

# wireless world

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NOVEMBER 1975 35p

## Teletext decoder Audio Fair



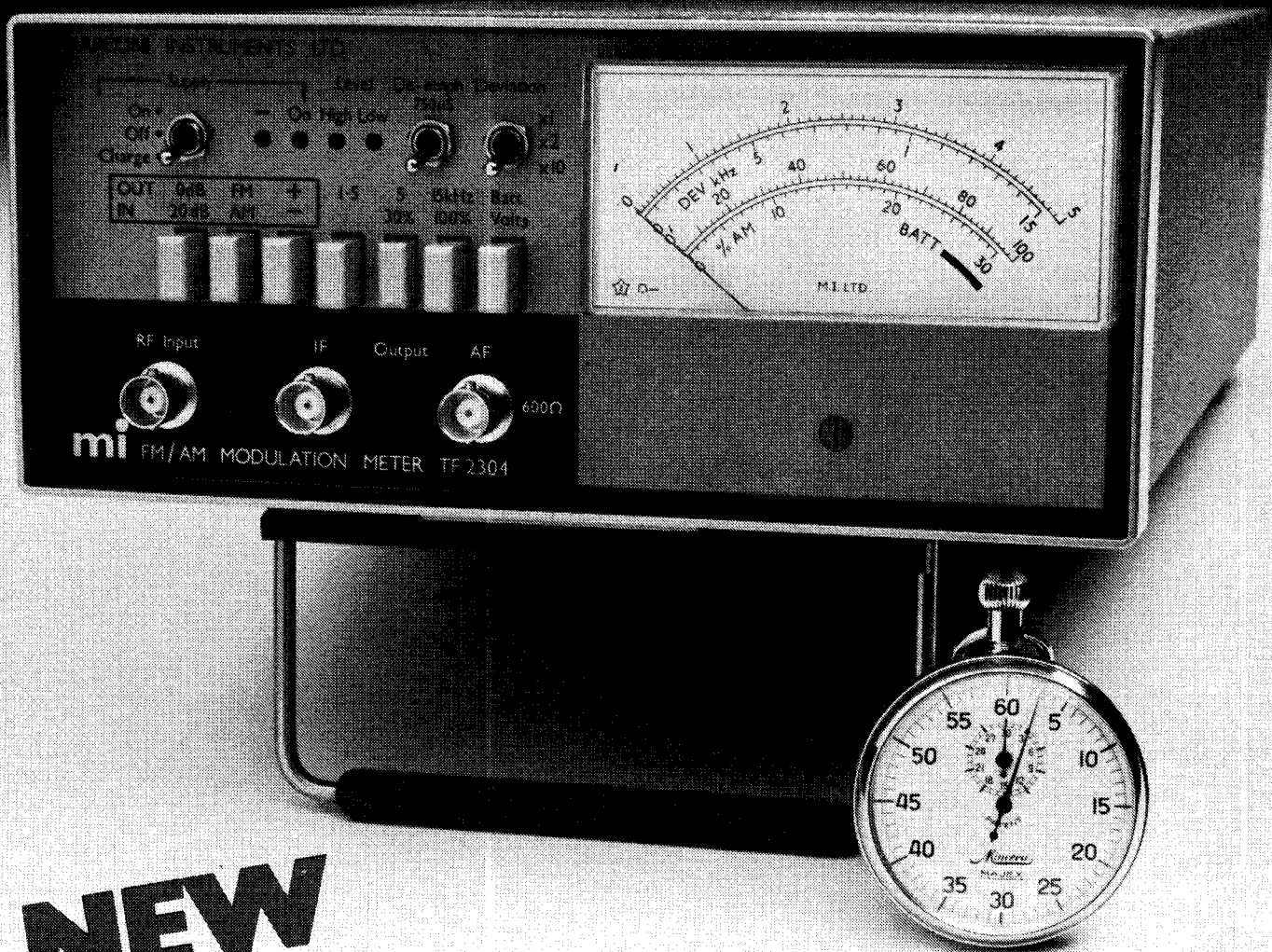
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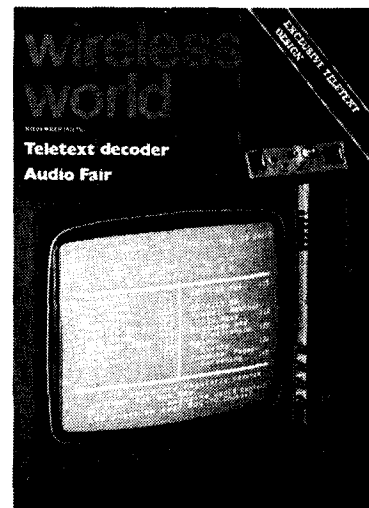
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This month's front cover shows a colour TV receiver displaying a Teletext page, processed by the Wireless World Teletext decoder seen on top of the set (see page 498). (Receiver lent by Thorn Television Rentals)

