Modern Communications Switching Systems—2nd Edition

by Marvin Hobbs

All the significant advances in computer-controlled telecommunications switching systems have been incorporated in this newly revised edition of *the* classic reference in the field. Plus, there's complete data on all major electromechanical equipment still in worldwide use—including crossbar, step-by-step and rotary systems.

This comprehensive text fully details the most recent innovations in SPC exchanges and their applications—systems the author projects will be switching all telecommunications lines in this country by the year 2000. Hobbs also appreciates the continuing widespread use of electromechanical exchanges by public *and* private systems in both the U.S. and the rest of the world. As a result, these have been thoroughly covered with attention to both unit design and applications.

Includes info on changes taking place in communications switching and subscriber services, the basic concepts of switching—factors in central office exchange design, circuits, switches, arrays, and grids—and logic switching algebra and electronic control. Circuits, relays, controls, and signaling methods in step-by-step, crossbar, crossbar with electronic control or memory, and SPC exchanges are all spelled out. Also lots of data on control and programming of SPC exchanges, info on time-division switching systems, data and telex switching, and automatic private branch exchanges. Plenty of illustrations, diagrams and schematics throughout. In short, this book is an important reference source for anyone involved in *any* aspect of public or private telecommunications technology.

Marvin Hobbs is senior technical editor for Bell Telephone Laboratories at Naperville, IL.

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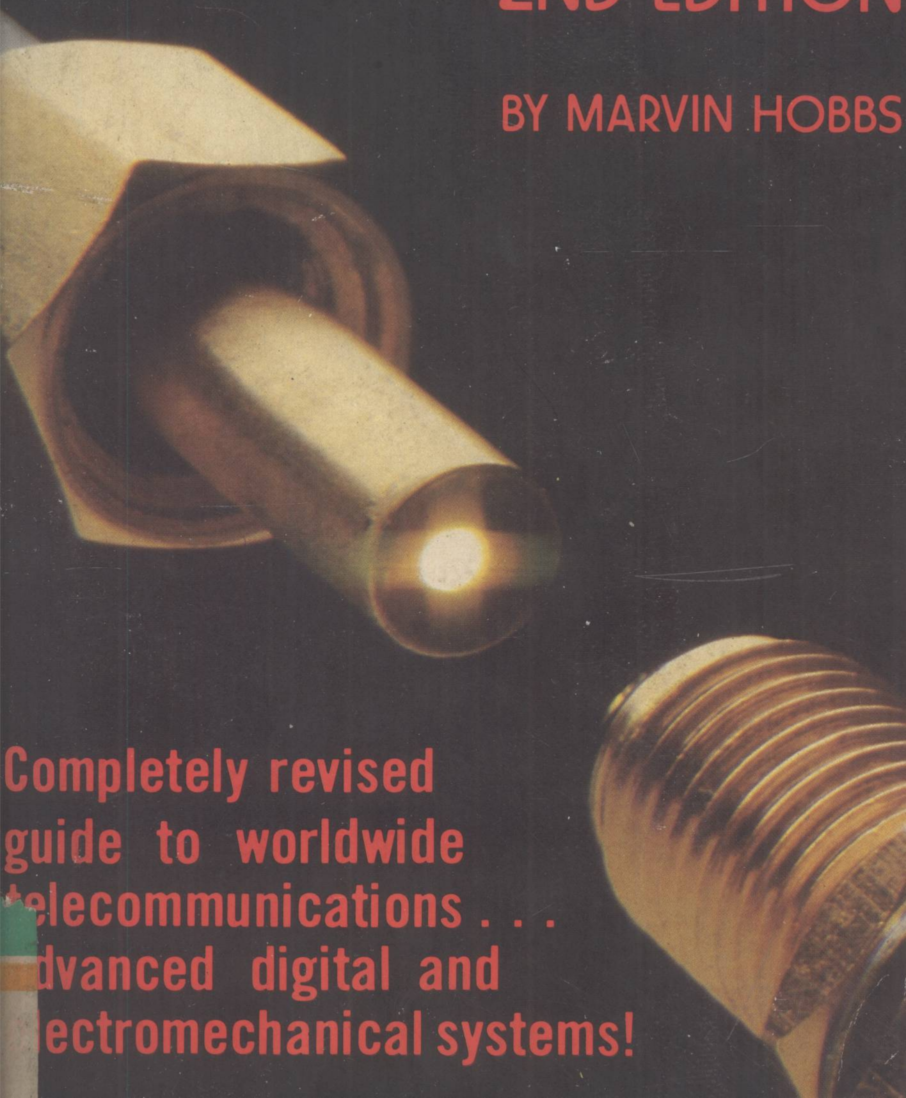

