operate trains without drivers.

This provides several advantages.

Advantages of driverless trains

- Instead of long trains with infrequent service, the Metro has many short trains with very frequent service. The interval between trains on the central section will be as short as 1.5 minutes. This means brief waits.
- The automatic operation enables the trains to run at closer intervals than under manual operation. Apart from the shorter waiting times, this also makes it easier to make up for delays.

- The trains are more punctual. At least 98% of the departures will be on time. Instead of driving the train, the Metro staff will serve the passengers and create a feeling of security.
- Using the Metro will be very safe since human error is avoided.

Automatic Train Control

The corner stone of the fully automatic operation is the Automatic Train Control (ATC) system, which has three sub-systems:

The Automatic Train Protection (ATP) system

The Automatic Train Operation (ATO) system, an autopilot system

The Automatic Train Supervisory (ATS) system, an overall traffic and monitoring system.

Automatic Train Protection

The ATP system performs a range of functions that protect passengers, staff and equipment from accidents, prevent excess speeds and incorrectly positioned points and make sure the doors are closed before departure. There are various fundamental approaches to the construction of ATP systems. The Metro uses a block based ATP system that divides each stretch into track system. When a train is located in a particular track section, no other train can enter the same section. There are a number of exceptions, such as at stations where an overlying “floating” block system is in effect enabling the trains to run closer to the preceding train and to exchange updated information with the Control Centre.

Automatic Train Operation

The ATO system, or autopilot, controls the trains according to a fixed timetable by:

- Performing programmed stops at stations.
- Operating and closing doors.
- Verifying that stopping times at the stations are observed.
- Starting the train after station stops.

Automatic Train Supervisory System

The ATS system. Monitors the status of all sub-systems and all trains in operation. This is done by:

- Controlling and coordination overall traffic movements.
- Maintaining the schematic overview of the entire line for the operators in the control room.
- Providing continuously updated data on each individual train (e.g. position and speed) to stations, points and other equipment on the line.

- Continuously updating registers of alarms, faults and other events regarding all equipment on the line and all processes being performed, whether carried out by control system or operators.

Quality assurance for critical safety components

The advantage of using the above functional divisions between ATP, ATO and ATS is that ATP is the only sub-system that is critical to safety. It is the only sub-system that must be guaranteed never to fail. If a fault arises in the ATO sub-system, for example, the ATP system will intervene before the fault develops into an accident situation. This level of security is achieved by subjecting the ATP system to quality assurance testing in accordance with predetermined standards.

Not a new technology

The technology described above is not new. The principles of the ATP system date back to the turn of the millennium when the first Metros were equipped with ATP systems, ATO and ATS have been operational in the Paris Metro since 1961.

Almost all major railway and metros have some form of ATP system, and many underground railways have been operation with ATS and ATO for many years. The only task performed by a driver in these metros is to press a button that closes the doors and starts the train, which then drives automatically to the next station. There are a number of driverless systems in France, Canada and Japan that have been operating for more than fifteen years.

Automatic door closing and accurate braking

Moving up from an ATO system to a completely driverless system mainly consists of automating the door closing procedure and achieving accurate train braking.

- Door closing is designed to prevent anyone or anything from being trapped between the doors when the train starts to move. If the ATP system registers that just one of the doors cannot close and lock completely, the train cannot depart.
- Target braking is important in a driverless system because the train has to stop with relative precision at the platform doors of the tunnel stations. Therefore, the trains are equipped with several odometers that are constantly updated with their precise position by the ATC system and that compare the mutual result. In addition, the brakes are equipped

with an electronic anti-blocking protection system (ABS) and the train motors are equipped with wheelspin protection. Lastly, the ATC system checks the train's precise position at the station before opening the doors.

Entire line operated from the control room

The control room is the core of the Metro and the entire line is controlled from here. The control room is staffed by four or five supervisors who monitor the automatic operations of the Metro round the clock.

Typically, two persons are engaged in monitoring and controlling the actual Metro operations. One person is in charge of all communication with call points, loudspeakers, displays and Metro Stewards and monitors the station cameras and, if necessary, the train cameras, and one person monitors the operations of the CMC, power supplies and the SCADA system. Under normal circumstances, Metro operations are fully automatic, and the supervisors solely monitor the system. In the event of irregularities, the supervisors intervene in the system operations to re-establish normal operations as quickly as possible.

Unit 10

Cybernetics

Cybernetics is the study of communication and control, typically involving regulatory feedback, in living organisms, in machines, and in combinations of the two, for example, in sociotechnical systems. The term cybernetics stems from the Greek (kybernetes, steersman, governor, pilot, the same root as government). It is an earlier but still-used or rudder generic term for many of the subject matters that are increasingly subject to specialization under the headings of adaptive systems, artificial intelligence, complex systems, complexity theory, control systems, decision support systems, dynamical systems, information theory, learning organizations, mathematical systems theory, operations research, simulation, and systems engineering. A more philosophical definition, suggested in 1956 by Louis Couffignal, one of the pioneers of cybernetics, characterizes cybernetics as "the art of ensuring the efficiency of action".

History

Contemporary cybernetics began as an interdisciplinary study connecting the fields of control systems, electrical network theory, logic modeling, and neuroscience in the 1940s. The name cybernetics was coined by Norbert Wiener to denote the study of "teleological mechanisms" and was popularized through his book Cybernetics, or Control and Communication in the Animal and Machine (1948).

The word cybernetics had, unbeknownst to Wiener, also been used in 1834 by the physicist Andre Marie Ampere (1775 -1836) to denote the sciences of government in his classification system of human knowledge. It was also used by Plato in The Laws to signify the governance of people. The words govern and governors are also derived from the same Greek root.

The study of teleological mechanisms (from the Greek telos for end, goal, or purpose) in machines with corrective feedback) dates from as far back as the late 1700s when James Watt's steam engine was equipped with a governor, a centrifugal feedback valve for controlling the speed of the engine. In 1868 James Clerk Maxwell published a theoretical article on governors. In 1935 Russian physiologist P.K. Anokhin published a book in which the concept of feedback ("back afferentation") was studied. The Romanian scientist Stefan Odobleja published Psychologie consonantiste (Paris, 1938), describing many cybernetic principles. In the 1940s the study and mathematical modelling of regulatory processes became a continuing research effort and two key articles were published in 1943. These papers were "Behavior, Purpose and Teleology" by Arturo Rosenblueth, Norbert Wiener, and Julian Bigelow; and the paper "A Logical Calculus of the Ideas Immanent in Nervous Activity" by Warren McCulloch and Walter Pitts.

Cybernetics as a discipline was firmly established by Wiener, McCulloch and others, such as W. Ross Ashby and W. Grey Walter. Together with the US and UK, an important geographical locus of early cybernetics was France where Wiener's book was first published. In the spring of 1947, Wiener was invited to a congress on harmonic analysis, held in Nancy, France and organized by the bourbakist mathematician, Szolem Mandelbrojt (1899-1983), uncle of the world famous mathematician Benoit Mandelbrot.

During this stay in France, Wiener received the offer to write a manuscript on the unifying character of this part of applied mathematics, which is found in the study of Brownian motion and in telecommunication engineering. The following summer, back in the United States, Wiener decided to introduce the neologism cybernetics into his scientific theory. Wiener popularized the social implications of cybernetics, drawing analogies between automatic systems such as a regulated steam engine and human institutions in his best-selling The Human Use of Human Beings : Cybernetics and Society (Houghton-Mifflin, 1950).

Scope

In scholarly terms, cybernetics is the study of systems and control in an abstracted sense, that is, it is not grounded in any one empirical field. The emphasis is on the functional relations that hold between the different parts of a system, rather than the parts themselves. These relations include the transfer of information, and circular relations (feedback) that result in emergent phenomena such as self-organization, and, (expressed as a term coined much later by Humberto Maturana, Francisco Varela and Ricardo Uribe), autopoiesis. The main innovation of cybernetics was the creation of a scientific discipline focused on goals: an understanding of goal-irectedness or purpose, resulting from a negative feedback loop which minimizes the deviation between the perceived situation and the desired situation (goal). As mechanistic as that sounds, cybernetics has the scope and rigor to encompass the human social interactions of agreement and collaboration that, after all, require goals and feedback to attain. Cybernetics is somewhat erroneously associated in many people's minds with robotics, due to uses such as Douglas Adams' Sirius Cybernetics Corporation and the concept of a cyborg, a term first popularized by Clynes and Kline in 1960. Additional confusion arose when terms such as 'cyberspace', 'cybercrime', and many others arose. A primary force behind second-order-cybernetics was Heinz von Foerster, an Austrian trained in physics and magic, who was appointed by Warren McCulloch as the editor of the Macy Meetings, a series of meetings held between 1946 and 1955, involving Gregory Bateson, Margaret Mead, F.S.C. Northrop, John von Neumann, Claude Shannon, Conrad Lorenz, Warren McCulloch, W. Grey alter, and Norbert Wiener. (Wiener is usually considered the father of cybernetics because of his authorship of the book Cybernetics, published in 1948, but this is an oversimplification that Wiener would be the first to point out.) These meetings were originally called Circular Causal and Feedback Mechanisms in Biological and Social Systems. From this original title, as well as the breadth of fields represented by the attendees, the scope and depth of second-order cybernetics is dramatically apparent.

Exercises

Answer the following questions

1. Where were cybernetic principles published firstly?
2. Who established cybernetic as a discipline?

3. Functional relations that hold between the different parts of systems include… (complete the expression)
4. “Teleological mechanisms” what does this definition mean?
5. Give the origin of the term “cybernetic”.

Translate the following phrases into English

1. Термин «кибернетика» имеет греческое происхождение.
2. Современная кибернетика затрагивает такие области, как системы контроля, теория электрических сетей, логическое моделирование и науку о нейронах.
3. Н. Винер считается отцом основателем кибернетики благодаря своей книге, написанной в 1948.
4. Некоторые люди ошибочно ассоциируют термин «кибернетика» с экранными киборгами, терминами «киберпространство» и «киберпреступление».
5. Н. Винер популяризовал последствия влияния кибернетики на социум, приводя исторические аналогии – автоматическая паровая машина и человек и их влияние на человека.

Additional reading

Feed- forward automatic control system

Li Dazhi, Wang Yanshan, Li Yonggui, Xie Jialin
Institute of high Energy physics, the Chinese Academy of Sciences, Beijing 100080, China

Abstract

A feed-forward automatic control system based on a novel control principle is developed, in order to compensate the amplitude and phase fluctuations of the microwave field in the thermionic RF gun cavity. The fluctuations, which are mainly caused by beam-loading effect, can be effectively restrained through this method. It is experimentally demonstrated that the novel control system has the excellent characteristics of stability and reliability.

Introduction

Beijing free electron laser facility (BFEL) is operable at infrared wave band. It adopts thermionic RF gun and linac to produce high energy electron beam (~30

MeV), in order to yield 5~20μm, 3mJ laser, during about 4μs micro-pulse operation, the back-bombardment of the electrons on the gun cathode increases beam current, declines the field amplitude and disturbs the RF phase in the cavity, which degrades the performance of output electron beam, especially energy spread. As we know, the performance of free electron laser strongly depends on the quality of electron beam, hence improvement on the quality of electron beam becomes very important. Though, generally, back-bombardment effect in this kind of guns is inevitable, many methods have been presented for optimizing the RF gun, including feed-forward control method.

Feed –forward control method is based on good reproducibility of system output. It adjusts RF amplitude and phase in a later macro-pulse to expected value, according to the information from former one. In 1990s, every point will be transferred to a computer for processing. During processing, these sample data are averaged firstly, and the average is considered as the feed-forward control system was first developed in Brookhaven national laboratory, on ATF line accelerator, and then many labs have studied this method on their own facility. Most of these works are based on the control principle of “transfer matrix”, which is used to describe the relation between input and output signal. Though the transfer matrix method avoids the difficulty of finding out the analytic expressions, it is hard to get the exact matrix because of the error from hardware and computation. On the other hand, the software designing becomes very complicated by using matrix calculation, which leads to unreliability and instability during operation. Therefore, those control systems cannot be applied widely and effectively, just being thought as experimental device.

