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DP/IND/82/034

INDIA

Technical Report

Prepared for the Government of India by the United Nations Industrial Development Organisation, acting as executing agency for the United Nations Development Programme

Based on the work of D. Popovic
Expert in Automation and Control

United Nations Industrial Development Organisation
Vienna

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1. Summary

In order to meet the objectives of the mission as defined in 2.here the Expert has

1. visited the Project Centres in New Delhi, Trivandrum and Calcutta,
2. informed himself about the running Project activities within the Centres and has planed the new activities for the near future,
3. visited some research institutions for process automation,
4. consulted some users of plant automation from the industry,
5. delivered a series of internal and public lectures during the seminars on computer-based process automation systems.

The findings of the Expert during his mission as well as the corresponding recommendations for future work within the Project Centres visited are extensively discussed in the following Technical Report and once more summarized at its end.

2. Objectives of the Mission

As per Job Description of UNIDO, the purpose of the Mission of the Expert has been

- to apprise himself of the current status of industrial control technology,
- to suggest appropriate state-of-the-art technologies,
- to suggests configurations for latest control hardware for augmentation of the process control laboratory, to
- evolve the course of industrial control technology for developing countries,
- participate as a faculty on the courses.

3. Activities of the Experts during his Mission

In order to meet the objectives of his Mission, as defined in 2. here, the Expert has

- visited the Project Centre in New Delhi and in connection with the MAEP-Project, also the Central Electronics Engineering Research Institute PILANI (Rajasthan) and the Corporate Research and Development of Bharat Heavy Electricals Limited, Hyderabad,
- visited the Project Centres in Trivandrum and Calcutta.

During the visit of Project Centres, the following activities have been carried out by the Expert:

- review of the on going work within each Centre,
- discussions about the main difficulties in the Project work,
- advising the personnel of the Centres in problem solving and planing of future activities,
- working out of detailed plans for the future education and training of Project staff,
- helping the Project Centres in planing and carrying out of training and other educational courses for engineers from the industry,
- lecturing within the Project Centres as well as within the industrial and professional organizations in different topics of computer-based plant automation.

4. Findings concerning the state-of-the-art of automation in the Indian industry

In his last Technical Report(1984) the Expert has described the state-of-the-art in Indian industry based on his Mission 1984 in India. In his Technical Report (1985) on DP/IND/84/030/A/01(37) the Expert has limited his impressions to the changes in the above mentioned state-of-the-art since his last visit.The main impressions will be summarized as follows:

1. The general trend in automation of Indian industry lies in increased application of most modern, multi-computer systems which will be imported or produced in the country in co-operation with the foreign companies.

2. With this in connection, many Indian companies try to use the modern automation systems installed in the plant for process optimization in order to
   - increase the productivity, the yield or the productivity,
   - save the energy or/and the raw material,
   - reduce the production costs.

   The tendency just mentioned is obvious within the industry branches like
   - steel and iron,
   - fertilizers,
   - chemicals,
   - shugar
   - cement, etc.

   Similar tendencies are noticable within the
   - power generation plants, and the
   - energy distribution systems.

3. There is the tendency of instrumentation vendors to produce, distribute and maintain the most modern automation systems in co-operation with the international well known instrumentation vendors.Such systems are for instance the programmable controllers, microcomputer-based data acquisition systems, distributed computers control systems, etc.In this way only the problem of efficient maintainance has perheaps been solved,

but in no way the more important problem:the technological lack of Indian Control Instrumentation Industry.

4. There is a general impression that also many Indian Research Institution an Research and Development Centres of Indian companies intend seriously to work in the field of

   - Process Modelling,
   - Systems Identification,
   - Parameter Estimation,
   - Systems Simulation and
   - Optimal and Adaptive Process Control.

5. The same tendency is also noticable in the field of education of engineers at Indian Universities and Colleges: in the sense of modern systems theory.This is an essential change since the last Mission of the Expert but with the limitation that the practical component of this education is still not there as it should be.This is, naturally due to the insufficient or out-of-date laboratory equipment in the Control Departments of the high schools.