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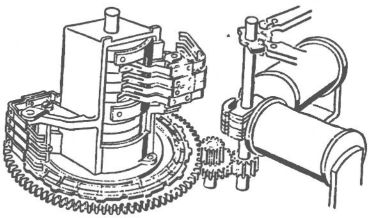

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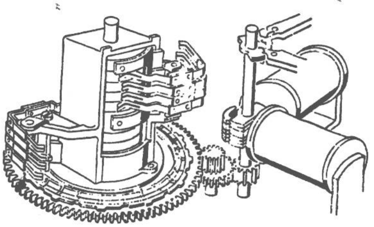

Preface

Some 80 years ago telephone switching began to change from manual to automatic operation, but this change did not come overnight with the invention of the Strowger switch. Decades were required for its full impact to be realized. It is likely that no change since then has been of equal importance in its effect on the structure of telecommunications services until the recent advent of computer-controlled switching techniques. In the years ahead, the application of digital central processor techniques (with their inherent software flexibility) to the control of switching elements can be expected to equal or exceed the impact on telecommunication operations created by the historic change from manual to automatic switching systems. The control of switching equipment based on fast operating, high-density digital memories to store readily changed programs marks the beginning of a new era in communications switching.

Unfortunately, the economics of capital investment and the demands for telephone service have made it impossible for this new era to be spawned as rapidly as technology would otherwise permit. Here again, it appears that decades will be required to replace the automatic equipment of an earlier vintage. Nevertheless, certain electronic features are being added to the existing equipment while a modest percentage of telephone lines are being equipped for service by completely new electronic systems. In the U.S., large urban centers are being served first by the new technology due mainly to the fact that it is more adaptable to large numbers of lines. In some countries, development has led in the direction of equipment to serve medium-sized communities first.

On a worldwide basis, much of the activity in electronic switching for telecommunications is still largely in the developmental or field-trial stages, but most major industrial countries have definite plans to produce and install a significant number of electronic switching systems over the next several years. In some cases military systems have been the first to benefit from the new switching technology because economic considerations have not played as great a role in dictating decisions in this area.

The rapidly increasing activity in digital data transmission, as well as the benefits derived from converting analog signals to digital form prior to transmission, has emphasized the need for digital switching. Since both time-division and message-switching techniques lend themselves to this phase of communications, developments in these directions have been accelerated. Digital switching lends itself well to digital transmission networks and will be seen there increasingly in the future. However, it cannot interface economically with existing analog telephone instruments and therefore cannot be expected to penetrate the entire communications hierarchy in the foreseeable future.

Modern Communications Switching Systems might logically encompass only those employing the new techniques of computerized control and digital switching. However, in view of the reality of the situation as stated, one must at least include crossbar and step-by-step systems as well, especially since both of these types, being modernized through the application of electronic control techniques, are likely to serve the public for some time in the future.

This book deals with the basic principles of telecommunications switching techniques ranging from step-by-step and rotary systems to the most modern stored-program control electronic systems, as well as time-division switching and those systems used in the switching of digital data. It is intended for use primarily by technical schools and colleges offering courses in telecommunications and related subjects and by engineers and technicians interested in learning more about this field of switching.