Fundamental Principle

The control principle presented here is summed up as tracking every sample point and approaching the expected value step by step.

The control system includes four parts, data collector, data processing, signal generator and executing component. A digital oscilloscope is used to receive amplitude and phase signal through detector and DBM separately, and the signal is divided into a set of sample points by a certain interval (e.g. 10ns), next, the data of expected value; secondly, every sample data will contrast the expected value to find the difference; finally, the control data is to be built according to the difference, and is transferred to AFG to generate the analog signals.

As a result, the analog signal will modulate the input microwave before it goes into RF gun cavity, through executing components, attenuator and phase shifter. Repeat the above operation until the RF amplitude and phase in the RF gun cavity is uniform enough during a macro-pulse. Certainly, the whole process is operated automatically under control of computer. The control software is based on the Windows operating system, and developed by Visual Basic computer language.

Experimental Results

The control system has been mounted on the thermionic RF gun of BFEL facility and experiments about the control system have been demonstrated. The amplitude of RF field in the gun cavity declines nearly 50 mv over a period of 4.5 μs before control, due to beam-loading effect. That is to say, fluctuations in the amplitude (peak-peak) reduced from 15% to 1% after control. While before control, the top of phase signal is inclined with several peaks. And fluctuations are reduced from 6 degree to 0.6 degree after control, during a micro-pulse of 4.5μs, too. However, the most advantages of this control system contrasting to the old one are the excellent stability and reliability during the operation, and these characteristics are proved through large numbers of experiments. That means, the control system including software and hardware not only is experimental device, but also can be applied concretely to an accelerator system.

Conclusion

A novel principle was presented to realize feed-forward control system to compensate the beam-loading effect in the thermionic microwave gun. The system developed with the principle well does work and demonstrates excellent stability and reliability. Large numbers of experiments show that the control system can apply extensively to the relevant accelerator field.

Beam - луч, пучок лучей
Loading - нагрузка (максимальная сила тока или мощность, на которые рассчитана конструкция электрического устройства)
Software - программное обеспечение
Hardware – жёсткий диск
Attenuator - аттенюатор; развязка
Shifter - устройство переключения регистров (в печатающем устройстве)
Fluctuation - колебание; неустойчивость
Cavity - полость
Thermionic - термоэмиссионный
RF- радиочастота, высокая частота
Feed-forward - упреждение; предварение

Unit 11

Sensors

Encoder/angular encoder

Electrical signals

The signal data comprises, electrically, two individual signals – an inverted and non-inverted signal. The individual signals have a DC voltage component with a magnitude of half of the encoder power supply voltage. The differential signal of 1 V/pp is obtained in the encoder interface of the drive converter subtracting the individual signals. As a result of this situation, the DC voltage component of the signal track disappears and the signal amplitude doubles with respect to the individual signals.
The phase position of the reference signal maximum is between (centered) the sinusoidal and cosinusoidal signal.

Connection assignment

The encoder is connected through a 17-pin flange-mounted socket. Pre-assembled cables should be used to connect the encoder to the drive converter.

Clamping state sensors

Contactless transistor switches with 3-wire connection are used for the clamping status sensors. These clamping status sensors are connected through plug connectors. The connector is directly integrated into the sensor.

The cables which are used to establish a connector on the sensor side are not included with the spindle. These cables are commercially available as standard products.

Dependent on the position of the pool rod, the clamping status sensors respond and allow the clamping state to be detected.

A tool may only be changed when the spindle is at a complete standstill. The pneumatic cylinder must have the correct pressure while removing and inserting the tool.

The clamping system could be damaged if tool change operations are carried-out without the pneumatic cylinder having the correct pressure.

If the spindle is used without sensors, then other measures must be applied to ensure that the correct clamping state is reached before the spindle is enabled for rotation or a tool can be changed. These measures include, for example, toll monitoring or specific operator actions.

Exercises

Find mistakes in these sentences and correct them. Each sentence contains 2 mistakes.

1. The most people agree that women can do the same work as men.
2. The trouble with the large meetings is that they go on for a longer time than small ones.
3. You have to catch train from the Paddington Station to get to Wales.
4. She's a student and she's studying the economics at the Vienna University.
5. I'm staying in the room number 609 at Holiday Inn near the airport.
6. The most of my colleagues are more interested in the sport than in business.
7. Could you give me an information about the venue of meeting.
8. Does the machine need new component or do we need to think about ordering a new equipment?
9. I sometimes get feeling that I spend all my time in the meetings.

10. I don't enjoy talking on a phone, I prefer to send an e-mail or write the letters.

Fit suitable conjunctions into these sentences: *if   in case unless   until   when*

1. We are unable to supply the goods____ we receive payment in advance.
2. A spare axle is provided___ one is damaged during routine use.
3. The machine should not be modified___ a service engineer is present.
4. The filter should be changed____ the unit has been in operation for two months.
5. The red light will come on___ the machine overheats.
6. The machine shouldn't be touched____ it has cooled down.
7. There's a first aid box____ someone hurts themselves
8. The red light will not go out____ the green switch has been pressed.

Underline the correct alternatives in these sentences.

1. *Eat/Eating/To eat* the local food and *drink/drinking/to drink* the local wine made me feel ill the next day
2. We were very annoyed *find out/finding out/to find out* that customs formalities took so long.
3. I'm afraid I didn't remember *post/posting/to post* the letter.
4. I try *avoid/avoiding/to avoid go/going/to go* abroad during the summer.
5. On the way to my host's house I stopped *buy/buying /to buy* some flowers.
6. After a long day I was looking to *have/having* a drink, a shower and a rest.
7. If you go to live in another country it can take a long time *get/getting/to get* used the way of life.
8. Have you managed *get/getting/to get* me a seat on tomorrow's flight?

Additional reading

How to present your company.

After having read the presentation, try to present the company you are working for.

Factory Automation Systems is a full-service engineering and integration services company with exceptional knowledge in a broad range of automation techniques. We are the experts on control systems, but our customers are the experts on the intricacies of their businesses. Only through partnership can we deliver the highest level of quality workmanship and service which suits our customers' individual technologies and requirements. Our success at making our customers' manufacturing systems more efficient and profitable is attributable to this partnering approach.

About Our Company

Factory Automation Systems, Inc. specializes in the integration of Programmable Logic Controllers (PLC's), computers, robotic technologies, motion control and drive systems in order to provide effective manufacturing process control and information systems. We are recognized experts in the field of factory automation and control systems because we develop and implement innovative solutions.

MISSION

Our mission is stated by four basic principles:

Quality
The company's associates will provide the very highest quality service in all aspects of our business.

Efficiency
Every associate will assume responsibility for maintaining the most efficient use of resources and assets on all projects. It is only through efficient projects that we provide value to our customers.

Leadership
The company shall strive to be an industry leader in every aspect of business that it pursues. Technical leadership in the factory automation business can only be maintained by having the best people, supported in an environment of personal growth and commitment.

Responsibility
Each associate is responsible to maintain the highest degree of professionalism, keeping focus on being responsible for all actions in every endeavor.

HISTORY

Factory Automation Systems was established in February of 1992 as a Georgia based S corporation. Our operations are based in our 50,000 square foot facility in Atlanta, Georgia. We currently have a staff of over 120, and we continue to grow.

In addition, Factory Automation Systems established operations in Mexico. FAS de Mexico S.A. de C.V. was established in 1997 to further service our already strong relationships in Central and South America.

About our Services

Robotics

Integrated Manufacturing Systems

Manufacturing Execution Systems

Automation System Specification Development

System Conceptual Design

Project Management

Hardware Design

Software Design

Turn-key Robotic/Automation Systems Implementation

Motion Control & Drive Systems

Programmable Logic Control Systems

Emergency Service Solutions

Panel Fabrication (UL Approved Panel Fabricator)

Installation

Start-up and System Initialization

Documentation

Training

Technical Support Services

We can offer any or all of these services for your particular project. We deal with all major brands of PLC equipment, application enabler software, and computer hardware. We are an authorized **Allen-Bradley** Solution Provider, **Rockwell Software** Solution Provider, **US DATA - FactoryLink** and **InTouch - Wonderware** authorized integrators, and **HP** Channel Partners. In robotics, we are authorized integrators for **ABB** and **Motoman**. Factory Automation Systems is also a member of the **Manufacturing Execution Systems Association (MESA)** and is a **Microsoft Solutions Provider**

The ability of machines to replace human effort is at an unsurpassed level. Factory Automation Systems offers the experience, creativity and perspective to properly implement robotic technologies.

We are fully qualified and experienced in the proper implementation of gantry robots, 6 axis articulated arm robots and custom designed units.

Our experienced staff has successfully completed over 1,500 robotic installations. We are industry leaders in creative end-of-arm tooling design and recognized worldwide as leaders in robotic applications. But two things separate Factory Automation Systems from other robotic technology providers:

1. **Creativity**. The measure of creativity at Factory Automation Systems is how **simple** we can make things.
2. **Completeness**. Factory Automation Systems is expert in multiple technologies-computer integration, discrete controls-PLCs and sensors, drive and motion control systems and robotics.

Additionally, our written corporate project methodologies and daily practice in proper project management, combined with our technology expertise, provide you with a truly turnkey robotics engineering resource.

Controller takes charge of Cartesian robot

TM Robotics' new TS2000 controller offers enhanced monitoring and control for its Cartesian linear actuator, the ROIbot.

The built-in PLC makes it easy for the robot to interface with peripheral devices, rendering the robotic cell a tool for complete system control. The TS2000 simplifiers and increases the speed of data transfer and can handle up to 38 inputs and 32 outputs with the capacity to extend I\O. All outputs are selectable between plus- common and minus-common, allowing both negative and positive switching. The ROIBot can be configured in up to 250 variations, and has a payload capacity of up to 150kg per axis. Despite such payloads, constant-speed control provides the smooth movement required in delicate application such as sealing, gluing and water jet cutting. Featuring control of up to five axes simultaneously, the controller has a memory capacity of up to 6400 points, or 12800 steps. Any one program can store up to 2000 points or 3000 steps. There are 256 operable programs, comprised of 247 user files and nine systems files. Serial communication ports are RS232C with options for DeviceNet and Profibus connectivity. The controller can be used in conjunction with a TP1000 teach pendant. Self-diagnosis makes maintenance easy, as the teach pendant displays an error code in the event of multifunction. The robot program can also be written on a PC, thus making programming a simpler process. The controller itself operates using a proprietary programming language, SCOL, which is very similar to Basic. An interruptive function allows the robot to complete discrete tasks and then return to its primary program. Torque control for downward pressure protects the robot, gripper and the product being manufactured. Measuring only 290mm wide by 230mm high and weighing just 12kg the controller is sufficiently compact to fit into any application where a Cartesian robot might be required

Unit 12

Electrical engineering

Electrical engineering (sometimes referred to as electrical and electronics engineering) is a professional engineering discipline that deals with the study and application of electricity, electronics and electromagnetism. The field first became an identifiable occupation in the late nineteenth century with the commercialization of the electric telegraph and electrical power supply. The field now covers a range of sub-disciplines including those that deal with power, control systems, electronics and telecommunications. The term electrical engineering may or may not encompass electronics engineering. Where a distinction is made, electrical engineering is considered to deal with the problems associated with large-scale electrical systems such as power transmission and motor control, whereas electronics engineering deals with the study of small-scale electronic systems including computers and integrated circuits. Another way of looking at the distinction is that electrical engineers are usually concerned with using electricity to transmit energy, while electronics engineers are concerned with using electricity to transmit information

History of electrical engineering

Early developments

Electricity has been a subject of scientific interest since at least the 17th century, but it was not until the 19th century that research into the subject started to intensify. Notable developments in this century include the work of George Ohm, who in 1827 quantified the relationship between the electric current and potential difference in a conductor, Michael Faraday, the discoverer of electromagnetic induction in 1831, and James Clerk Maxwell, who in 1873 published a unified theory of electricity and magnetism in his treatise on
Electricity and Magnetism. During these years, the study of electricity was largely considered to be a subfield of physics. It was not until the late 19th century that universities started to offer degrees in electrical engineering. The Darmstadt University of Technology founded the first chair and the first faculty of electrical engineering worldwide in 1882. In 1883 Darmstadt University of Technology and Cornell University introduced the world's first courses of study in electrical engineering and in 1885 the University College London founded the first chair of electrical engineering in the United Kingdom. The University of Missouri subsequently established the first department of electrical engineering in the United States in 1886.