## IN OUR NEXT ISSUE

**Microprocessors** for computer control. What they are and how they work, with a table of types on the market

**New audio amplifier design** uses "current dumping" output transistors and feedforward distortion correction

**Interference from pocket calculators** can cause trouble. Measurements of electromagnetic radiation from three named calculators

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## The dugs of war

It's a sad comment on our times that you can now get a degree in destruction. To be more precise, an M.Sc. in guided weapon systems, under the auspices of the Council for National Academic Awards. Look into the olive-grove of Academe and what do you see but a war-head pointing out at you.

This little fact is only a symptom of our permanent involvement in war technology. To adapt Von Clausewitz's famous saying, "Peace is nothing more than the continuation of war by other means." Commentators speak nowadays of "the industrial-military complex" and by this they mean that certain parts of manufacturing industry have become closely identified with, and commercially dependent upon, the production of military equipment. This is certainly true of electronics. The art of war has come to depend on rapid communication and information processing, continuous surveillance and accurate control of mechanisms. And why? Because electronics has made these things possible. But electronics technology itself has been greatly developed by the pressures of actual wars — for example radar and the electronic digital computer in the 1939-45 war — and it continues to be stimulated by our fear of aggression and our consequent need to maintain the nuclear and military balance of power. It is really a chicken-and-egg situation.

Even though the basic drives in this reproductive cycle are fear and profit, it is possible to draw up an impressive list of benefits. For example, one of the significant "spin-offs" of nuclear missile development was the integrated circuit. This has produced a revolution in the design of electronic equipment. Calculator chips, microprocessors, counters, decoders and the like have made possible, simply and cheaply, the kind of information processing operations which, in the days when there were only discrete active devices, would have been quite inconceivable in domestic and industrial applications. Military electronics business is becoming an important factor in the economy of industrial countries. In the UK the Ministry of Defence is the biggest single customer for electronics. Profits are made, dividends are issued, jobs are created, and the export of the military equipment helps to pay for the import of essential raw materials and food.

Although engineers and technologists are beginning to show concern about the effects of their work on the environment, they seem not to be worried by the use of their technologies for destroying life and property. Perhaps we have been bamboozled by the use of the word "defence" as a euphemism for war. More likely, we are just too far away to see the blood being spilt. Anyway, "it's just a job." As long as the milch cow of defence expenditure continues to provide a steady flow of cash there will be plenty of us — individuals and firms — lining up and ready to feed off it, without looking too closely at the implications.

# Wireless World Teletext decoder

## 1 — The background

by Philip Darrington

### The first of a series of articles on the Teletext television information display system and the construction of a decoder for use with domestic television receivers.

In succeeding articles of this series we shall describe the design and construction of the *Wireless World* Teletext Decoder. But, before we do that, it seems only sensible to make sure that readers are up to date with current activity in the field and have an idea of other systems which have been proposed. We will also describe the basic operation of Teletext and mention the techniques used to decode the transmissions for display on a domestic television receiver.

In the early years of "wireless", the vision of millions of people being entertained by transmissions was just not credible. Television was thought to be sheer science fiction and wireless itself was for the transmission of vital information. Even if it had been possible to communicate phonically, that was not the idea at all — ships were the real users of radio and if amateurs could derive pleasure from listening to marine morse traffic or Eiffel Tower time signals, so much the better.