Since the first edition of this book was written, significant advances in the use of stored-program controlled (S/C) exchanges have been made in the U.S. As we enter the 1980s, approximately one-third of the lines in this country are switched by such systems. Projections indicate that by the year 2000, all of the lines in this country will be switched by computer-controlled exchanges. In other major developed countries, the percentages of lines switched by such systems are much lower. However, all of the major manufacturers of telephone exchanges throughout the world have developed SPC exchanges, and projections indicate that during the next decades the percentage of electronically switched lines will rise rapidly.

Digital switching has also made rapid progress in its application to toll exchanges in the U.S. Digital exchanges have been developed or are being developed by major telephone companies of the world and their application to local central office switching is making progress particularly outside the U.S. Some countries are pushing harder than others for its application at all exchange levels and have already made significant progress in that direction.

Despite all of this progress, the majority of the lines in the U.S. and in the rest of the world are still switched by electromechanical exchanges. Practically all major electromechanical systems, such as crossbar and step-by-step, are still in widespread use. Therefore, while an attempt has been made to update this book in SPC and digital-switching as much as necessary, it does not appear desirable to delete material about electromechanical switching systems.

A chapter on the control and programming of SPC exchanges has been added. The statistics have been updated and the chapters on time division switching systems, data and telex switching and automatic private branch exchanges have been expanded. I wish to acknowledge the assistance of the *ITU Telecommunication Journal*, the Institute of Electrical and Electronics Engineers IMC., the *Japan Telecommunications Review* of the Nippon Telegraph and Telephone Public Corp. and the National Engineering Consortium.

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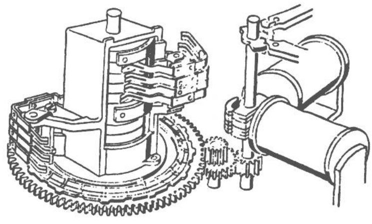

Chapter 1

The Slow Push for Progress

During the 10 years between 1970 and 1980 the number of telephones in the world has doubled. The number of countries with more than a million telephones has risen to 36. During this same period, the number of countries with over 200 annual conversations per person has reached an all-time high. Through cables, land lines, and satellite relays, the U.S. resident has access to more than 98 percent of the world's nearly 400 million telephones. Nineteen of the world's major cities had more than a million telephones each by 1972. In Table 1-1 the top 15 countries in numbers of telphones are listed and in Table 1-2, 20 of the cities and urban areas with more than 1,000,000 telephones each are listed in the order of their number of phones. In addition to the transmission of voice, the telephone system was called upon increasingly to send and receive data from computers, facsimile equipment, video devices and other data sources.

TELECOMMUNICATIONS SWITCHING

Because relatively few telephones can provide contact without switching from a multitude of local lines to a much smaller number of trunks between exchanges, the demands for service have not only increased the amount of switching required but have emphasized the need for greater dependability, faster connections, and new conveniences. The importance of switching to telecommunications can be measured to a degree by comparing its costs to that of the other elements of the overall systems. In that regard it represents nearly half the cost of an average telephone call and

Table 1-1. Top Telephone Countries.

Country	Number of Telephones
United States	162,076,146
Japan	50,625,589
United Kingdom	23,182,239
West Germany	22,931,683
Russia	19,600,000
France	17,518,813
Italy	16,118,928
Canada	14,505,728
Spain	9,527,781
Sweden	5,930,276
Netherlands	5,845,894
Australia	5,835,330
Brazil	4,708,000
Switzerland	4,145,169
Mexico	3,712,407

more than half the cost of a long-distance call. However, with the present-day mix of switching systems—which are predominantly electromechanical—about one-fourth the cost of an average call pays for switching equipment and approximately one-fifth goes for operators' salaries. However, the huge capital investment in electromechanical exchanges precludes their replacement for many years especially on a worldwide basis.

Telephone switching is the means by which a communication channel, capable of carrying analog or digital information between two or more subscribers, is established and maintained. Only in

Table 1-2. Top Telephone Cities.