Thomas Edison built the world's first large-scale electrical supply network. During this period, the work concerning electrical engineering increased dramatically. In 1882, Edison switched on the world's first large-scale electrical supply network that provided 110 volts direct current to fifty-nine customers in lower Manhattan. In 1887, Nikolai Tesla filed a number of patents related to a competing form of power distribution known as alternating current. In the following years a bitter rivalry between Tesla and Edison, known as the "War of Currents", took place over the preferred method of distribution. AC eventually replaced DC for generation and power distribution, enormously extending the range and improving the safety and efficiency of power distribution.

Nikolai Tesla made long-distance electrical transmission networks. The efforts of the two did much to further electrical engineering ”Tesla's work on induction motors and polyphase systems influenced the field for years to come, while Edison's work on telegraphy and his development of the stock ticker proved lucrative for his company, which ultimately became General Electric. However, by the end of the 19th century, other key figures in the progress of electrical engineering were beginning to emerge. Modern developments Emergence of radio and electronics during the development of radio, many scientists and inventors contributed to radio technology and electronics. In his classic UHF experiments of 1888, Heinrich Hertz transmitted (via a spark-gap transmitter) and detected radio waves using electrical equipment. In 1895, Nikolai Tesla was able to detect signals from the transmissions of his New York lab at West Point (a distance of 80.4 km). John Fleming invented the first radio tube, the diode, in 1904.

Two years later, Robert von Lieben and Lee De Forest independently developed the amplifier tube, called the triode. Manfred von Ardenne then introduced the cathode ray tube, a crucial enabling technology for electronic television, in 1931. In 1920 Albert Hull developed the magnetron which would eventually lead to the development of the microwave oven in 1946 by Percy Spencer. In 1934 the British military began to make strides towards radar (which also uses the magnetron), under the direction of Dr Wimperis culminating in the operation of the first radar station at Bawdsey in August 1936. In 1941 Konrad Zuse presented the Z3, the world's first fully functional and programmable computer. In 1946 the ENIAC (Electronic Numerical Integrator and Computer) of John Presper Eckert and John Mauchly followed, beginning the computing era. The arithmetic performance of these machines allowed engineers to develop completely new technologies and achieve new objectives, including the Apollo missions and the NASA moon landing. The invention of the transistor in 1947 by William B. Shockley, John Bardeen and Walter Brattain opened the door for more compact devices and led to the development of the integrated circuit in 1958 by Jack Kilby and independently in 1959 by Robert Noyce. In 1968 Marcian Hoff invented the first microprocessor at Intel and thus ignited the development of the personal computer. The first realization of the microprocessor was the Intel 4004, a 4-bit processor developed in 1971, but only in 1973 did the Intel 8080, an 8-bit processor, make the building of the first personal computer, the Altair 8800, possible education. Electrical engineers typically possess an academic degree with a major in electrical engineering. The length of study for such a degree is usually four or five years and the completed degree may be designated as a Bachelor of Engineering, Bachelor of Science, Bachelor of Technology or Bachelor of Applied Science depending upon the university. The degree generally includes units covering physics, mathematics, project management and specific topics in electrical engineering. Initially such topics cover most, if not all, of the sub-disciplines of electrical engineering. Students then choose to specialize in one or more sub-disciplines towards the end of the degree. Some electrical engineers also choose to pursue a postgraduate degree such as a Master of Engineering/Master of Science, a Master of Engineering Management, a Doctor of Philosophy in Engineering or an Engineer's degree. The Master and Engineer's degree may consist of either research, coursework or a mixture of the two. The Doctor of Philosophy consists of a significant research component and is often viewed as the entry point to academia. In the United Kingdom and various other European countries, the Master of Engineering is often considered an undergraduate degree of slightly longer duration than the Bachelor of Engineering. Practicing engineers in most countries, a Bachelor's degree in engineering represents the first step towards professional certification and the degree program itself is certified by a professional body. After completing a certified degree program the engineer must satisfy a range of requirements (including work experience requirements) before being certified. Once certified the engineer is designated the title of Professional Engineer (in the United States, Canada and South Africa), Chartered Engineer (in the United Kingdom, Ireland, India and Zimbabwe), Chartered Professional Engineer (in Australia and New Zealand) or European Engineer (in much of the European Union).The advantages of certification vary depending upon location. For example, in the United States and Canada "only a licensed engineer may seal engineering work for public and private clients". This requirement is enforced by state and provincial legislation such as Quebec's Engineers Act. In other countries, such as Australia, no such legislation exists. Practically all certifying bodies maintain a code of ethics that they expect all members to abide by or risk expulsion. In this way these organizations play an important role in maintaining ethical standards for the profession. Even in jurisdictions where certification has little or no legal bearing on work, engineers are subject to contract law. In cases where an engineer's work fails he or she may be subject to the tort of negligence and, in extreme cases, the charge of criminal negligence. An engineer's work must also comply with numerous other rules and regulations such as building codes and legislation pertaining to environmental law.

Professional bodies of note for electrical engineers include the Institute of Electrical and Electronics Engineers (IEEE) and the Institution of Electrical Engineers (IEE). The IEEE claims to produce 30 percent of the world's literature in electrical engineering, has over 360,000 members worldwide and holds over 300 conferences annually. The IEE publishes 14 journals, has a worldwide membership of 120,000, and claims to be the largest professional engineering society in Europe. Obsolescence of technical skills is a serious concern for electrical engineers. Membership and participation in technical societies, regular reviews of periodicals in the field and a habit of continued learning are therefore essential to maintaining proficiency. In countries such as Australia, Canada and the United States electrical engineers make up around 0.25% of the labor force . Outside of these countries, it is difficult to gauge the demographics of the profession due to less meticulous reporting on labor statistics. However, in terms of electrical engineering graduates per-capita, electrical engineering graduates would probably be most numerous in countries such as Japan and South Korea. Tools and work from the Global Positioning System to electric power generation, electrical engineers are responsible for a wide range of technologies. They design, develop, test and supervise the deployment of electrical systems and electronic devices. For example, they may work on the design of telecommunication systems, the operation of electric power stations, the lighting and wiring of buildings, the design of household appliances or the electrical control of industrial machinery.

Radar is one of many projects an electrical engineer might work on Fundamental to the discipline are the sciences of physics and mathematics as these help to obtain both a qualitative and quantitative description of how such systems will work. Today most engineering work involves the use of computers and it is commonplace to use computer-aided design programs when designing electrical systems. Nevertheless, the ability to sketch ideas is still invaluable for quickly communicating with others Although most electrical engineers will understand basic circuit theory (that is the interactions of elements such as resistors, capacitors, diodes, transistors and inductors in a circuit), the theories employed by engineers generally depend upon the work they do. For example, quantum mechanics and solid state physics might be relevant to an engineer working on VLSI (the design of integrated circuits), but are largely irrelevant to engineers working with macroscopic electrical systems. Even circuit theory may not be relevant to a person designing telecommunication systems that use off-the-shelf components. Perhaps the most important technical skills for electrical engineers are reflected in university programs, which emphasize strong numerical skills, computer literacy and the ability to understand the technical language and concepts that relate to electrical engineering.

For most engineers technical work accounts for only a fraction of the work they do. A lot of time is also spent on tasks such as discussing proposals with clients, preparing budgets and determining project schedules. Many senior engineers manage a team of technicians or other engineers and for this reason project management skills are important. Most engineering projects involve some form of documentation and strong written communication skills are therefore very important.

The workplaces of electrical engineers are just as varied as the types of work they do. Electrical engineers may be found in the pristine lab environment of a fabrication plant, the offices of a consulting firm or on site at a mine. During their working life, electrical engineers may find themselves supervising a wide range of individuals including scientists, electricians, computer programmers and other engineers.

Sub-disciplines

Electrical engineering has many sub-disciplines, the most popular of which are listed below. Although there are electrical engineers who focus exclusively on one of these sub-disciplines, many deal with a combination of them. Sometimes certain fields, such as electronics engineering and computer engineering, are considered separate disciplines in their own right.

Power engineering

Power engineering deals with the generation, transmission and distribution of electricity as well as the design of a range of related devices. These include transformers, electric generators, electric motors and power electronics. In many regions of the world, governments maintain an electrical network called a power grid that connects a variety of generators together with users of their energy. Users purchase electrical energy from the grid, avoiding the costly exercise of having to generate their own. Power engineers may work on the design and maintenance of the power grid as well as the power systems that connect to it. Such systems are called on-grid power systems and may supply the grid with additional power, draw power from the grid or do both. Power engineers may also work on systems that do not connect to the grid, called off-grid power systems, which in some cases are preferable to on-grid systems.

Control engineering

Control engineering focuses on the modeling of a diverse range of dynamic systems and the design of controllers that will cause these systems to behave in the desired manner. To implement such controllers' electrical engineers may use electrical circuits, digital signal processors and microcontrollers. Control engineering has a wide range of applications from the flight and propulsion systems of commercial airliners to the cruise control present in many modern automobiles. It also plays an important role in industrial automation. Control engineers often utilize feedback when designing control systems. For example, in an automobile with cruise control the vehicle's speed is continuously monitored and fed back to the system which adjusts the motor's speed accordingly. Where there is regular feedback, control theory can be used to determine how the system responds to such feedback.

Electronics engineering

Electronics engineering involves the design and testing of electronic circuits that use the properties of components such as resistors, capacitors, inductors, diodes and transistors to achieve a particular functionality. The tuned circuit, which allows the user of a radio to filter out all but a single station, is just one example of such a circuit. Another example (of a pneumatic signal conditioner) is shown in the adjacent photograph. Prior to the Second World War, the subject was commonly known as radio engineering and basically was restricted to aspects of communications and radar, commercial radio and early television. Later, in post war years, as consumer devices began to be developed, the field grew to include modern television, audio systems, computers and microprocessors. In the mid to late 1950s, the term radio engineering gradually gave way to the name electronics engineering. Before the invention of the integrated circuit in 1959, electronic circuits were constructed from discrete components that could be manipulated by humans. These discrete circuits consumed much space and power and were limited in speed although they are still common in some applications. By contrast, integrated circuits packed a large number, often millions of tiny electrical components, mainly transistors, into a small chip around the size of a coin. This allowed for the powerful computers and other electronic devices we see today.

Microelectronics

Microelectronics engineering deals with the design of very small electronic components for use in an integrated circuit or sometimes for use on their own as a general electronic component. The most common microelectronic components are semiconductor transistors, although all main electronic components (resistors, capacitors, inductors) can be created at a microscopic level. Most components are designed by determining processes to mix silicon with other atoms to create a desired electromagnetic effect. For this reason microelectronics involves a significant amount of quantum mechanics and chemistry.

Signal processing

Signal processing deals with the analysis and manipulation of signals. Signals can be either analog, in which case the signal varies continuously according to the information, or digital, in which case the signal varies according to a series of discrete values representing the information. For analog signals, signal processing may involve the amplification and filtering of audio signals for audio equipment or the modulation and demodulation of signals for telecommunications. For digital signals, signal processing may involve the compression, error detection and error correction of digitally sampled signals.