Then, of course, radio telephony was developed and the entertainment possibilities were recognized. It is now an extraordinary and rather depressing fact that out of the few thousand megahertz available for radio transmission, nearly 600MHz are taken up by broadcasting stations, most of which put out entertainment of one sort or another. Sound is reasonably restrained in its use of bandwidth, but television occupies 566MHz — a staggering figure, particularly as the television signal contains so much redundancy. Anything designed to make better use of this signal is to be welcomed and Teletext is one way of doing that, in that a previously unused part of the waveform is used to transmit more information.

Many ways of using television transmissions to better effect have been proposed<sup>1, 2</sup>. Since the early sixties, test signals inserted in the field blanking interval have been in common use, and have been supplemented by coded data

transmitted on lines 16 and 329 of each frame<sup>3</sup>. It apparently did not, at the time, occur to ORTF, who originally used the system, that the technique could be developed to allow the transmission of visible information, but the system was used for switching remote transmitters, identification for remote supervision purposes, etc.

Other systems of transmission aimed at "still" display, with or without sound and in colour or monochrome depend on the exclusive use of a television or sound channel. For instance, the NHK "A" system<sup>4</sup> is able to carry over 50 channels of colour still pictures, with sound, in the bandwidth of one normal television channel. The pictures are transmitted at the rate of one still per frame, together with a code to enable a magnetic disc memory in the receiving equipment to record a selected frame, which is then continuously replayed. Sound is multiplexed with video information and transmitted in the frame intervals.

The NHK "B"<sup>4</sup> system falls into the multiplexed television channel category, using uncoded signals. Three unused lines per field are used to transmit three lines of a still picture, which is magnetically recorded at the receiver. Sound is transmitted by the use of additional sound carriers at low level, spaced further in the spectrum from the vision channel than the original sound carrier.

In 1971, W. D. Houghton of RCA described the Homefax<sup>5</sup> system in which additional information was multiplexed with a broadcast television waveform to produce "hard copy" from an electro-optical printer, using a cathode-ray tube to produce the "printing" on Electrofax paper. The information, uncoded, was carried in an unused vertical interval line and transmitted in the normal way — each of these lines producing part of one line of a row of print on the receiver paper. Transmission tests of this system had been carried out in 1967, and improve-

ments were being carried out in 1970. A method of data transmission not using the vertical blanking interval<sup>6</sup> was described by P. T. King of Hazeltine Research, Inc., at the SMPTE Technical Conference in 1973. In this system, known as an "add-on" type, a low-level subcarrier was inserted on the vision signal at an odd multiple of half the line frequency, a method which is well known in colour television circles as a method of avoiding interference between two signals in a common waveform. The added signal is shifted in phase from line to line and the visible effects are reduced. The actual frequency is chosen to be between 2 and 3MHz in the NTSC standard, because radiated energy is at a minimum in that region in a typical picture. The data signal is biphase modulated at 21 kilobits per second and at the receiver is synchronously detected, the data decoded and used to operate a character generator, which can, for example, produce subtitles in languages using the characters available.

These two techniques — the use of previously blank lines in the vertical blanking interval and the provision of a character generator at the receiving end — paved the way for Teletext. A system of this kind is able to carry more information, more flexibly, by leaving the receiver to do rather more of the work than an analogue or uncoded digital system. If the transmitted signal is made to carry instructions to the receiver on what to do, the receiver can then hold much of the information in store, releasing it when commanded to do so.

Peter Hutt of the IBA described an embodiment of this principle in a paper read to the IPC, 1972<sup>7</sup>. The system was named SLICE and was primarily intended for the labelling of programmes with a source identification. The information was carried on lines 16 and 329 in the form of 112 binary digits per line and, at the receiver, was read

into a memory where a complete message was assembled. SLICE was the fore-runner of ORACLE and CEEFAX. (Hutt mentioned the possibility of a domestic information service in his paper.)

### Teletext

ORACLE was developed by the Independent Broadcasting Authority in the light of its experience with SLICE and the BBC announced their own system, which was very similar and bore the name CEEFAX. (ORACLE is an acronym — Optional Reception of Announcements by Coded Line Electronics — CEEFAX is See Facts as pronounced by an adenoidal dyslexic.) There is little profit in trying to decide which organization hit upon the idea first, or which was on the air first, as the two were quickly and sensibly to agree on a common standard of transmission, in conjunction with BREMA<sup>3</sup>. Both names will probably continue to be used for each organization's broadcasts, but the generic term "Teletext" is now common, and will be used henceforth. Teletext has been broadcast on the present standard since September 1974 — the beginning of a two-year experimental period. The system uses a multiplex-with-vision type of transmission and uses lines 17 and 18/330 and 331 to carry coded information. There is no accompanying Teletext sound.