6. The establishment of Project Centres of AAPP can in a smaller degree improve the practical component of education and training of Indian engineers in the future if

   - the training laboratories of Project Centres are at least minimal equiped with the control instrumentation as recommended here(Annex A.3),
   - as much as possible teachers and lecturers from the Universities and Colleges participate in training courses of Project Centres.

5. Project Centres

The establishment of Regional Project Centres within the AAPP has created new possibilities for a wide, application-oriented education and training of engineers from the industry in process control and plant automation.Here, different courses have been held at different technical levels(Microcomputer, input/output programming, data acquisition, real-time systems, etc).In the past, approximately 100 partitipants from the industry have been trained each year.Furtheremore, in most of the Project Centres there already exist the corresponding course materials written by very well skilled Project staff.

However, the lack of interconnections between the microcomputer system and the control instrumentation is obvious in nearly all Centres.That was the reason for the Expert to recommend in his last Technical Report(1984) for each Project Centre a minimum amount of control equipment, a small analog computer and the relevant Project library.Thus, the Expert recommends here once more to follow his last recommendations and order the items as defined in Annexes A.1 to A.3 here.

5.1 Southern Regional Centre, Trivandrum

In the past period, e.g. since the last visit of the Expert the Project Centre(situated vith Electronic Research and Development Centre of KELTRON) has concentrated its activity mainly on

- training of engineers from the local industry,
- sponsoring and co-sponsoring of National Workshops on Computer Applications for Power Plants,
- further development of /usic system, now covering over 16 modules and a 6800 microcomputer board,
- development of a Data Communication Network for process control application.

Based an extended discussions with the Project staff during his stay in Trivandrum, the Expert recommends the following activities to be carried out in the next future:

- Data Transport Networks for Process Automation

  Comparative analysis of the most suitable bus systems for data exchange within a widely distributed, multicomputer plant automation system.

  Developement, test and application of one (or two alternative) bus systems, which should be the main communication links in a distributed computers control system to be developed within the Project.

  For this purpose one Project engineer should be sent for training abroad.

- Microcomputer-Based Process Monitoring System

  Development of a /USIC-based system for monitoring of distributed systems like power generation or power distribution systems.A color graphic CRT as well as some remote data acquisition features should be included into the system.

In addition to this, a modular and easy expandable software should be developed for process data acquisition and plant monitoring purposes.

- Advanced Programmable Controller

A multiloop field station should be developed as a basic element of modular Distributed Computers Control System. Here, a Project engineer should be sent abroad for training. The training abroad should include also his work on main design problems of the Microcomputer-Based Process Monitoring System as stated above.

- Systems Modeling and Simulation

Within this activity, the following should be studied:

  - Methods of Model Building and Parameter Estimation and their implementation on a microcomputer(generation of corresponding software packages)
  - Simulation Languages and Simulation Systems for analog simulation on digital systems

As a result, the adaptation of some existing parameter estimation and simulation packages should be adapted to the /USIC-System.

Here also, an engineer should be sent for training abroad.

5.2 Eastern Regional Centre, Calcutta

The activities of the Centre, situated within the Jadavpur University of Calcutta, can be summarized for the last period of 12 months as follows:

- Education and training in the field of microcomputers application to process control, including application to the chemical industry
- Development of a microcomputer-based
  - pH-Controller for ACCI
  - temperature controller(including a corresponding case study in this field)
  - stepper motor controller
- Design and setting up of a process model (in co-operation with the Department of Chemical Engineers of the University
- preparation of a survey on Jute Tea Industries for the purpose of a microcomputer-based process automation of tea plants
- Development of a microcomputer-based multiloop station for automation in chemical industry
- Development of a temperature monitoring and sequence controller of a kettle in painting industry

Based on the development activities of the centre, described above, the following will be recommended by the Expert:

- all controllers, developed thus fas as laboratory versions only should be brought to a final industrial version and on-line tested in a local chemical plant
- the process models, developed in the past and described as the third item above should be provaded with the final version of controllers to be developed

- the multiloop controller, developed thus far as hardware only shoul be provided with the corresponding software(operating system, library of functions, loops configurator and parametrizer, etc)
- the controllers and model set ups developed within the Centre should be interconnected via a data communication link(a long-distance data highway) to be developed in the next future

For the purpose of future Project activities, recommended here, two advanced engineers should be sent abroad for training.

