Electronic Telephone Exchange at Highgate Wood

The electronic telephone exchange which has been in public service at Highgate Wood in North London since December 12th, 1962, is another step towards the ultimate objective of an economic automatic telephone exchange using only electronic components. Highgate Wood is a considerable step forward from the previous experimental exchange at Dollis Hill, and work is already well advanced on the next electronic exchanges, which will include many more improvements based on the experience gained in the design and operation of Highgate Wood.

This exchange has 800 lines and operates on the principle of time division multiplex using pulse amplitude modulation, which enables 100 speech channels to be carried simultaneously on a single highway. Setting up and register functions are also time shared. This is believed to be the first exchange employing this combination of multiplexing and modulation techniques to be used for public traffic anywhere in the world.

The importance of the development of the electronic telephone exchange has already been stressed by the Postmaster General in the House of Commons.

"This", he said, "will represent a major breakthrough and we are determined that Britain shall have the best modern telephone exchanges not only to use here at home but also to market abroad.

We are, therefore, giving this work a very-high priority and so, too, are the principal manufacturers who are co-operating with us. We have recently reaffirmed the policy of moving straight from the existing automatic systems to fully-electronic exchanges as soon as possible"

Operation

The exchange at Highgate Wood, though thoroughly operational, is not entirely typical of the systems that are to follow it. The design was completed before semiconductor devices for all the required functions were generally available or sufficiently well proved. Consequently, although diode switching is used throughout the time-sharing circuits and transistors are used exclusively in subscribers' line units, magnetic-drum circuits and the register apparatus, several thousand thermionic valves are incorporated into other sections of the equipment—for example, pulse amplifiers driving coaxial cables. All valves and transistors are British, including specially made valves for the pulse output amplifiers.

Highgate Wood operates on a time-division multiplex system. This enables highways and switching paths through the exchange to carry 100 simultaneous channels in the form of 1-microsecond amplitude-modulated pulses at a pulse-repetition frequency of 10kc/s. Overall frequency control is maintained by a 1Mc/s quartz crystal.

Incoming lines and junctions are connected to the exchange highways and to the various time-shared control functions by coincidence gates. These, in turn, are controlled by circulating stores each consisting of a 100-microsecond magnetostrictive delay line. Each connexion uses a pair of multiplex channels, spaced 50 microseconds apart, to overcome side-tone which would be troublesome if the same channel pulse were used for within-group connexions.

Fig. 1. Typical 100-microsecond delay-line store.

A magnetic-drum "memory" store constitutes the "central information library" of the exchange. All the permanent factors relating to each line are stored on the drum in the form of a 28-bit word containing data as to the type of line, class of service and directory address (the relationship between the subscriber's telephone number and the physical location of the corresponding exchange equipment). In addition, a 7-bit word is temporarily written into the drum to provide information on the state of the line, *e.g.*, busy or parked. The drum also records subscribers' meter pulses. Other drum tracks carry translator information and provide the digitally-coded instructions required by the setting-up equipment for the routing of calls.

The drum makes one revolution every 28 milliseconds and each subscriber's line is scanned every 224 milliseconds to coincide with a pulse of 1 microsecond, applied through the line-connecting gates to each free line in turn, to test whether or not a subscriber has lifted the handset, *i.e.*, whether the line is looped. Junctions from outside exchanges are scanned at a faster rate because, although a delay of approximately a quarter of a second can be accepted in applying dialling tone to a subscriber's line (it is physically impossible to lift a handset to the ear in that period), it is not permissible to delay the receipt of information from an incoming junction. For this reason, junctions are scanned once in every revolution of the drum, *i.e.*, every 28 milliseconds.

When a test pulse finds that a line or junction is calling, an indication is given to a channel selector together with the instruction that a connexion with the register equipment is required. The fact that the calling line is now busy is recorded in the state-of-line section of the memory drum.

Control functions in the exchange are based on 900-microsecond magnetostrictive delay lines. In the register equipment, these provide for nine independent bits of storage for each 1-microsecond channel.

The control sequences include the register functions of receiving, storing and sending dial-pulse information and the supervisory requirements of ringing, detecting answer, metering and clearing the finished call. At the same time, a complete "memory" must be maintained of which time-slots are available in the multiplex groups of the system.

Both the register and the supervisory delay lines must be able to accept and store all the information necessary for the progress of a call. This includes the routing instructions acquired from the magnetic drum via the translator equipment.

Routing a call

The following is a much-simplified description of the handling of a call originating on a Highgate Wood exchange line.