Before proceeding further, a look at the facilities offered by a Teletext transmission and a résumé of some of the specification will be a help when considering the equipment needed in the receiver. Briefly, the Teletext page consists of 23 rows of 40 characters each, plus a page header, which is only partly displayed. As seen in Fig. 1, the header gives the name of the service (Ceefax or Oracle), the page number, the date and the time. The time display is continually changing and is always visible.

Visible characters are either capitals or lower-case letters assembled on a 7 × 5 dot matrix and in one of six colours or white: diagrams or low-resolution "pictures" can be assembled by the use of a block of cells on a 3 × 2 pattern, each of which can be "on" or "off", in colour. A variety of other symbols (commas, brackets, @, £, etc.) can also be shown, and the set of characters is known as the ISO-7 code, which is a version of the ASCII code with some of the "National usage" characters substituted. Characters can be made to flash on and off, though our own feeling is that this will be used rather less when the service is finally in use than it is now, if it infuriates other people as it does the writer.

The Teletext editing teams can use the pages in three different ways, the norm being single pages which appear when selected by the viewer at any time and which are up-dated perhaps once or twice a day. A second type is one of a

ORACLE p100 Thu 14 Aug 10.44/74			
<b>ORACLE</b>			
SPECIAL OFFERS	200	ABOUT ORACLE	101
IN NEWS INDEX	201	PUBLIC ADVICE	550
ADDRESSES	220	HELP	750
NEWSFLASH	230	POLICE & EMERGENCY SERVICES	720
WEATHER	300	SHOPPING	115
TV PROGRAMMES	400	HOME ADVICE	350
TRAVEL	500	JUNIOR ORACLE	650
ENTERTAINMENTS	600	THE ITU REGIONS	800
MEASURE	160	ENGINEERING	490
RECORDS & BOOKS	190		

Fig. 1. The main index page (p. 100) of ORACLE for August 14, 1975, produced by the W.W. decoder on a Thorn colour receiver.

group of, perhaps, four such pages which change at about one minute intervals. They will usually be on a related topic, such as sport, and are identified by the letters A B C or D, the relevant letter being in a different colour so that the viewer knows which point in the set of pages has been reached. This type is really the same as the first variety, but pages are changed automatically at minute intervals. The third kind of page can be selected by the time-code on the header, so that it can be received, placed in store and read out at a convenient time.

The data to be displayed can be presented as a complete page or, in the case of news flashes or subtitles, can be inserted in a blank rectangle on the screen, leaving the rest of the picture visible. The full page can be superimposed on the picture, but in our experience this is a good way to ruin one's eyesight.

A typical magazine has the capacity of 100 pages. Four lines are transmitted per television frame and there are 24 lines per Teletext page. A full magazine would therefore take 600 frames or 24 seconds to cycle. The BBC and IBA appear to differ on what they consider acceptable access times; the BBC suggest a typical time of 12 seconds (for an unspecified number of pages) while a recent check on Oracle gave an access time of 28 seconds for well over 100 pages. The theoretical time can be reduced considerably by not transmit-

ting blank lines, a practice which is already followed by the IBA and which the BBC intend to change to shortly (they already omit blank lines at the bottom of a page).

To select a Teletext page, one first switches the signal path through the decoder, selects a page by means of thumbwheel switches or a set of push-buttons and waits for the selected page to be assembled.

### Teletext signal

The method of transmission of the Teletext data is of interest at this point. As has been said, the data signals are carried by lines 17 and 18 and the corresponding lines in the alternate field, 330 and 331. The choice of lines is influenced by the need to avoid the early part of the vertical blanking interval and the few lines near the start of the video signal (lines 23 and 336). If early lines were used, it is possible that data would appear on the field flyback on some receivers and if lines later than 18/331 carried the information, receivers with incorrect picture height adjustment or with a downward-shifted picture might show the data as an extremely "busy" pattern of dots at the top of the screen — this sometimes occurs even with the present line allocations. A further reason for avoiding lines 19/332, 20/333 is that they are currently used for insertion test signals, which are often visible but, being static, are not obtrusive.