5.3 Northern Regional Centre, New Delhi

During my stay with the Electronics Commission in New Delhi as UNIDO Expert for Microcomputers Application(MAEP-Project) the talks have been possible with the staff and the Chief Project Co-ordinator of AAPP-Project on activities going on within the Centre and about the activities planed for the next future. Here, the following can be stated:

- A series of training courses and application seminars have been organized by the Centre in New Delhi as well at some other locations(Pilani,etc) for people from different industrial branches, so that the Centre has the best results in this area within the Project.This holds also for the diversity of training areas covered during the courses which includes digital logic circuits, microcomputer hardware and software, organization of input, output and interrupts, connection to electrical, electromechanical and pneumatic elements(sensors, actuators, switches, valves, etc) which about the completed course printed materials for the participants are available.

- Hardware and software was designed for a series of small industrial automation projects, like for instancea microcomputer-based inertial track monitoring system for railways, a data acquisition system for gas distribution within a steel plant, many developments in the erea of microcomputer-based input/output controllers, etc.

- Model building of industrial processes(in co-operation with the industry and some research organizations).In mean time very capable people in this field are available within the Centre due to a obligue contact to most different indus-

trial branches(cement, steel, shugar, tea, fertilizers, chemical, railways, etc).Beside this, the Centre has excellent connections to various Research Institutes of the country which are application-oriented in the field of computer-based plant automation.

Outgoing from the above statements, the Expert recommends for the Centre in the next future:

- continuation of work on small automation systems for different industrial branches as desired by clients
- model building for processes within the cement, steel, shugar and fertilizers industry in cooperation with the concerned companies and the relevant research and development centres
- development of a system for simulation and parameter-estimation of continuous process models on a microcomputer system available within the centre(Here, the adaptation of an existing programme package, available at University Department of the Expert, can be of great advantage).
- work on system analysis, model building, etc. oriented toward some processing units(Blast Furnace, Basic Oxygen Furnace, Continuous Casting, Finishing Mills, etc.) of Bhilai Plant as a preparation and technical support of future Project in this field(the INCOS-Project).

For each of the above 4 activities at least one engineer should be sent abroad for training, whereby for the last activity even 2 engineers should be sent twice in the distance of one year(in order to stay in close contact with foreign experts in the field of analysis and modeling of different steel plant process units). From the same reason, also a study tour must be undertaken as soon as possible and repeated not leater than within one year. The study tours should update the technological and the theoretical informations of the Centre (and of the AAPP itself) concerning the modern automation approaches in the industry.
It has to be pointed out that the Northern Regional Center has not used its possibilities for training an study tours in the past.

8. Summary of Findings

1. In all Project Centres, especially in the Northern Regional Centre in New Delhi the work on modelling of processes in different industrial branches is going on.
2. There is a multiple intersection between the on going activities of the Project Centres (programmable controllers, field station, data communication systems, etc) and the future national Project INCOS.
3. The Project staff working on mathematical model building need some technical and methodological help as soon as possible.
4. Project activities to be carried out in the near future are well-known and defined here in 5.1 to 5.3.
5. In some cases the products of Project work (equipment, programmes) are brought up to the laboratory only.There is not in all cases completed technical documentation about the products.
6. There is sometimes the case that some microcomputer systems will be chosen as a basis for further development instead of /USIC system,already developed within the Project.This needs unnecessary imports of equipment and costs additional foreign currency,which can be saved by using the /USIC system.
7. Not all trainings abroad and study tours, as originally planed within the Project have been used up to now.
8. There is the tendency to spend the training time abroad with the microcomputer vendors in participation in a system course(hardware and software).This is that can also be done in the Centre itself by using the procured microcomputer system itself.However, the Project has an application character, so that the training with the institutions applying the microcomputer systems for process automation is more usefull.
9. This does not hold for study tours:the Project Co-ordinators should also visit the microcomputer vendors in order to be informed about the state-of-the-art in the field of microcomputer technology.
10. It has proved, that the total duration time of 3 months is not always enough for training abroad.This holds for the cases when the trainee is involved in a small project for training purposes that can not be finished in 3 months exactly.