City	Number of Telephones
New York City	5,936,829
Los Angeles	5,861,543
Tokyo	5,673,845
London	4,691,468
Chicago	2,610,000
Paris	2,502,414
Moscow	2,480,000
Osaka	1,936,280
Madrid	1,720,789
Toronto	1,689,359
Philadelphia	1,683;341
Mexico City	1,671,950
Sidney	1,614,598
Minneapolis-St. Paul	1,580,900
Rome	1,514,246
Milan	1,483,946
Houston	1,359,494
Baltimore	1,353,051
Buenos Aires	1,341,484
Melbourne	1,327,644

the case of private lines is it not required. Any modern telecommunications switching system consists of a great many intricate equipment and components combined into a overall system operating along certain well defined principles. A typical electromechanical automatic switching system contains several master control circuits, each of which consists of some 1500 relays. Such circuits are able to select particular paths and establish a desired connection in less than one second. In doing this, some 700 relays operate and about 10,000 electrical contacts are closed and opened. As an example, a single telephone call from Ann Arbor, Michigan, to downtown Detroit through an electromechanical exchange requires 37,000 relay contacts to make connection. To link any U.S. telephone with any other, the Bell System switching network provides a staggering 2.5 million billion possible connections. The installation of electronic exchanges will reduce the number of relay contact operations considerably—especially in the control portion of the system. But there are still 15 reed relay crosspoints for each subscriber's line in the No. 1 ESS offices. Even when a majority of the subscribers have such electronic switching service, it can be seen that the number of connections to be made for many calls will not be minor.

Present-day telephone-circuit switching equipments are based on either electromechanical techniques (employing crossbar, Strowger, or rotary switches) or electronic techniques (employing either electromechanical or solid-state speech switches and some form of electronic common control). The development of most of these systems has required years of time due largely to the extreme requirements for dependability and reliability. Even a "negligible" amount of downtime of a network cannot be tolerated by the telephone operating companies. There would be a much higher percentage of program-controlled electronic exchanges in use today if the demands for service in the late 1950s had not forced the installation of many crossbar exchanges while the full development of practical electronic exchanges was awaited. Also, at the present time stored-program electronic exchanges are economical only in medium to large central offices and for large private branch exchanges (PABXs). For these reasons, Western Electric produced more electromechanical crossbar switches annually 20 years after the invention of the transistor than ever before; and Japan (a major source of telephone switching systems in the international market) exported only exchanges with crossbar and step-by-step switches during the past decade. Even more surprisingly, Western Electric manufactured more stepping equipment in 1969 and 1970 than ever before and installed the ancient panel system equipment in the world's largest telephone city to cope with the service crisis in the city of New York.

"New Generation" Switching Systems in Service

Table 1-3 shows the "New Generation" Telephone Switching System in service as of mid-1978 listed by the first country of application. As indicated in the table, most of these exchanges featured stored program control (SPC).

Electronic Switching in the U.S.

As of mid-1979, more than 30 percent of the Bell System lines were being served by electronic switching systems. The number of their lines being switched by such systems was growing at the rate of about 6 million lines per year. New ESS offices were being cutover at a rate of about one per day. Despite all of this progress Bell's No. 5 Crossbar System continued to switch about 40 percent of their lines. The remaining 30 percent was served by other crossbar and step-by-step systems of earlier vintage. However, it was projected that about 60 percent of the Bell System lines would be switched electronically by 1985. Among the independent telephone companies it is estimated that not more than 10 percent of their lines are served by electronic switching systems produced mainly by General Telephone. The remaining 90 percent was switched by a relatively small number of crossbar exchanges and a large number of step-by-step (Strowger) exchanges. The latter were also produced by General Telephone.

In the Bell System, digital switching was being applied only to high-capacity toll exchanges. Here the No. 4 ESS, a large digital-switching exchange, is employed. One-half of the trunk circuits terminating at these exchanges will soon be handling pulse-code modulation of 24-channel capacity. No. 4 ESS exchanges now serve 30 percent of the toll circuits in the Bell System and are projected to serve 90 percent of them within five years. Toll service is also provided with lower capacity digital exchanges by the independent telephone companies. The No. 3 EAX of General Telephone and the DMS-series of Northern Telecom are examples of such exchanges.