A form of binary code is used for the data, known as non-return-to-zero, which possesses the advantage over a complemented-element code of a reduced bandwidth requirement. As its name suggests, the resulting waveform is not a continuous train of pulses, but rather a series of voltage levels. A

typical sequence is shown in Fig. 2(b), where it is seen that a "1" level does not automatically return to zero at the end of the pulse and if the succeeding level is also 1, the voltage merely stays up — similarly with a succession of "0". One result of this is seen in Fig. 2(c) where a train of the form 0 1 0 1 0 1 etc. turns out to be a square wave at half the repetition frequency of the clock. As transmitted the pulses are "raised-cosine" in form and the square wave becomes a half-clock-frequency sinusoid.

The diagram in Fig. 3 shows one line of the complete picture frame. A complete line occupies 64µs, of which about 12µs are taken up with the synchronizing pulse, back porch with colour burst and front porch. The first 40 of the 360 bits are concerned with clock synchronization (in a manner similar to that of the colour burst), a series of bits which constitute a "start" sequence and 16 bits for control and row address information. The rest of the line contains 320 bits for display and control. Figure 4 shows the layout of information in the line.

**Coding**

All transmission paths are subject to errors, and television has its share. Noise can be a problem, but the type of distortion caused by multipath propagation is perhaps the deadliest source of error. Both BBC and IBA have done work on this in the U.K., Sweden and Germany, and have come to the conclusion that Teletext transmissions are fairly robust, but require a good performance in the receiver. This relative invulnerability to attack is assisted by the application of code protection — additional bits of information transmitted with the data.

Code protection is applied in two levels. Data bits which are intended for addressing and control are heavily protected, while those used to produce the displayed characters are protected rather less. The transmitting authorities consider that the occasional error in, or rejection of, a character is not serious as it will quite probably be corrected on the succeeding transmission of the page, but that an error in an address would lead to complete nonsense and must be avoided in the presence of the average amount of noise and ghosting.

The character code is basically 7-bit ISO-7 and is protected quite simply by means of a parity bit, giving odd parity. This means that if the total of "1s" in the basic 7 bits is odd, the parity bit is "0". An even total of "1"s in the 7 bits dictates a "1" parity bit to maintain an odd overall total. On examination at the receiver, any byte (the name for a "word" of 8 bits) with an even number of "1"s is seen to contain one error and is rejected. Previously-correct words in a display will not, therefore, be overwritten by an incorrect one and the effect is a reduction in errors in succeeding pages. Double errors, pre-

serving odd parity, are not rejected and will be written.

Address data bits, on the other hand, are more heavily protected by being transmitted in a type of code which will detect 2, 4 or 6 errors in the byte and will detect and correct a single error. This type of code was described by R. W. Hamming in a classic paper<sup>9</sup> in 1950, and is known as the Hamming code. It takes the form of four parity bits in positions 1, 3, 5 and 7 of the eight-bit byte (the addresses are in a four-bit code). Three of the parity checks are associated with groups of three of the four message bits and the overall parity check covers all message and parity bits. Failure of the overall parity indicates an error and the position of the error is identified by the checks on the groups of three bits. If the overall parity appears true, but the individual checks show that a correction is required, there will have been a double error and the byte will be rejected as unusable.