11. The Project staff needs more frequent help from the UNIDO experts than once a year, as it was the case in the past.More frequent discussions with the experts accelerate the work within the Centres and avoid the unnecessary irritations in developing of new items.

12. It has proved that more general purpose equipment has originally been planed for the Project than the special equipment that will rely be needed for the future activities.Furthermore, some of such equipment are already available on the domestic market.

    On the other side, it has also proved that more direct exchange of know-how by training abroad, study tours and visits of experts will be necessary than originally planed.

13. The total duration of the Project(4 years) seems to be to short due to the long-tome activities necessary for development of equipment really applicable in the industry and due to the initial difficulties of the organization of Project work.

14. In his last Technical Report (1984), the Expert has made some recommendations which have proved to be essential for further Project progress and which have not been realized until now. The recommendations are:

    ' 10.2 For practical training of personnel, augment the training equipment of project centres as recommended in Appendix A.3 to this Report.'

    ' 10.4 For software development in the area of model building, process parameter and state estimation, optimal and adaptive control, DDC, etc., provide each project centre with an analog simulator(analog computer), which technical specifications are given as Appendix A.4 of this Report.'

    ' 10.12.Generally, enlarge the project libraries of the centres according to the list of recommended journals, proceedings and books(see Appendix A.5).'

    The above cited Appendices are included in this Report as Appendices A.1 to A.3.

    The recommendations 10.2, 10.4 and 10.12 as given in the last Reports are still urgent.

7. Summary of Recommendations

1. The work on model building and systems simulation should go on in all Centres of AAPP, especially the work in the area of steel power plants as well as of chemical, cement, fertilizer, food(incl. the tea) and of sugar industry.With this in connection, the connections to the relevant companies should be spread out and tightned so that the models, developed in different areas will be of practical use.

2. Special attention should be paid to the close co-operation with the Bhilai steel plant due to the INCOS-Project to come. Here, all Centres of AAPP (as well as some Centres of MAEP, like the Centre in Bangalore, Ranchi and in New Delhi)should check there activities against the usefullness of the results to the bigest Indian automation project to which also the UNIDO support of AAPP and of MAEP can directly contribute.

3. Special courses in model building, parameter estimation and systems simulation should be held by UNIDO experts for the Project staff of all Centres(of both Projects)

4. Project activities to be carried out in the Centres, visited by the Expert , should be as stated in 5.1 to 5.3 here.

5. Special attention should also be paid to the fact, that each Project activity containing the development component for hardware or software should finally give an industrial version of the equipment or of a program developed.For this, also the completed technical documentation should be generated and the equipment(the program) itself tested within a plant e.g. under normal industrial conditions.The best success of the Project work will, naturally, be in the case that the developed items will later on produced by a vendor.

6. For development of microcomputer-based automation systemsthe /USIC-System, developed within the Project should be used in all cases where it is possible.The use of other microcomputer systems should always be an exception.

7. It is urgent to send the Project staff for training and the Project Coordinators for study tours abroad as recommended in 5.1 to 5.3 in this Report.A delayed action in this area will have negative concequences to many activities within the Project.

8. In the future,the institutions applying the computer technology and the advanced engineering methods for process automation should be chosen for training of Project staff, rather the microcomputer vendors.Only a short visit to the microcomputer producers should be planed by trainees.