By 1980, at least six companies, outside of the Bell System, had introduced digital switching systems for local exchange application. The prices of these exchanges appeared to offer considerable promise toward the replacement of the many electromechanically switched exchanges now in use by the Independent Telephone Companies. By the end of 1979, the Bell System had not placed any local digital exchange in regular service, but an announcement had been made that a No. 5 ESS system was to fill this role. At the PABX level, most of the new equipment incorporated digital switches.

Electronic Switching Outside the U.S.

Outside the U.S., Japan led in the application of electronically-switched SPC systems, with about 7 percent of their local subscriber lines and 24 percent of their toll circuits being switched by such systems by mid-1979. According to their present five-year plan, the percentage of local subscriber lines served by SPC switching systems would more than double by mid-1981. Japan still depended upon crossbar-switching systems to handle the bulk of its telephone traffic with a small percentage still switched by step-by-step exchanges.

In mid-1979, England was second after Japan switching about 6 percent of its local lines with electronically-switched exchanges. However, they used primarily a system—initially developed in 1966—with wired logic rather than the computer software control of typical modern SPC systems. Just the opposite of Japan, England still depended upon step-by-step (Strowger) switching systems to handle most of its telephone circuits with a small percentage switched by crossbar systems.

Although all of the world's telephone exchange manufacturers have various models of SPC exchanges available, and most countries, including several of the lesser developed ones, have plans for extensive if not total use of electronic switching systems by the year 2000, the amount of their use outside of the U.S., Japan and Britain was comparatively small in 1979. Large numbers of step-by-step (Strowger) and crossbar systems continued to carry the telephone traffic in many parts of the world.

In so far as the application of digital (time-division) switching at the local exchange level is concerned, the U.S. is not the leader. France now holds the distinction of being in first place. Proceeding from a military application, France has promoted the use of digital switching with vigor. At the end of 1979, more than 500,000 lines were being switched at the local level in France. Through export efforts as well as domestic efforts, the French company, CIT-Alcatel, had 3,000,000 lines in service or on order for digital

Table 1-3. New Generation Telephone Switching Systems.

Date of First Service	System Designation	First Country of Application	Manufacturer	Switching Network	Type of Control	Exchanges in Service	Lines Served (trunks = T) x 10^3
1965	No. 1 ESS	USA	Western Electric	ML-Reed	SPC	963	16.000
1966	TXE 2 (Pentex)	United Kingdom	Plessey	EH-Reed	EWL	950	1,076
1967	10C	Belgium	ITT	EH-Reed	SPC	47	406
	ESK 10000E	Denmark	Siemens	ESK-Reed	EWL	737	1,460
1968	No. 1 ESS-SP	USA	Western Electric	ML-Reed	SPC	657	NA
	No. 1 ESS-Tandem	USA	Western Electric	ML-Reed	SPC		
1970	ESC 1	USA	Stromberg-Carlson	EH-Reed	EWL	143	300
	E10	France	CIT-Alcatel	Digital TDM	EML	57	363
	C1-EAX	Canada	GTE-AE Canada	Crosspoint switch	SPC	152	288
	No. 2 ESS	USA	Western Electric	ML-Reed	SPC	262	1,120
	NX-1E	USA	North Electric	Crossbar	SPC	85	370
1971	SP-1	Canada	Northern Telecom	Minibar	SPC	143	1,500
	AKE-13	Netherlands	LM Ericsson	Codebar	SPC-MP	24	203
1972	Mentaconta L	Morocco	CGCT	Metabar	SPC	13	340
	Metaconta 10R	France	LMT	ML-Reed	SPC	7	60
	No. 1 EAX	USA	GTE-AE	EH-Reed	SPC	155	951
	D10 Toll	Japan	(1)	Mini-crossbar sealed-metallic	SPC	126	1,645
	D10 Toll	Japan	(1)	Mini-crossbar sealed-metallic	SPC	63	624
1973	PRX 205	Netherlands	Phillips	EH-Reed	SPC	160	900
	AKK-50	Mexico	LM Ericsson	Codebar	EWL	180	41
	ARE 11 Local	Denmark	LM Ericsson	Crossbar	SPC-MP	24	168