Figs. 3 and 4 indicate that the bits at

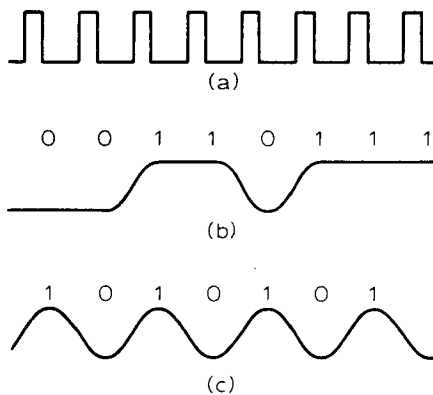
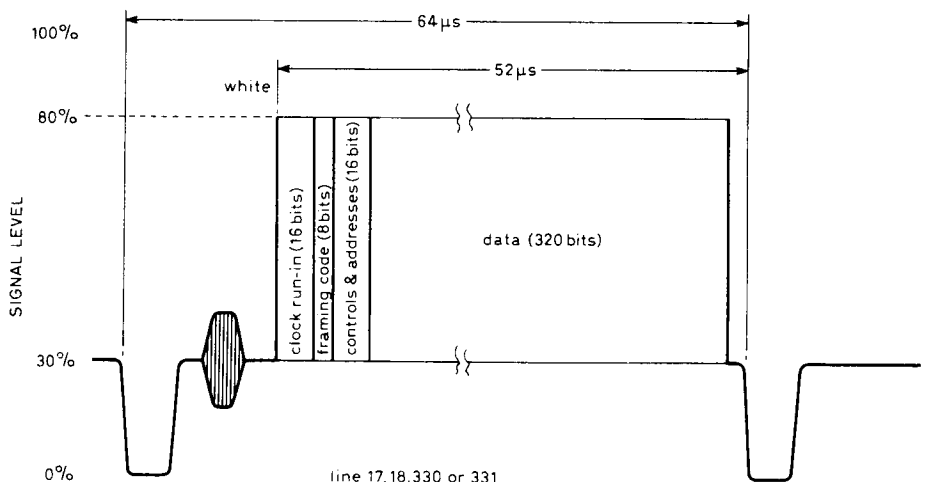


Fig. 2. The non-return-to-zero method of transmitting binary information is at (b) with the attendant clock at (a). A succession of 101010 etc. gives a half-clock frequency waveform and, if the pulse shape is a raised cosine, as used in Teletext, the result is a sinusoid at 3.5 MHz.

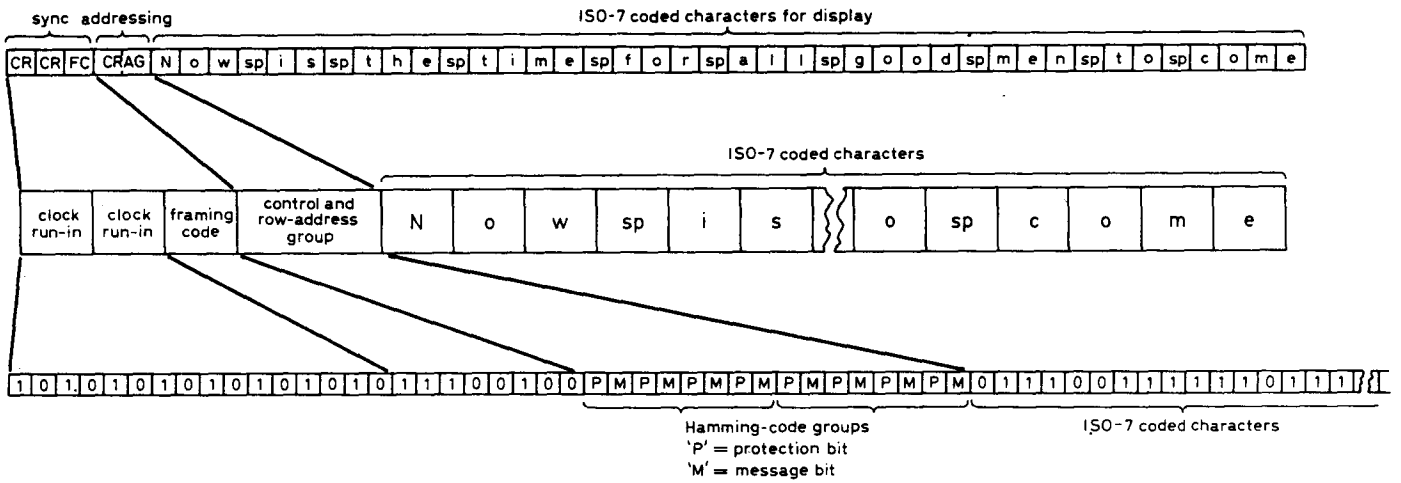
Fig. 3. A line of Teletext data. Sync. pulses are the 30% pulses and the colour burst is on the back porch.