9. This should not hold for study tours, where the Project Coordinators should inform themself about the microcomputer and instrumentation technology as well as about their applications.

10. It must be possible - when especially usefull small project works during the training abroad should be finished - to automatically prolonge the stay abroad at an additional month.

11. In the future also, the international experts should be invited more frequently for a shorter time rather than in long time distanced for a longer time This is necessary for better review of Project work and for planing of new activities within the Project.Beside this, the more frequent visits of the experts will help to organize more special training courses, seminars and symposia for Project staff as well as for engineers from the industry.

12. It is also recommendable to review once more the Project budget from the point of view of proportionality between the UNIDO inputs for the procurement of equipment and for training abroad, study tours and visit of foreign experts.For the Project progress, it is of more use to increase the part of the budget concerning the trainings, study tours and expert visits by decreasing the expences reserved for the equipments.The Expert is convinced that the know-how transfer process by direct contact between the Project staff (abroad or at home) and the international experts is a more efficiert way to help a country in development than simply the procurement of a greate amount of equipment.The Expert thas recommends to even increase the total UNIDO input to the AAPP-Project in order to really intensify the process of know-how transfer.

13. It is finally questionable whether the total duration of a complex Project like AAPP should be limited, as planed,to 4 years. It is at this point recommendable - especially in view of the activities within the INCOS-Project - to extend this duration for a further year.This will anyhow be necessary when the total UNIDO input should be increased.

14. Relize as soon as possible the recommendations of the Expert given in his last Report and attached to this Report as Appendix A.1 to A.3.
Extend for this purpose the Project budget.

Appendix A.1.: List of control instrumentation equipment for training in computer-based process contrc

Objectives

The equipment should help to

- understand the working principles and technical characteristics of individual instrumentation elements;
- design and manufacture of small-scale control-loops for temperature, flow, pressure, and pressure control;
- realize the experiments in the area of system identification and direct digital control(DDC);
- on-line test of microcomputer programms, developed for above purposes.

Instrumentation list

	number	US $
a) Sensing elements		
- Thermoresistivities		
- up to 150°C	8	120
- up to 400°C	2	160
- Thermoelements		
- Fe-CuNi(up to 300°C)	4	320
- NiCr-Ni(up to 400°C)	4	320
- NiCr-Ni(up to 1100°C)	2	160
b) Transducers		
- For thermoresistivities		
- non-isolated	4	1,000
- isolated	4	1,200
- For thermoelements		
- non-isolated	4	1,000
- isolated	4	1,400
		US $ 5,680.

- For pressure and pressure-difference

	number	US $
- range:0.1-1mbar	4	2,400
- range:0.4-4mbar	2	1,600
- range(absolute):0.8-1.1bar	2	2,200
- for level	2	3,000

- For flow

- pulse output	2	1,600
- analog output	4	3,600
- inductive(for tubes)	4	4.000

- Pressure-to-current converters

- for pressure-difference	2	2,500
- for flow	2	3,000

- Instrumentation amplifiers

- DC-current(isolated)	8	2,000
- DC-voltage(isolated)	6	2,100
- resistivity	4	1,000

- Multichannel recorders

- 3 channel recorder	2	3,000

- Controllers

- pneumatic P-controller	2	2.000
- on-off controller	2	2.500
- indicating controller	8	500
- universal P-,PI-,PID-controller	4	5.000

- Actuators

- positional valves	-	
-positional motors	-	5,000
- stepping motors	-	
	US $	47,000
	(from p.1)	5,680
	US $	52,680

Note: The prizes correspond to the relevant instrumentation prizes in Germany.