Telecommunications engineering

Telecommunications engineering focuses on the transmission of information across a channel such as a coax cable, optical fiber or free space. Transmissions across free space require information to be encoded in a carrier wave in order

to shift the information to a carrier frequency suitable for transmission, this is known as modulation. Popular analog modulation techniques include amplitude modulation and frequency modulation. The choice of modulation affects the cost and performance of a system and these two factors must be balanced carefully by the engineer. Once the transmission characteristics of a system are determined, telecommunication engineers design the transmitters and receivers needed for such systems. These two are sometimes combined to form a two-way communication device known as a transceiver. A key consideration in the design of transmitters is their power consumption as this is closely related to their signal strength. If the signal strength of a transmitter is insufficient the signal's information will be corrupted by noise.

Instrumentation engineering

Instrumentation engineering deals with the design of devices to measure physical quantities such as pressure, flow and temperature. The design of such instrumentation requires a good understanding of physics that often extends beyond electromagnetic theory. For example, radar guns use the Doppler effect to measure the speed of oncoming vehicles. Similarly, thermocouples use the Peltier-Seebeck effect to measure the temperature difference between two points. Often instrumentation is not used by itself, but instead as the sensors of larger electrical systems. For example, a thermocouple might be used to help ensure a furnace's temperature remains constant. For this reason, instrumentation engineering is often viewed as the counterpart of control engineering.

Computer engineering

Computer engineering deals with the design of computers and computer systems. This may involve the design of new hardware, the design of PDAs or the use of computers to control an industrial plant. Computer engineers may also work on a system's software. However, the design of complex software systems is often the domain of software engineering, which is usually considered a separate discipline. Desktop computers represent a tiny fraction of the devices a computer engineer might work on, as computer-like architectures are now found in a range of devices including video game consoles and DVD players.

Related disciplines

Mechatronics is an engineering discipline which deals with the convergence of electrical and mechanical systems. Such combined systems are known as electromechanical systems and have widespread adoption. Examples include automated manufacturing systems, heating, ventilation and air-conditioning systems and various subsystems of aircraft and automobiles. The term Mechatronics is typically used to refer to macroscopic systems but futurists have predicted the emergence of very small electromechanical devices. Already such small devices, known as micro electromechanical systems (MEMS), are used in automobiles to tell airbags when to deploy, in digital projectors to create sharper images and in inkjet printers to create nozzles for high-definition printing. In the future it is hoped the devices will help build tiny implantable medical devices and improve optical communication. Biomedical engineering is another related discipline, concerned with the design of medical equipment. This includes fixed equipment such as ventilators, MRI scanners and electrocardiograph monitors as well as mobile equipment such as cochlear implants, artificial pacemakers and artificial hearts.

Exercises

Define what historical inventions in electrical engineering were done by those scientists.

George Ohm – in 1827, Michael Faraday – in 1831, James Clerk Maxwell – in 1873, Thomas Edison – in 1882, Nikolai Tesla – in 1887, Henrich Hertz – in 1888, John Fleming – in 1904, Albert Hull – 1904, Percy Spencer – 1946, Marcian Hoff – 1968.

Complete the following sentences.

1. Electrical engineers are responsible for a wide range of technologies, they design…

2. The basic circuit theory – is the interactions of elements such as …

3. Electrical engineering connects with such sub-disciplines as …

4. Power engineering deals with …

5. Control engineering focuses on …

6. Radio engineering that uses the properties of components such as …….. gradually gave way to the name – electronics engineering.

7. To create desired electro-magnetic effect, most components are designed by determining process to …

8. ….deals with the analysis and manipulation of signals.

9. To shift the information to a carrier frequency suitable for transmission is called …

10. The domain of software engineering deals with the…

Unit 13

Measuring Instruments

Ammeters

Ammeters measure current. Current in electronics is usually measured in mA which are called milliamperes, which are 1/1000s of an ampere.

..... Basically an ammeter consists of a coil that can rotate inside a magnet, but a spring is trying to push the coil back to zero. The larger the current that flows through the coil, the larger the angle of rotation, the torque (= a rotary force) created by the current being counteracted by the return torque of the spring.

..... Usually ammeters are connected in parallel with various switched resistors that can extend the range of currents that can be measured. Assume, for example, that the basic ammeter is "1000 ohms per volt", which means that to get the full-scale deflection of the pointer a current of 1 mA is needed (1 volt divided by 1000 ohms is 1 mA - see "Ohm's Law").

..... To use that ammeter to read 10 mA full-scale it is *shunted* with another resistance, so that when 10 mA flows, 9 mA will flow through the shunt, and only 1 mA will flow through the meter. Similarly, to extend the range of the ammeter to 100 mA the shunt will carry 99 mA, and the meter only 1 mA.

Voltmeters

Voltmeters are basically ammeters that are *connected in series with resistors*. Assume that the basic ammeter is "1000 ohms per volt", meaning that to get a full-scale deflection, 1 mA is needed. To extend the range to measure 10 volts for full-scale deflection the resistor needed to be connected in series has to be large enough to take up most of the voltage, so that only 1 mA will flow through the meter when 10 volts are connected.

Ohmmeters

Ohmmeters are basically ammeters that are *connected to an internal battery, with a suitable resistance in series*. Assume that the basic ammeter is "1000 ohms per volt", meaning that 1 mA is needed for full-scale deflection. When the external resistance that is connected to its terminals is zero (the leads are connected together at first for calibration), then the internal, variable, resistor in series with the ammeter is adjusted so that 1 mA will flow; that will depend on the voltage of the battery, and as the battery runs down that setting will change. The full scale point is marked as zero resistance. If an external resistance is then connected to the terminals that causes only half of the current to flow (0.5 mA in this example), then the external resistance will equal the internal resistance, and the scale is marked accordingly. When no current flows, the scale will read infinity resistance. The scale of an ohmmeter is NOT linear.

Multimeters

A digital multimeter

Multimeters contain Ohmeters, Voltmeters, Ammeters and a variety of capabilities to measure other quantities. AC and DC voltages are most often measurable. Frequency of AC voltages. Multimeters also feature a continuity detector, basically an Ohmmeter with a beeper if the multimeter sees less than 100 Ω then it beeps otherwise it is silent. This is very useful for finding whether components are connected when debugging or testing circuits. Multimeters are also often able to measure capacitance and inductance. This may be achieved using a Wien bridge. A diode tester is also generally onboard, this allows one to determine the anode and cathode of an unknown diode. A LCD display is also provided for easily reading of results.

What is a Transistor?

We've seen "resistors" that change their resistance in response to light (photoresistors) or to mechanically turning a knob (potentiometers).
A transistor can be initially thought of as an "electronically-controlled resistor", although the name is quite misleading. Two of the pins act like a normal resistor (more or less). The other "control" pin controls the resistance "seen" between the other 2 pins.
The "control" pin is called the *gate* in a FET transistor (the other 2 pins are the *source* and *drain*).
The "control" pin is called the *base* in a BJT transistor (the other 2 pins are the *emitter* and the *collector*).
Two electrical quantities can be used to control the resistance between the two terminals - current and voltage. In an FET, the voltage at the gate controls the resistance between source and drain, while in the BJT, the current flowing into the base controls the resistance between the emitter and collector.

General

While often referred to as an amplifier, a transistor does not create a higher voltage or current of its own accord. Like any other device it obeys the Kirchoff's laws. The resistance of a transistor dynamically changes, hence the term *trans*istor. (*Actually the word came from a contraction of "transconductance varistor" or "transfer varistor", but this is a useful mnemonic for remembering its function.*)
One of its popular uses is in building a signal amplifier (note that it is not like a transformer), but it can also be used as a switch. Transistors were the second generation devices, and have revolutionalized the world of electronics. They have almost completely replaced vacuum tubes and are as ubiquitous as resistors.
The transistor revolution gave way to the Integrated circuit technology around the early 50s when Jack Kilby from Texas Instruments made the first Integrated Circuit (IC) of the world. Today's transistors are mostly found inside ICs. Stand-alone transistors are used mostly only in high power applications or for power-regulation.
Both the BJT and the FET are popular today, (among the FETs, the MOSFET being the most popular form of transistor) each one having certain advantages over the other. BJT's are much faster and high current devices, while FETs are small-sized low-power devices. Attempts are underway to integrate both features on a single chip (BiCMOS technology) to produce extremely fast, dense logic ICs, that can perform complex functions. Understanding the function of a transistor is a key to understanding electronics.

Field Effect Transistor

The most common transistors today are FETs.
Field Effect Transistor: These transistors are characterized as having a conductance between source and drain dependent on the voltage applied between the gate and the source terminals. The dependance is linear if the gate to drain voltage is also high along with the gate to source voltage. It turns into a square-law relationship if the gate to drain voltage is not enough.
One of the issues that comes up in circuit design is that as chips get smaller the insulator gets thinner and it starts to look like swiss cheese. As a result the insulator starts acting like a conductor. This is known as leakage current. One solution is to replace the insulator by a material with a higher dielectric coefficent.
Two types: enhancement and depletion. Enhancement is the standard MOSFET, in which a channel must be induced by applying voltage. Depletion MOSFETs have the channel implanted, and applying voltage causes the channel to cease being conductive.
FET transistors respond to the difference in voltage bias between the gate and the source.
MOSFET (Metal-Oxide-Semiconductor FET): standard FET
JFET (Junction Fet): When voltage is applied between the source and drain current flows. Current only stops flowing when a voltage is applied to the gate.
MESFET (MEtal-Semiconductor FET): p-n junction is replaced with Scottky junction. Not made with Silicon.
HEMT (High Electron Mobility Transfer): A MESFET
PHEMT (Pseudomorphic HEMT):

Complementary Metal Oxide Semiconductor

CMOS is not a type of transistor. It is a logic family, based on MOS transistors.
Complementary Metal Oxide Semiconductor CMOS is made of two FETs blocking the positive and negative voltages. Since only one FET can be on at a time, CMOS consumes negligible power during any of the logic states. But when a transition between states occurs, power is consumed by the device. This power consumed is of two types.
Short-circuit power: For a very short duration, both transistors are on and a very huge current flows through the device for that duration. This current accounts for about 10% of the total power consumed by the CMOS.
Dynamic power: This is due to charge stored on the parasitic capacitance of the output node of the device. This parasitic capacitance depends on the wire's area, and closeness to other layers of metal in the IC, besides the relative permittivity

of the quartz layer separating consecutive metal layers. It also depends (to a much smaller extent) upon the *input capacitance* of the next logic gate. This capacitance delays the rise in the output voltage and hence the rise or fall in the output of a gate is more like a that in a resistor-capacitor (RC) network. Thus the dynamic power consumed due to switching action in one gate is given by:

$$P_d = CV_d^2 f$$

Bipolar Junction Transistor

Bipolar Junction Transistor: The current through the collector and emitter terminals of a BJT is controlled by the current entering the base. If one applies the Kirchoff's current law on the device, the current entering the device through all the terminals must add up to zero. Hence I_C is not the same as I_E.

Construction

A lightly doped region called base is sandwiched between two regions called the emitter and collector respectively. The collector handles large quantities of current, hence its dopant concentration is the highest. The emitter's dopant concentration is slightly lesser, but its area is larger to provide for more current than the collector. The collector region should be heavily doped because electron-hole pair recombine in that region, while the emitter is not such a region. We can have two varieties in this kind of transistor.

NPN

Here a lightly doped p-type semiconductor (semiconductor with more holes than electrons) is sandwiched between two well-doped n-type regions. It is like two pn-junctions facing away. An IEEE symbol for the npn transistor is shown here. The arrow between the base and emitter is in the same direction as current flowing between the base-emitter junction. Power dissipated in the transistor is

$P = V_{CE}I_C$, where V_{CE} is the voltage between the collector and the emitter and I_C is the collector current.

PNP

Here everything is opposite that of npn. This one is more like two pn-junctions facing each other. Its IEEE symbol is shown here. Again, note the direction of the arrow.

Operation

The BJT functions

Other materials

Nearly all transistors are built into integrated circuits on slabs of high-purity silicon.

Some high-speed transistors are built of GaAs.

Some space-rated integrated circuits are silicon-on-sapphire.