As soon as the test pulse identifies the fact that a line requires attention, a signal is passed to the setting-up apparatus. This causes "busy" to be written in the state-of-line sector of the magnetic-drum track relating to the calling line, and the setting-up equipment takes from the drum the permanent information—directory address, etc.—of the line, which it stores. This information is passed to the register as soon as a free time-slot has been allocated, and the identity of this time-slot is written into the line-connexion stores (also 100-microsecond delay lines), which prevent seizure of the line by any other call. A tone store is advised of the identity of the line calling and the antiphase pulse train controlling the outward speech highway (50 microseconds away from the inward highway) passes dialling tone to the subscriber.

This train of events has only occupied a few thousandths of a second from the moment the test signal scanned the subscriber's line and detected that a call was required.

Dialled information from the subscriber is passed through the multiplex to the register equipment, which counts and stores the make-and-break of the dial signals in modified binary code in the circulating delay lines. With a delay period of 900 microseconds these lines can store nine decimal digits for each time-slot of the 100 channels.

The first three digits of the dialled information are fed back, via the translator, to the memory drum, ten tracks of which consist of permanent translations of the various exchange destinations and services (HIG for Highgate Wood, INF for supervisor). The incoming binary-coded signals are compared with the magnetically-recorded tracks and, when coincidence is achieved, the drum reads out the equipment address of the outgoing junction or line group and any additional routing instructions that are needed to steer the call to its destination. This information returns to the register and is again stored. In addition, in every case the wanted connexion is referred to the temporary recordings on the drum. If the line is already engaged, instructions are sent back to the supervisory equipment to generate "busy tone" If the line is available, the required line information is staticised to connect the called line to the time-division multiplex highways and the "busy" signal is written on to the drum. The final steps are to set up equipment that selects the necessary free channels to establish the connexion, apply ringing tone to the called line and record metering information.

Throughout the exchange, common supervisory equipment monitors all the channels in use in order to detect any change in their state. as soon as a time-slot is vacated, it is made ready for re-use.

An important aspect of electronic exchanges is that they must be capable of uninterrupted service for 24 hours a day and one of the design parameters is that they should be capable of operation for reasonably long periods without maintenance. Because much of the equipment controlling the traffic is common to a large number of lines, failure cannot be tolerated. For this reason, a large amount of the exchange apparatus consists of routining equipment, which constantly monitors the various sections to detect fault conditions. Pulse patterns are set up at the various gates and compared with the resulting output pulses to indicate faults. Where equipment is duplicated (in some cases it is triplicated) the routining equipment regularly switches in each section in turn, at a periodicity of some 30 seconds, so that every piece of redundant equipment is in regular periodic use until fault conditions are detected.

Faults are pin-pointed by substitution analysis and, when the offending equipment is identified, its location

Fig. 2. Track assembly of cards for electronic telephone exchange Mark 2.

Fig. 3. Rack wiring of equipment for electronic telephone exchange Mark 2.

is indicated by lamp signals. Throughout the system, maintenance is simplified by enabling any faulty piece of equipment to be withdrawn and replaced as a unit, obviating on-the-spot repairs.

Future Development

Designs for future exchanges include the facility of automatic fault indication. At Highgate Wood, some 25 per cent. of the electronic equipment is related to routiners used in fault analysis.

Highgate Wood exchange is in the nature of an advanced field experiment, following the success of the smaller exploratory installation at the G.P.O. Research Station at Dollis Hill, London, in 1959. The electronic exchange is backed up by a conventional electro-mechanical automatic exchange. This allows the engineers to carry out development tests without interfering with the service to subscribers.

Three further electronic exchanges of a more sophisticated type are now being built. Two of these, Pembury and Goring-on-Thames, will replace manual exchanges and will operate on slightly different applications of the time-division pulse-amplitude modulation principle. The third exchange, at Leighton Buzzard, will replace an early type of automatic exchange and will operate on a space-division principle.

These new exchanges will be completely transistored and consequently more compact, devoid of ventilating problems and requiring considerably less power to operate. The exchanges will be essentially trials of potential production systems and will not have conventional standby exchanges. It is anticipated that they will be in service in eighteen months.

The design and construction of Highgate Wood and the other electronic exchanges is the result of an extensive programme of co-operative research and development between the Post Office and the five principal British manufacturers of exchange equipment. The co-ordinating body in this work has been the Joint Electronic Research Committee, set up in 1956, on which are represented the Post Office and the five Companies including G.E.C.

Frontispiece Time division multiplex suite in the electronic telephone exchange, Highgate Wood, North London.