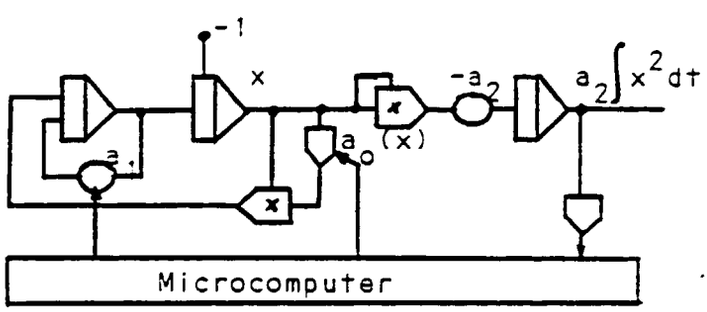
Appendix A.2.: Technical specifications of an analog simulator (Analog Computer) for training purposes

Objectives

By the use of the simulator

- mathematical models of dynamic systems (i.e. of simple industrial plants) should be simulated,
- parameter and state estimation as well as optimal and adaptive control schemes for the simulated systems can be realized by a microcomputer, connected to the analog simulator, and
- the corresponding software can be designed, implemented and on-line tested.

An example in this sense shows the following Figure.



Technical specifications

a) Specifications of the system

Generally, the system should be modular, i.e. extendable.

- Reference voltage unit of the system
  - output voltage 5 - 10V
  - output current 20mA
  - thermal stability .01%
- Repetitive operations timer
  - control modes CONT.OPER.-HOLD-REPET.OPER.
  - run periods 1msec - 10sec
- Patch board
  - remouvable
- Display
  - for analog functions LED
  - for addresses 7-segment LED
  - accuracy 3-4 digits
- Keyboard selection
  - selectable
    - addressing

- potentiometer setting
- mode
- mode speed

- System inputs/outputs

  - video display
  - teletype
  - xy-plotter
  - instrumentation bus IEEE 488 for connection to a microcomputer system

b) Specifications of analog part of the system

- General:Number of elements

- integrators	4 - 16
- summers	4 - 8
- multipliers	4 - 6
- comparators	2 - 4
- analog switces	2 - 4
- free functions generators	2 - 4
- potentiometers	10 - 20

- Integrators and summers

- number of inputs	5
- input gain	1, (5), 10
- accuracy	0.1 - 0.25%
- output current	5mA
-	

- Multipliers

- type	4 quadrant
- operational modes	MUL, DIV, SQRT
- accuracy	0.5%
- output current	5mA

- Comparators

- type	dual input
- function	A>B for logic 1
- switching error	$\pm$(5 - 10)mV
- switching time	20µsec

- Analog switch

- type	single-pole,double-throw
- static error	0.1%

- Free functions generators

- type	diode
- number of segments	5 - 10
- output current	5mA

- Potentiometers

- resistance	10KOhm
- number of revolutions	10
- accuracy	0.01 - 0.05%
- linearity	0.01%
- output	buffered

Analog Computers Examples

- EAI 1000 of Electronic Associates Ltd., USA
- Dornier 960 of Dornier System GmbH, Germany

Prize spectrum

- 20.000 - 40.000 $

Appendix A.3.: List of recommended technical journals, conference proceedings and books for libraries of projec centres

a) Journals

- Automatica (IFAC)
- Control Engineering (USA)
- IEEE Transactions on Automatic Control (USA)
- International Journal of Control (UK)
- Optimal Control Applications and Methods (IKAC)
- Systems and Control Letters (UK)

b) Proceedings

- Proceedings of IFAC (International Federation of Automatic Control) World Congresses and International Symposia, especially of Symposium on Identification and System Parameter Estimation.
- Proceedings of IFIP(International Federation for Information Processing) International Conferences.
- Proceedings of IASTED (International Association of Science and Technology for Development) International Conferences and Symposia.

c) Handbooks

- Considine, D.M.: Process Instruments and Control Handbook(2nd Ed.), McGraw-Hill, 1974.
- Harrison, T.J.: Handbook of Industrial Control Computers, Wiley, 1972.
- Korn, G.A. and Th.M.Korn: Mathematical Handbook for Scientists and Engineers(2nd Ed.), McGraw-Hill, 1980.