Because transistors are limited by the amount of power they can dissipate, it seems that diamond (which has an unusually high thermal conductivity for such a good insulator) would be a good choice.

Some people speculate that tiny transistors can be built out of individual carbon .

External links

Basics

Capacitors as memory

- Capacitors can be charged, and when they are charged they can be discharged.
- When charged they act like a source of voltage but only for a limited time unless they are "refreshed".
- If charged they can be "refreshed" by charging them again and again to keep their voltage above a specified minimum. This procedure can be quite automatic at regular intervals and applies ONLY to capacitors that already have a voltage that is above that set minimum.
- "Writing" into a capacitor-memory means either charging that capacitor or discharging it as required. We say that a memory is "a zero" if its voltage is below a specified value, and it is "a one" if above. Putting a 1 into the memory means charging the capacitor, while putting a 0 into the memory means discharging the capacitor.
- "Reading" a capacitor-memory is equivalent to putting a voltmeter across its terminals to see whether its voltage is or is not above a given minimum.

NOTE: Modern memories use transistors, gates, diodes, etc.

Examples

Reference 1: Programmer's Reference Guide for the Commodore 64 Personal Computer, published in 1988 by Commodore Business Machines, Inc.

- part of the microprocessor 6510's characteristics:
- For a 0 the minimum is minus 0.3 Volt, and the maximum is plus 0.3 Volt.
- For a 1 the minimum is plus 2.0 Volt, and the maximum is 1 Volt above the supply voltage which usually is about 5 Volt, but whose absolute maximum is 7.0 Volt. Note that static electricity (by friction on the carpet for example) can cause a lot of damage and must be guarded against.

Reference 2: The Semiconductor Memory Data Book for Design Engineers, published in 1975 by Texas Instruments Inc.

Bits

- Think of "one bit" as one memory unit, such as one capacitor-memory. It can have a 0 or a 1 "in it", as required; a "High" (H) usually is a 1, and a "Low" (L) usually is a 0. Bit is a shortened version of binary digit.

Bytes

A byte is a group of bits. One bit can only represent "a count" of zero or one, two bits grouped together into a byte can represent a count of zero to 3, 3 bits into a byte can count up to 7 and n bits in a byte can count up to 2^n minus 1. A byte with 8 bits in it can count from 0 to 255. "Words" are bytes; they each have a stated number of bits in them.

- Bytes can also be combined; 2 bytes, each with 8 bits in it, can count up to 256 times 256 minus 1, that is 0 to 65535.

Words

- Words are a concept that dates back to early computer architechtures, where a single "unit" of memory was different from 8 bits. Common early word sizes were often 10 bits, but sometimes six or 20 bits.
- Generally a word was defined as the size of the memory bus for internal storage (i.e. RAM or ROM), as well as the minimum independently addressable unit of memory.

- Most modern CPU architechtures use independently addressable byte architechture, but some modern CPUs (like the Pentium and other x86 CPUs) perform memory and instruction tasks more efficiently if the memory is "aligned" on word boundaries.
- Terms like **word** and **longword** date back to 16-bit and 32-bit CPU architechtures respectively, and to give a common framework for backward compatable software tools. More recently, the term **quadword** is used to denote a 64-bit piece of memory, although the term **octaword** is sometimes used (because it is 8-bytes being accessed at once).
- Endian architechture defines how the memory is encoded within the RAM of the computer and its relationship with the byte addresses. Generally this is not an issue for most software except when you write data files meant for consumption on multiple platforms that have multi-byte components.

Address Bus connection

Just as the mail delivery person needs to have an address on each item to be delivered/collected, so also access to a particular byte of memory is "delivered" to a particular address, or "collected" from a particular address.

- For example a memory can have 16 address connections, labelled 0 to 15. That means that data can be fed into, or taken out of, a specific memory cell, whose address is between 0 and (2^{16} minus one), which is between 0 and 65535.

Data Bus connection

After the specific address has been fed into the memory, a specific given number is fed ("written") into the data bus connection, or the content of that address is "read".

- For example a memory can have 8 data connections, labelled 0 to 7. That means that the number fed into the selected byte must be between 0 and (2^8 minus one), which is between 0 and 255.

Read/Write connection

There is also an input terminal connection that indicates the operation required. A 0 into that connection may indicate that the next operation will be a "write", while a 1 may indicate that it will be a "read".

Clock connection

A memory may require one or more clock signals, possibly "phase 1" and "phase 2", etc., which are inputs into the memory from oscillators, meaning they alternate very fast between 0 and 1 continously. While the clock is, maybe, 0 various changes can be made, such as an address change and/or a change of data, but the actual reading or writing takes place only while the clock is, maybe, 1. Some memories include clock oscillators, possibly requiring external crystals.

Volatile memories lose their contents if the power supply is lost or switched off.

RAM

A RAM is a "Random Access Memory" - Sizes and their architecture vary considerably, users can put into any of their addressed bytes any number up to a given maximum, and that number can be replaced by another number as required, when required. Some memories supply the complements of what was put into them.

- For example a memory with 1024 bits can require only a 0 or 1 to be put into any of the 1024 cells, while another memory can require 4 bits (0 to 15) per word, but only 16 words can be retained at a time, etc.

Dynamic Read/Write Memories require frequent refreshing.

Static Read/Write Memories retain the data even if control signals are absent, however such memories may use dynamic addressing

ROM

A ROM is a "Read Only Memory". It is factory-produced, and usually its contents are fixed. A ROM can be read, but it usually cannot be written into. Usually a ROM contains very important fixed information required for the proper operation of the equipment.

Mask-Programmed Read-Only Memories use a mask during manufacture, contents cannot be altered. Programmable Read-Only Memories permit a change of each cell after manufacture, but once only. Reprogrammable Read-Only Memories permit changes to each cell after manufacture, more than once.

Execises

Find one wrong word in each sentence and give the wright variant.

1. Current in electronics is usually measured in Volt which are called milliamperes, which are 1/1000s of an ampere.
2. To extend the range to measure 10 Volts for full-scale deflection the resistor needed to be connected seperately.
3. Multimeteres aren't also often able to measure capacitance and inductance.
4. The "control" pin is called the *base* in a FET transistors (the other 2 pins are the *source* and *drain*).
5. The "control" pin is called the *gate* in a BJT transistors (the other 2 pins are the *emitter* and *collector*).

Find the odd one out.

1. transistor, conductance, voltage, bearing.
2. ohmeter, torque, voltmeter, ammeter.
3. bytes, words, bits, sentences.
4. FET, PHEMT, JFET, USA
5. software, hardware, RAM, framework.

1. Explane the structure and functions of multimeters, transistors.

2. Explane the word combination "transistor revolution". Why was it so important?

Unit 14
About the Society

The IEEE Control Systems Society (CSS) was founded in l954 as a scientific, engineering and professional organization dedicated to the advancement of the theory and practice of systems and control in engineering. Today, the Society has more than 10,000 members around the world. Membership in the Society has many benefits for practical engineers as well as theory specialists. Society members receive three journals: the Control Systems Magazine, the Transactions on Automatic Control, and the Transactions on Control Systems Technology. The Magazine has articles on current applications; in fact, many of the illustrations in this brochure appeared first in

the Magazine in connection with such articles. In addition, the Magazine contains information about Computer-Aided Design (CAD) tools, conferences, as well as book reviews. The Transactions contain more technical articles about applications and theoretical developments. Control Systems Society members, and particularly student members, are entitled to benefits such as reduced conference registration fees, discounts on IEEE Press publications and more.

Control and Its Applications

Control methods are used whenever some quantity, such as temperature, altitude or speed, must be made to behave in some desirable way over time. For example, control methods are used to

make sure that the temperature in our homes stays within acceptable levels in both winter and summer; so that airplanes maintain desired heading, speed and altitude; and so automobile emissions meet specifications.

The thermostat that regulates the operation of the furnace in a typical home is an example of a device that controls the heating system, so that the temperature is maintained at a specified level.

The autopilot in a passenger aircraft that maintains speed, altitude and heading is an example of a more sophisticated automatic control system. The cruise control in a car, which maintains constant speed independently of road inclines, is yet another example of a control system. Control methods in biomedical applications make possible the use of electrical nerve signals to control prosthetics, and precision robots for cutting holes in bone for implanting artificial joints, resulting in much tighter fits than previously thought possible.

Control is All Around Us

Control is a common concept, since there always are variables and quantities, which must be made to behave in some desirable way over time.

In addition to the engineering systems, variables in biological systems such as the blood sugar and blood pressure in the human body, are controlled by processes that can be studied by the automatic control methods. Similarly, in economic systems variables such as unemployment and inflation, which are controlled by government fiscal decisions can be studied using control methods.

Our technological demands today impose extremely challenging and widely varying control problems. These problems range from aircraft and underwater vehicles to automobiles and space telescopes, from chemical processes and the environment to manufacturing, robotics and communication networks.

The Practice of Control

A large fraction of engineering designs involves automatic control features. Frequently, control operations are implemented in an embedded microprocessor that observes signals from sensors and provides command signals to electromechanical actuators. Applications may range from washing machines to high performance jet engines. Designers frequently use computer-aided-design (CAD) software that embodies theoretical design algorithms, and permits tradeoff comparisons among various performance measures such as speed of response, operating efficiency and sensitivity to uncertainties in the model of the system. Proposed control designs, especially those for complex and expensive applications, are usually tested using computer based simulations.

Control engineering experts keep up with the latest theoretical developments. Most control systems are put together by practical minded engineers who have a thorough understanding of application areas such as automotive engines, factory automation, robot dynamics, heating, ventilating and air conditioning.

Methodology

The first step in understanding the main ideas of control methodology is realizing that we apply control in our everyday life; for instance, when we walk, lift a glass of water, or drive a car.
The speed of a car can be maintained rather precisely, by carefully observing the speedometer and appropriately increasing or decreasing the pressure on the gas pedal. Higher accuracy can perhaps be achieved by looking ahead to anticipate road inclines that affect the speed. This is the way the average driver actually controls speed. If the speed is controlled by a machine instead of the driver, then one talks about automatic speed control systems, commonly referred to as cruise control systems. An automatic control system, such as the cruise control system in an automobile, implements in the controller a decision process, also called the control law, that dictates the appropriate control actions to be taken for the speed to be maintained within acceptable tolerances. These decisions are taken based on how different the actual speed is from the desired, called the error, and on the knowledge of the car's response to fuel increases and decreases. This knowledge is typically captured in a mathematical model. Information about the actual speed is fed back to the controller by sensors, and the control decisions are implemented via a device, the actuator, that increases or decreases the fuel flow to the engine.

Foundations and Methods

Central in the control systems area is the study of dynamical systems. In the control of dynamical systems, control decisions are expected to be derived and implemented over real time. Feedback is used extensively to cope with uncertainties about the system and its environment.

Feedback is a key concept. The actual values of system variables are sensed, fed back and used to control the system. Hence the control law decision process is based not only on predictions about the plant behavior derived from the system model (as in open-loop control), but also on information about the actual system behavior (closed-loop feedback control).

The theory of control systems is based on firm mathematical foundations. The behavior of the system variables to be controlled is typically described by differential or difference equations in the time domain; by Laplace, Z and Fourier transforms in the transform (frequency) domain. There are well understood methods to study stability and optimality. Mathematical theories from partial differential equations, topology, differential geometry and abstract algebra are sometimes used to study particularly complex phenomena. Control system theory research also benefits other areas, such as Signal Processing, Communications, Biomedical Engineering and **Economics.**

Challenges in Control

The ever increasing technological demands of society impose needs for new, more accurate, less expensive and more efficient control solutions to existing and novel problems. Typical examples are the control demands for passenger aircraft and automobiles. At the same time, the systems to be controlled often are more complex, while less information may be available about their dynamical behavior; for example such is the case in large flexible space structures. The development of control methodologies to meet these challenges will require novel ideas and interdisciplinary approaches, in addition to further developing and refining existing methods.