d) Books

- Instrumentation Engineering
  - Johnson, C.D.: Process Control Instrumentation Technology, Wiley, 1977.
  - Gregory, B.A.: An Introduction to Electrical Instrumentation and Measurement Systems(2nd Ed.), Macmillan Press, 1981.
  - Rangan, C.S., G.R.Sarma and V.S.V.Mani: Instrumentation:Devices and Systems(T-M), McGraw-Hill, 1982.
  - CHEMICAL ENGINEERING MAGAZINE: Practical Process Instrumentation and Control, McGraw-Hill Publications Co., 1980.
  - Carrick, A.: Computers and Instrumentation, Heyden and Son Ltd., London, 1979.
  - Bibero, R.J.: Microprocessors in Instruments and Control, Wiley, 1978.
  - Garrett, P.H.:Analog Systems for Microprocessors and Minicomputers, Reston Publishing Company, Inc., 1978.

- Harrison, T.J.: Minicomputers in Industrial Control: An Introduction, Wiley, 1980.

- Signals and Data Processing

- Chatfield, C.: The Analysis of Time-Series, Chapman and Hall, 1980.
- Peled, A. and B.Liu: Digital Signal Processing:Theory, Design and Implementation, Wiley, 1976.
- Lynn, P.A.: An Introduction to the Analysiys and Processing of Signals, Macmillan Press, 1973.
- Schwartz, M. and L.Shaw: Signal Processing, McGraw-Hill, 1975.

- Data Filtering

- Terell, T.J.: Introduction to Digital Filters, Macmillam Press, 1980.
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- Random Data Analysis

- Bendat, J.S. and A.G.Piersol: Random Data:Analysis and Measurement Procedures, Wiley, 1971.
- Afifi, A.A. and S.P.Azen: Statistical Analysis:A Computer Oriented Approach(2nd Ed.), Academic Press, 1979.
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- Systems and Control Theory

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- Fossard, H.J.: Multivariable System Control, North-Holland Publ. Co., 1979.
- Strejc, V.: State Space Theory of Discrete Linear Control, Wiley, 1981.

- Applied Digital Control

- Deshpande, P.B. and Ash: Elements of Computer Process Control with Advanced Control Application, Wiley, 1981.
- Ray, W.H.: Advanced Process Control, McGraw-Hill, 1981.
- Franklin, G.F. and J.D.Powell: Digital Control of Dynamic Systems, Addison-Wesley, 1980.

- Chard, R.A.: Introducing Software Engineering for Process Control, Wiley, 1983.

- Optimal and Adaptive Control

  - Blatt, J.M.: An Elementary Introduction to Optimal Control, Published by Computer Systems, Sudney, 1981.
  - Bryson,Jr., A.E. and Y.C.Ho: Applied Optimal Control, Blaisdel Publishing Company, Waltham, Mass, 1969.
  - Kwakernaak, H. and R.Sivan: Linear Optimal Control Systems, Wiley, 1972.
  - Landau, Y.D.: Adaptive Control:The Model Reference Approach, Marcel Dekker, Inc., 1979.
  - Narendra, K.S. and R.V.Monopoli(Editors):Applications of Adaptive Control, Academic Press, 1980.
  - Unbehauen, H.(Editor): Methods and Applications of Adaptive Control, Springer, Berlin, 1980.

- System Modeling and Identification

  - Eykhoff, P.: System Identification(Parameter and State Estimation), Wiley, 1974.
  - Mendel, J.: Discrete Techniques of Parameter Estimation, Marcel Dekker, 1973.
  - Eykhoff, P.(Editor): Trends and Progress in System Identification, Pergamon Press, 1981.
  - Mehra, R. and D.G.Lainiotis: System Identification: Advances and Case Studies, Academic Press, 1976.
  - Ljung, L. and T.Söderström: Theory and Practice of Recursive Identification, MIT Press, 1983.

- System Simulation

  - Bekey, G.A. and W.J.Karplus: Hybrid Computation, Wiley, 1968.
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