Emerging Control Areas

The increasing availability of vast computing power at low cost, and the advances in computer science and engineering, are influencing developments in control. For instance, planning and expert systems can be seen as decision processes serving purposes analogous to control systems and so lead naturally to interdisciplinary research and to intelligent control methods. There is significant interest in better understanding and controlling manufacturing processes typically studied in disciplines such as Operations Research, and this has led to interdisciplinary research to study the control of discrete-event systems (DES) that cannot be described by traditional differential or difference equations; and to the study of hybrid control systems that deal with the control of systems with continuous dynamics by sequential machines. Fuzzy control logic and neural networks are other examples of methodologies control engineers are examining to address the control of very complex systems.

Future Control Goals

What does the future hold? The future looks bright. We are moving toward control Systems that are able to cope and maintain acceptable performance levels under significant unanticipated uncertainties and failures, systems that exhibit considerable degrees of autonomy. We are moving toward autonomous underwater, land, air and space vehicles; highly automated manufacturing; intelligent robots; highly efficient and fault tolerant voice and data networks; reliable electric power generation and distribution; seismically tolerant structures; and highly efficient fuel control for a cleaner environment.

Control systems are decision-making systems where the decisions are based on predictions of future behavior derived via models of the systems to be controlled, and on sensor-obtained observations of the actual behavior that are fed back. Control decisions are translated into control actions using control actuators. Developments in sensor and actuator technology influence control methodology, which is also influenced by the availability of low cost computational resources.

Put Control in Your Future

The area of controls is challenging and rewarding as our world faces increasingly complex control problems that need to be solved. Immediate needs include control of emissions for a cleaner environment, automation in factories, unmanned space and underwater exploration, and control of communication networks. Control is challenging since it takes strong foundations in engineering and mathematics, uses extensively computer software and hardware and requires the ability to address and solve new problems in a variety of disciplines, ranging from aeronautical to electrical and chemical engineering, to chemistry, biology and economics.

We are very proud to be in control. Join us, and together we will face future challenges.

Additional reading

Transatlantic aviation

Chocks away

The prospect of more open skies across the Atlantic is shaking up Europe's air-lines

"CHICKEN or beef?" If you think the menu on transatlantic flights is limited, try choosing a European airline to fly across the ocean. European airlines are heavily outnumbered by American ones on most transatlantic routes. Passengers at some

European airports, such as Barcelona and Brussels, have no choice but to fly with an American airline if they want to go non-stop. Regulatory restrictions on flights between the European Union (Eu) and America are largely to blame. Now an "open skies" deal between the two, which will allow any airline from either side of the Atlantic to fly to any intercontinental destination from March 2008, is shaking up Europe's airline industry.

One effect of the agreement, which will be signed in Washington, DC, on April 30th, is to make takeovers more likely. Without an open-skies deal, any airline that bought a rival based in another вu state risked losing that airline's landing rights in America. Accordingly, on March 30th Texas Pacific Group (TPG), a ravenous private-equity firm, made a preliminary approach to buy Iberia, Spain's leading airline, for €3.60 ($4.80) per share. Spain is one of 11 EU states (Britain, Greece, Hungary and Ireland are among the others) not to have an existing bilateral open-skies deal with America. Passengers in these countries are expected to benefit most from liberalisation.

Acquisition talk is not restricted to Spain. The bidding for a controlling stake in Alitalia, Italy's beleaguered national carrier, edged closer to a result on April end with the announcement of a shortlist of three bidders. (**TPG** is part of one consortium; Aeroflot, Russia's flag carrier, dominates another.) BMI, a British airline, is the subject of much takeover gossip, largely because it holds coveted landing slots at London's Heathrow airport, Europe's primary transatlantic gateway. A host of smaller **EU** carriers-Austrian Airlines, Scandinavia's SAS and Poland's LOT among them-aye also being talked about as potential targets. "I've never seen it as active as it is now," says Tim Coombs of Aviation Economics, a consultancy.

The open-skies deal is the main reason for all this activity, but not the only one. Deep-pocketed private-equity firms provide a new source of capital, although many analysts are sceptical that they can thrive in such a capital-intensive and cyclical industry. Nor does the open-skies deal mean that takeovers are free of opposition. Iberia's attractions include its strong Latin American route network, which is not covered by the EU-American pact. A nonSpanish buyer would have to make agreements with aviation authorities there and in other parts of the world. And whatever the rules say, European governments, Spain's and Italy's among them, tend to blanch at foreign control of prized national assets. (In Rome Aeroflot's bid for Alitalia has caused alarm in some quarters.)

The fight for Iberia is likely to be a long one. **TPG** has not yet tabled a formal offer and its mooted price is below the share price, which has soared since the start of the year on speculation of a bid. British Airways (BA), which already owns 10% of Iberia and has right of first refusal on another 30%, could stymie progress, join forces with **TPG**, or mount a bid of its own. Lufthansa, another of Europe's big beasts, is watching events in Madrid closely and may yet enter the fray.

If acquisitions prove too costly or complex, carriers can take advantage of the new regime in other ways, such as by adding routes to their schedules. But that depends on getting hold of take-off and landing slots, which are particularly scarce at Heathrow. Just four airlines-BA, Virgin Atlantic, American Airlines and United Airlines-carve up Heathrow's transatlantic slots between them. (Frankfurt divides about half the number of flights to and from America between twice as many carriers; see table on next page). Anticipating a wave of slot-trading, **BA** bought 51 weekly slots from BMI last week, consolidating its dominant position at Heathrow.

For its part, Virgin Atlantic is examining the potential for flights to New York from six continental European airports. Virgin is an unusual airline, with a strong brand, a record of taking on an entrenched incumbent and a proven ability to run standalone routes without a network of feeder flights. Other airlines lack its potential to operate outside their home bases, says Peter Morrell of Cranfield University.

The most intriguing possibility is the entry of low-cost carriers into the transatlantic market. The low-cost model is difficult to transfer from short-haul flights to long-haul ones. Long-haul economy fares are already pretty cheap. But there may be room for all-business-class operators to undercut established carriers on denser routes. Some airlines such as Silverjet and ~**,'**

Overactive Atlantic

Scheduled flights to European airports from the US

June 2007

Airport	No. of flights	Airlines	
		US	European
London Heathrow	2,203	2	2
Frankfurt	1,298	6	2
Paris Charles de Gaulle	1,209	6	1
Amsterdam	939	5	2

London Gatwick	796	5	2
Madrid	364	4	2
Dublin	324	4	1

MAXjet already offer good fares on transatlantic services from London; the open-skies deal makes it easier for them to extend their services to other business hubs. And at the top end of the market, Lufthansa could expand the all-business service it runs with PrivatAir, a Swiss private jet operator, to London.

The full effects of the new open-skies deal will take some time to materialise. Many of the benefits bandied about by the European Commission assume an end to restrictions on foreign investment in EU and American airlines. But America's limits on foreign ownership remain in place, despite the promise of future negotiations, and economic nationalism shows no sign of abating in continental Europe. Even so, the outline is emerging of a more normal industrial landscape, in which loss-making operators consolidate and profitable ones expand.

The Economist April 7th 2007

Unit 15

Industrial robot

An **industrial robot** is officially defined as an *automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes*. The field of **industrial robotics** may be more practically defined as the study, design and use of robot systems for manufacturing (a top-level definition relying on the prior definition of *robot*).

Industrial robots doing vehicle underbody assembly (KUKA).

Typical applications of industrial robots include welding, painting, ironing, assembly, pick and place, packaging and palletizing, product inspection, and testing, all accomplished with high endurance, speed, and precision.

Industrial robot types, features

The most commonly used robot configurations for industrial automation, include articulated robots (the first and most common), SCARA robots and gantry

robots (aka Cartesian Coordinate robots, or x-y-z robots). In the context of general robotics, most types of industrial robots would fall into the category of robot arms (iherent in the use of the word *manipulator* in the above-mentioned ISO standard).
Industrial robotics exhibit varying degrees of autonomy:

- Some robots are programmed to faithfully carry out specific actions over and over again (repetitive actions) without variation and with a high degree of accuracy. These actions are determined by programmed routines that specify the direction, acceleration, velocity, deceleration, and distance of a series of coordinated motions.
- Other industrial robots are much more flexible as to the orientation of the object on which they are operating or even the task that has to be performed on the object itself, which the robot may even need to identify. For example, for more precise guidance, robots often contain machine vision sub-systems acting as their "eyes", linked to powerful computers or controllers. Artificial intelligence, or what passes for it, is becoming an increasingly important factor in the modern industrial robot.

History of industrial robotics

George Devol received the first patents for robotics in 1954. The first company to produce an industrial robot was Unimation, founded by George Devol and Joseph F. Engelberger in 1956, and was based on Devol's original patents. Unimation robots were also called *programmable transfer machines* since their main use at first was to transfer objects from one point to another, less than a dozen feet or so apart. They used hydraulic actuators and were programmed in *joint coordinates*, i.e. the angles of the various joints were stored during a teaching phase and replayed in operation. For some time Unimation's only competitor was Cincinnati Milacron Inc. of Ohio. This changed radically in the late 1970s when several big Japanese conglomerates began producing similar industrial robots. Unimation had obtained patents in the United States but not in Japan who refused to abide by international patent laws, so their designs were copied.
In 1969 Victor Scheinman at Stanford University invented the Stanford arm, an all-electric, 6-axis articulated robot designed to permit an arm solution. This allowed the robot to accurately follow arbitrary paths in space and widened the potential use of the robot to more sophisticated applications such as assembly and arc welding. Scheinman then designed a second arm for the MIT AI Lab,

called the "MIT arm." Sheinman sold his designs to Unimation who further developed it with support from General Motors and later sold it as the Programmable Universal Machine for Assembly (PUMA).

In 1973 KUKA Robotics built its first industrial robot, known as FAMULUS, this is the first articulated industrial robot to have six electromechanically driven axes.

Interest in industrial robotics swelled in the late 1970s and many companies entered the field, including large firms like General Electric, and General Motors (which formed joint venture FANUC Robotics with FANUC LTD of Japan). US start-ups included Automatix and Adept Technology, Inc. At the height of the robot boom in 1984, Unimation was acquired by Westinghouse Electric Corporation for 107 million US dollars. Westinghouse sold Unimation to Stäubli Faverges SCA of France in 1988. Stäubli was still making articulated robots for general industrial and clean room applications as of 2004 and even bought the robotic division of Bosch in late 2004.

Eventually the myopic vision of American industry was superseded by the financial resources and strong domestic market enjoyed by the Japanese manufacturers. Only a few non-Japanese companies managed to survive in this market, including Adept Technology, Stäubli-Unimation, the Swedish-Swiss company ABB (ASEA Brown-Boveri), the Austrian manufacturer igm Robotersysteme AG and the German company KUKA Robotics.

Technical description

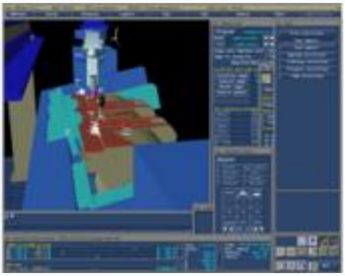
Defining parameters

- *Number of axes* – two axes are required to reach any point in a plane; three axes are required to reach any point in space. To fully control the orientation of the end of the arm (i.e. the *wrist*) three more axes (roll, pitch and yaw) are required. Some designs (e.g. the SCARA robot) trade limitations in motion possibilities for cost, speed, and accuracy.
- *Degrees of freedom* which is usually the same as the number of axes.
- Working envelope – the region of space a robot can reach.
- *Kinematics* – the actual arrangement of rigid members and **joints** in the robot, which determines the robot's possible motions. Classes of robot kinematics include **articulated, cartesian, parallel and SCARA.**
- *Carrying capacity or payload* – how much weight a robot can lift.
- *Speed* – how fast the robot can position the end of its arm. This may be defined in terms of the angular or linear speed of each axis or as a

compound speed i.e. the speed of the end of the arm when all axes are moving.

- *Acceleration* - how quickly an axis can accelerate. Since this is a limiting factor a robot may not be able to reach it's specified maximum speed for movements over a short distance or a complex path requiring frequent changes of direction.
- *Accuracy* – how closely a robot can reach a commanded position. Accuracy can vary with speed and position within the working envelope and with payload (see compliance). It can be improved by Robot calibration.
- *Motion control* – for some applications, such as simple pick-and-place assembly, the robot need merely return repeatably to a limited number of pre-taught positions. For more sophisticated applications, such as **arc welding**, motion must be continuously controlled to follow a path in space, with controlled orientation and velocity.
- *Power source* – some robots use electric motors, others use **hydraulic** actuators. The former are faster, the latter are stronger and advantageous in applications such as spray painting, where a spark could set off an explosion.
- *Drive* – some robots connect electric motors to the joints via gears; others connect the motor to the joint directly (*direct drive*). Using gears results in measurable 'backlash' which is free movement in an axis. In smaller robot arms with DC electric motors, because DC motors are high speed low torque motors they frequently require high ratios so that backlash is a problem. In such cases the **harmonic drive** is often used.
- *Compliance* - this is a measure of the amount in angle or distance that a robot axis will move when a force is applied to it. Because of compliance when a robot goes to a position carrying it's maximum payload it will be at a position slightly lower than when it is carrying no payload. Compliance can also be responsible for overshoot when carrying high payloads in which case acceleration would need to be reduced.

Robot programming and interfaces



Offline programming by ROBCAD

Main article: Robotics suite

The setup or programming of motions and sequences for an industrial robot is typically taught by linking the robot controller via communication cable or wirelessly to the Ethernet, FireWire, USB, old serial or Wi-Fi port of a laptop, desktop computer or (internal or Internet) network.

The computer is installed with corresponding interface software. The use of a computer greatly simplifies the programming process. Robots can also be taught via teach pendant, a handheld control and programming unit. Specialized robot software is run either in the robot controller or in the computer or both depending on the system design. The teach pendant or PC is usually disconnected after programming and the robot then runs on the program that has been installed in its controller.

In addition, machine operators often use human machine interface devices, typically touch screen units, which serve as the operator control panel. The operator can switch from program to program, make adjustments within a program and also operate a host of peripheral devices that may be integrated within the same robotic system. These include end effectors, feeders that supply components to the robot, conveyors, emergency stop controls, machine vision systems, safety interlock systems, bar code printers and an almost infinite array of other industrial devices which are accessed and controlled via the operator control panel.

A robot and a collection of peripherals is referred to as a cell.

End Effectors

The most essential robot peripheral is the end effector without which the robot can not do anything. Obvious examples are grippers which are devices that can grasp an object, usually electromechanical or pneumatic. Another common means of picking up an object is by vacuum. End effectors are frequently highly complex, made to match the handled product and often capable of picking up an array of the products at one time.

Movement and singularities

Most articulated robots perform by storing a series of positions in memory, and moving to them at various times in their programming. For example, a robot which is moving items from one place to another might have a simple program like this (commonly called a 'pick and place' program):

Define points *P1–P5:*

1. Safely above workpiece
2. 10 cm Above bin A
3. At position to take part from bin A.
4. 10 cm Above bin B
5. At position to take part from bin B.

Define program:

1. Move to P1
2. Move to P2
3. Move to P3
4. Close gripper
5. Move to P4
6. Move to P5
7. Open gripper
8. Move to P1 and finish

For a given robot the only parameters necessary to locate the end effector (gripper, welding torch, etc.) of the robot completely are the angles of each of the joints or displacements of the linear axes (or combinations of the two for robot formats such as SCARA). However there are many different ways to define the points. The most common and most convenient way of defining a point is to specify a Cartesian coordinate for it, i.e. the position of the 'end effector' in mm in the X, Y and Z directions. In addition the angles of the end effector in pitch, roll and yaw and the length of the tool must also be specified, depending on the types of joints a particular robot may have. For a jointed arm these coordinates must be converted to joint angles by the robot controller and such conversions are known as Cartesian Transformations which may need to be performed iteratively or recursively for a multiple axis robot. The mathematics of the relationship between joint angles and actual spatial coordinates is called kinematics.

Positioning by Cartesian coordinates may be done by entering the coordinates into the system or by using a teach pendant which moves the robot in X-Y-Z directions. It is much easier for a human operator to visualize motions up/down, left right etc. than to move each joint one at a time. When the desired position is reached it is then defined in some way peculiar to the robot software in use, e.g. P1 - P5 above.

Recent and future developments

Main article: Future of robotics

As of 2005, the robotic arm business is getting to a mature state, where they can provide enough speed, accuracy and ease of use for most of the applications. Vision guidance (aka machine vision) is bringing a lot of flexibility to robotic cells. So we have the arm and the eye, but the part that still has poor flexibility is the hand: the end effector attached to a robot is often a simple pneumatic, 2-position wrench. This doesn't allow the robotic cell to easily handle different parts, in different orientations.

Hand in hand with increasing off-line programmed applications, robot calibration is becoming more and more important in order to guarantee a good positioning accuracy.

Other developments include downsizing industrial arms for consumer applications (micro-robotic arms), manufacture of domestic robots and using industrial arms in combination with more intelligent automated guided vehicles (AGVs) to make the automation chain more flexible between pick-up and drop-off.

Prices of industrial robots will vary with the features, but are usually from 12,000 USD for an entry level model, and as much as 100,000 or more for a heavy-duty, long reach robot.

Industrial robot manufacturers

- ABB
- Adept
- Cloos GmbH
- Comau
- DENSO Robotics
- Epson Robots
- FANUC Robotics

- HYUNDAI Robotics
- igm Robotersysteme
- Intelligent Actuator
- Janome
- Kawasaki
- KUKA Robotics
- Nachi
- Nidec Sankyo
- OTC
- Reis
- Stäubli Robotics
- ST Robotics
- Yaskawa-Motoman

Exercises

Answer these questions.

1. What this term "the industrial robot" defines?

2. What does this term include, according to degrees of autonomy?

3. The term "programmable transfer machines", appeared in 1954 meant… (What?).

4. Name the first industrial robot, which was built in 1973.

5. Name most of the defining parameters of that invention.

6. Explain the term "hand-in-hand"

7. Where "micro-robotic arms" can be used?

Revision exercise

Match part A with part B

A	B
1. light metals	a. iron, copper, zinc. нержавеющий
2. common metals	b. silver, gold, platinum
3. precious metals	c. aluminum, beryllium, titanium
4. nonmetals	d. carbon, silicon, sulphur
5. solid state	e. проводимость
6. property	f. твёрдое состояние
7. conductivity	g. свойство
8. poor conductor	h. прочность
9. hardness	i. плохой проводник
10. rust-resistance	j. нержавеющий

A
absorb *v*-абсорбировать
accelerate *v* **–** ускорять
accessible *adj.* – доступный, податливый
accord *n* **-**1) одобрение, согласие; 2) соответствие
achieve *v* - достигать
activate *v* **-** активировать
adapt *v* - приспосабливать
advantage *n* **-** преимущество
agent *n* - фактор
align *v* **-** спрямлять
allow *v* - допускать. позволять
ammeter *n* **–** амперметр
analyzer *n* **–** анализатор
angular *adj.* **-** угольный; угловой
applicable *adj.* - применимый, подходящий, пригодный
application *n* **–** применение, использование, употребление;
apply *v*- применять
appropriate *adj.* - 1) подходящий, соответствующий
appropriately *adv*-предназначено
approximately *adv.* **–** близко, около, почти, приблизительно
assembly *n* - монтаж; агрегат, сборка, устройство
associate **-** объединять (соединять)
attract *v* **–**привлекать, притягивать
attraction *n* **–**влечение, притяжение, тяготение
authorized *v* **-** 1)уполномочивать; давать право 2) разрешать
available adj. **-** доступный; имеющийся в распоряжении, наличный
average *adj.* **-** средний
avoid *v* - избегать
axial *adj.* – осевой

B
bearing *n* **-**подшипник
beer *n* **–** ход
bend *v* **–** изгиб, изгибать
benefit *n* - преимущество
**brake – ***v* задерживать, тормозить
brass *n* **–** латунь
brief *adj.* **–** сжатый
build-in *v* **–** встраивать

C
cable *n* **–** кабель
calibrate *v* - калибровать;

cancel *v*–сокращать
capability *n* **-** мощность, потенциал
capacitor *n* **–**конденсатор
capacity *n* **–** объём, вместимость
carrier *n* **-** держатель; кронштейн
carry out *v* - производить; выполнять, осуществлять,
cast *v* – отливать (металл)
cavity *n* **–** каверна; полость
cell *n* **–** элемент
centrifugal *n,*- центробежный
changeover *n* **-** переключение
characteristic *n* **–** характеристика
charge *n* **–** заряд
chemical *adj.* **–** химический
circuit *n* **–** электрическая цепь
clamp *n, v* **–**зажим, зажимать
clearance *n* **-** зазор; допуск
clockwise *adv.* – направление по часовой стрелке
coil *n* **–**виток, кольцо; змеевик
component *n* **–** компонент
compress *v* **–** сжимать, сдавливать
comprise *v* **-** включать, заключать в себе, содержать
condensation *n* **–** сгущение, конденсация
conduct *v* **–**проводить; ~ *adj.* проводящий; ~ *n* проводник
cone *n* **–** конус
construction *n* **–**конструкция
consumption *n* **–** расход
contingency *n* **–** соединение, контакт
convert *v* - трансформировать,
converter *n* **–** конвертер
cooling *n* - охлаждение
core *n* **–** средняя внутренняя часть чего-л.
corrosion *n* – коррозия
coulomb *n* **–**кулон, Кл
counteract *v* **-** препятствовать, сопротивляться
coupling *n* **-** пара сил, термопара, муфта; сцепление; сопряжение
cover *n* **–** оболочка, упаковка
creep *v* **-** а) набегать по инерции б) удлиняться
critical *adj.* **–** критический, предельный
current *n* **–** электрический ток
cycle *n* **-** (круговой) процесс, такт (при работе двигателя)
cylinder *n* **–** цилиндр

D
damage *n* **–** повреждение
data terminal – устройство электронных часов
debug *v* **–**выявлять и устранять; отлаживать
decay *n* **–** распад
decelerate *v* **–**снижать, замедлять
decline *n* – падение, спад, упадок;
decrease *v* **–** уменьшать, убывать, сокращать
define *v* - определять, ~*n* ясность
deflection *n* **–** отклонение
delta *n* **-** дельта соединение
demand *v* **-** требовать
deposit *v* **-** образовывать налет
de-rate *v* **-** уменьшение пропорции, отношения; коэффициента
detail *n*– деталь; ~ adj.детальный
determine *v* - определять, устанавливать

device *n* **–** приспособление, механизм
devise *v* **–** разрабатывать, продумывать
diagram *n* **–** диаграмма
digital *adj.* **-** цифровой
dilute *v* **–**разжижать, разбавлять
dimension *n* **-** размеры, величина;
disconnect *v* **–** разъединять
discrete *adj.* **–** дискретный
dissipate *v* **-** рассеивать, разгонять
dissipate *v* **–**рассеивать, разгонять
dopant *n* **-** присадка; (легирующая) примесь;
dope *v* **–**изменять структуру полупроводника с целью получить те или иные свойства
drain *n* **–**вытекание, истечение
drain *v* **–**истощать; высасывать, выкачивать
draw *v* **–** всасывать, втягивать; ~ *n* тяга
due to *v* **–** обусловленный

E

edge *n* – кромка
edition *n* **–** издание
effect *n* **–** эффект, результат, следствие
efficiency *n* **–** производительность
eject *v* **–** отделять, извлекать
electrostatic discharge **–** электростатический разряд; ~ field - ~ поле
embed *v* **-** вставлять; встраивать
emission *v* **–** эмиссия, сокращение, излучение
emitter (terminal) *n*–1) источник 2) генератор
enable *adv.* **–** возможный
enclose *v* **–** окружать, заключать
encoder *n* **-** кодировщик
energize *v* - возбуждать
enhance *v* **–**увеличивать, усиливать, улучшать
ensure *v* **-** гарантировать, обеспечивать
environment *n* **–** среда
equation *n* **–** выравнивание; стабилизация
equipment *n* **–** оборудование, приспособления
equip *v* **–** оборудовать
error *n* **-** изменение, погрешность,
establish *v* **–** устанавливать
etch *v* **–** гравировать
evaluate *v* **–** вычислять, оценивать
exceed *v* **–** превышать
excessive *adj.***–** чрезмерный
excite *v* **-** вызывать
exert *v* **–**напрягать, приводить в действие
expansion *v* **–** расширение
expire *v* **–** истекать (о сроке)
extend *v* **–** простирать(ся),
external *adj.***–** внешний
extremely *adv.***–** крайне

F

fail *n* **–** недостаток
fashion *n* **–** режим
fatigue *n***–** усталость (металла), износ
fault *n* **–** ошибка, просчёт
favorable *adj.* **–** благоприятный
feature *n***–** деталь
feed *v* **–** питать

feedback *v* – возвращать
ferrite *adj.* **–** ферритовый
fictional *adj.***–** беллетристический
field *n* **–** поле**,** область
fission *n* **–** расщепление, деление атомного ядра при цепной реакции
fit *v* **–** приспосабливать
fitting *n***–** сборка, комплектация
flange *n* **–** фланец
flange plane *n* **-** плоскость фланца
flexibility *n* - эластичность, гибкость
float *v* - работать вхолостую
flooring *n* **-** настил, пол
flow *n* **–** поток
fluid *n* **–** жидкость
flux *n* **–** поток
foam *n* **-** пена
follow *v* **–** следовать
force *n* **–** сила
foreign *adj.***–** посторонний, чужой
frequency *n* **–** частота (вращения)
front *adj.***–** передний
fulfill *v* **–** выполнять
fume *n* **–** возбуждение
functionality *n* **–** выполняемые функции
furthermore *adv.* **–** дальнейшие
fusion *n* **–** синтез

G
Gauge *n* - масштаб, калибр
gland *n* **–** сальник
goal *n* **–** цель
graduate *adj.***–** градуировать
grease *n* **–** смазка
gripper *n* **–** зажим
groove *n* **–** выемка, паз
ground *n* **-** заземление
guarantee *v* – давать гарантию
guide *n* **–** руководство

H
handled *v* **–**справляться с чем-л. руками
harmonize *v* **–**согласовывать, соразмерять
hazard *n* **–** риск, опасность
heat exchange *n* – теплообмен
hegligible *adj.***–** значительный
hence *adv.***–** следовательно
henry *n* **–** генри, Гн
high tension *n* **–** высокое напряжение
high-speed *adj.***–** высокоскоростной
hole *n* **–** отверстие
hose *n* **-** рукав, шланг
humid (air) *adj.* **–**влажный, сырой
hybrid *adj.*- гибридная
hydrogen *n* **–** водород, Н

I
ignite *v* **–** воспламенять, раскалять
imbalance *n* - отсутствие или нарушение равновесия **implement** *v* **-** снабжать, обеспечивать инструментами
in feed *adj.*– наполняющий, питающий
inertia *n* **-** инертность
infinite *n* **–** бесконечно большая величина
ingress *n* **-** право входа
inhibit *v* **–** задерживать, препятствовать

initiate *v* - начать, приступать,
installation *n* **-** установка; сборка
insulator *n* **–** изолятор, диэлектрик
integrate *v* **-** составлять целое; интегрировать
interaction *n* **-** взаимодействие
interface *n* **-** согласование
interlock *v* – блокировать
irreversible *adj.***–** не подлежащий отмене

J
jet *n* **-** жиклер, форсунка
join *n* - плоскость соединения; соединять
junction *n* **–** соединение

K
kilowatt - киловатт, кВт
kinetic *adj.*– кинетический

L
labyrinth *v* - лабиринт
lateral *adj.*- боковой; поперечный; направленный в сторону
lead *n* **-** а) опережение, б) шаг) ход (поршня)
leakage *n* - протечка, просачивание
leaned fluid – слабый поток жидкости
level *n* - степень, уровень
liability *n* **-** обязательства, ответственность
lifetime *n* - технологический срок службы
likilihood *n* - вероятность
linearly *adj.***-** продольная
liquid cooling - жидкостное охлаждение
load *n* **–** нагрузка, ~ *v* нагружать
loop *v* – петля, , хомут
loss *n* **-** убыток, потеря
lubricate *v*- смазывать
lug *n* **-** а) ушко, б) подвеска в)утолщение г) зажим

M
magnetic *adj.* - магнитный
magnitude *n* **–** величина колебания
maintain *v* **-** поддерживать, удерживать
manual *n* **–** руководство; учебник
manufacture *v* **–** производить, изготовлять
measure *v* **–** измерять, мерить,
medium *adj.***–** средний; промежуточный
minimize *v* –1) доводить до минимума, 2) преуменьшать
mnemonic *n* **–** мнемосхема
mode *n* **–** метод, режим
module *n* **–**модуль
moisture *adj.* **-** влажность, сырость
monitoring *n* – контроль, наблюдение
multiplication *n* **-** умножение –
multiply *v* – увеличивать, умножать

N
necessity *n* **-** необходимость
normal *adj.* - нормальный, обыкновенный

nucleonic *adj.* **–** нуклоидный
numerous *adj.* - многочисленный, множественный
nut *n* - гайка; муфта

O

obtain *v* - получать; добывать; приобретать
occur *v* **–**происходить, случаться, совершаться
offset *n* **-** ответвление, отвод
ohmic aj. - омический
on-ward - продвигающийся, идущий вперед
onward *adv.*- продвигающийся, идущий вперед
oppose *v* **-** противопоставлять,
option *n* **-** вариант; опция, предмет
oscillate *v* - вибрировать, колебаться
oscilloscope *n* **–** осциллограф
output *n* **–** продукция, изделие
over voltage *n* – перенапряжение,
overlapping *n* **–** наложение, совпадение
overload *n* -1) перегрузка 2) перенапряжение

P

particular *v* **-** детальный, обстоятельный
penetrate *v* - проникать внутрь, проходить сквозь, пронизывать
permanently *adv.***-** перманентно, надолго, постоянно
permeability *n* **–** проницаемость, пропускающая способность; магнитная проницаемость
permittivity *n* **–** диэлектрическая проницаемость
pin *n* **–** пробойник, палец, штифт
pipe *n* **-** труба, трубопровод, ~ *v* подаваться по трубам
pool rod – маленький стержень, брус
postitvely *adv.* - прямо, непосредственно
power source *n* **–** мощность источника
precise *adj.* **-** точный; определенный
precision *n* - точность
property *n* **-** право собственности, право владения, свойство, качество; отличительная черта, особенность
provide *v* **-** предоставлять; обеспечивать
pull rod *n* **-**1) главная тяга (группового привода станков-качалок) 2) тяга ручного тормоза
pull-in *v* - втягивать
pulse *v* **–**вибрировать

Q

quality *n* **–-**степень качества**,** добротность
quantity *n* **–** количество, величина, параметр

R

radial *adj.* – радиально-сверлильный станок; двигатель со звездообразно расположенными цилиндрами;
raggedness *adj.* **–** прорезиненный
range *n* - ряд, цепь; ~ *v* колебаться в известных пределах

ratio *n* **–** пропорция; коэффициент
reactant *n.***–** реагент
reactive *adj.***–** реактивный
rear *adj.* – задняя поверхность
recipe *n* - средство; способ
rectifier *n* **– (**выпрямительный) диод
reduce *v* **-** сокращать,
reference *n* **-** отношение **regenerative** *adj.* **-** регенеративный
reinforce *v* – укреплять, усиливать
relatively *adv* **-** относительно; по отношению к; соразмерно
release *v* – 1) освобождать, 2) отпускать,
relevant *adj.* – значимый
relief *n* - контраст, четкость,
remain *n* **-** оставаться в каком-л. состоянии
repel *v* **–** отталкивать
repulsion *n* **–** отталкивание
requirement *n* **-** требование; необходимое условие
residual *n* **-** остаточный продукт
resistance *n* **–** сопротивление
resonance *n* **–** резонанс
resonant *n* **-** резонирующий
resource *n* **-** способ, средство
respectively *adv.* **–** соответствующим образом
respond *v* **-** реагировать, срабатывать
restrict *v* **-** ограничивать
retain *v* **-** удерживать**,** аккумулировать; вмещать
rib *n* **-** ребро (жесткости**)**
rigid *adj.* **–** жесткий, негнущийся,
rod (inductors) *n* **–** стержень, рычаг
roller *n* **-** вращающийся цилиндр, бегунок
rotate *v* - вращать
roughing *n* **-** черновая обработка**;** обдирка

S
safety - безопасность; сохранность
scale *n* **–** осадок
seal *n* **-** перемычка, затвор
select *n* **-** выбирать, избирать
sensitive *adj.* - точный,; чувствительный
sensor *n* - датчик; сенсор
set point *n* -заданное значение, контрольная точка
shaft *n* **-** вал, ось, шпиндель
shield - экран; защитная ширма, щиток
shunt *v* **–** отодвигать; отталкивать
shutdown speed *n* – скорость при выключении
significant *adj.* - значительный, важный, существенный; знаменательный
simplify - упрощать
smooth *v* **-** полировать**,** шлифовать
solution *n* **–** растворение; метод решения
sophistication *n* **–** фальсификация
source *n* **–** начало**,** причина
specify *v* - точно определять, детально излагать
stiff *adj.* **-** труднообрабатываемый, твердый

stiffness *n* **-** жёсткость; устойчивость (конструкции
store *n* **-** запоминающее устройство, накопитель
strength *n* **-**1) интенсивность, мощность 2) сопротивление
stress *v* - подвергать напряжению; вызывать напряжение;
string *n***–** ряд, последовательность, цепочка
sufficient *adj.* **-** достаточный; обоснованный
suitable *adj.* **-** подходящий, пригодный
sulphuric acid *n* **–**серная кислота
support *n* -опорная стойка; кронштейн; штатив
suspend *v*–подвешивать
symmetrical *adj.* - симметричный

T
tag *n* **-** привесок, дополнение
thickness *n* **-** 1) толщина, плотность 2) консистенция
tilting *n* **-** 1) наклон 2) отклонение 3) опрокидывание
tolerance *n* **-** допуск
toroid *n* **–**тороидальный сердечник
transmit *v* - передавать,
transverse *v* - пересекающийся, поперечный
trapezoidal *adj.* - трапециобразный
traversing *n* **-** 1) пересечение 2) перемещение
trend *v* **–** отклоняться

U
ubiquitous *adj.* **–** вездесущий; повсеместный
unavoidable *adj.* **-** неизбежный, неминуемый, неотвратимый
undesirable *adj.* **-** неподходящий, неудобный
uneven *adj.* **-** неровный, негладкий; шероховатый
universal *adj.* **–**универсальный
uppermost *adj.* **-** самый верхний; высший
utilize *v* **-** утилизировать, расходовать, употреблять

V
velocity *n* **–** скорость; быстрота
velocity *n* **-** скорость; быстрота
verify *v* **–** проверять, контролировать; сверять
voltage *v* **-** вольтаж, электрическое напряжение

W
warm-up phase *n* **–** стадия прогрева мотора
waveform *n* **-** 1) форма волны 2) форма сигнала 3) форма колебания
weakening *n* **-** ослабление
wear *n* **-** трение
weighted *adj..* **-** взвешенный,
wind *v* **-** вентилировать
withstand *v* **-** устоять, выдержать;

Abbreviations
PID - Proportional-Integral-Derivative

Список дополнительной литературы

1. New International Business English Updated Addition
Leo Jones Richard Alexander
Cambridge University Press 2000
2.

4. Internet sites: Wikipedia, On-line Encyclopedia