the beginning of the line are not concerned with the displayed message. Three groups of bits are transmitted, of which one is two bytes (16 bits) designed to lock the receiver's clock in frequency and phase with the transmission, in a similar manner to the way in which the colour burst dictates phase in a colour receiver. The 16 bits are termed the *clock run-in* and consist of a train of 1 0 1 0 1s. It is a penalty of the n.r.z. code used that this run-in is necessary, as it entails a code which is not self-clocking. In other words, unless the data are of the 101010 variety, which conveys no information, the transitions do not occur at every interval, and the data pulses themselves could not be used as a clock source, if it were not for the choice of odd parity for the protection code, ensuring at least one transition per character, which can be used to refresh the clock generator. The 16-bit burst of 3.5MHz is also detected and used to identify the transmission as Teletext and not some other data system such as SLICE (IBA), ICE (BBC) or insertion test signals.

The second group of 8 bits forms the framing code, which is always the same and is used to indicate the start of the first 8-bit word. The order of bits used is 11100100 — an arrangement which is designed to avoid errors. A common way to detect the framing code is to pass all data through an 8-bit shift register and to examine the parallel outputs of the register. There will be only one step, when the register contains all eight bits of the framing code, when the above order of bits is present at the outputs of the shift register and gives a positive comparison with the "permanent" word used for detection. The framing code is shown in progress through the shift register in Fig. 6, which indicates that, even in the presence of bits from the clock run-in (c.r.i.) and succeeding information, a maximum of 5 bits "look like" the framing code. By means of more or less extensive circuitry, the framing code detector can be made to recognize the code in the presence of one error.





**Row addressing.** The 16 bits following the framing code are concerned with the identification of the following data. Each of the 24 rows of characters must be identified and this is done by numbering each with a row number from 0-23 and a magazine number (1 to 8). The bottom line of Fig. 4 shows the layout of bits in the 16-bit group and also indicates the fact that these are protected by being Hamming-coded. As, at the moment, we are not concerned with protection, the bits marked "P" can be ignored, and the groups become 4-bit words. In fact, this is an artificial distinction, because they form one word of three bits and one of five. The first group of three message bits (marked "M") identifies the magazine, and the remaining five contain the row address in a pure binary code (00001 is Row 1, 10111 is Row 23). The least significant bit is transmitted first.

**Data.** The rest of the line is filled with data for display, the previous bits not, of course, being visible on the screen. Fig. 5 shows the complete set (in use until Sept. 1, 1975) of available characters and blocks for graphic displays, together with the address code (bits 1-7). Bit 8 is the parity bit and plays no part in the display. A slightly modified table will be used exclusively after September, 1976, and the system is now in transition between the two.

**Decoding**

The circuitry for decoding Teletext transmissions is extra to that in an ordinary receiver and is mainly digital in nature. When the services are established and commercial receivers are sold (several firms already have models), the decoders will be built in, but before that happens, many viewers will want to convert their existing receivers, an add-on unit being the obvious solution, with video signals into and out of the decoder. U.h.f. input and output will probably not be used, the cost of a colour modulator, for instance, being prohibitive.

The extra circuitry needed can be considered in three groups; data acquisition, storage and output processing.

The detected vision signal is taken from the television receiver, having been disconnected from the video amplifier, and taken to the decoder, where clock regeneration, framing-code detection, parity checking, serial-to-parallel conversion and page selection are carried out. The selected and organized information is then passed to a store (either a multitude of shift registers or a random-access read/write memory) until the selected page is assembled. When this has been done, the store addresses the character generator in the output processor (a read-only memory containing the ISO-7 characters) which indirectly drives the guns of the display tube.

**Input processor.** This preliminary canter through the decoder is, of course, grossly over-simplified and a closer look at the sections is necessary, the first of these being the video processor which operates on the video signal to derive data and clock pulses. As has been said, the n.r.z. code in which data are transmitted, is not a self-clocking code and the decoder must contain its own clock. The clock run-in contained in the Teletext signal can operate as either a locking sequence for an oscillator which is continuously running, but which drifts out of phase with the Teletext clock between lines, or can be used to excite a passive oscillatory circuit which then rings for at least the duration of the Teletext line, being automatically in phase and frequency synchronization with the signal when the LC circuit is properly tuned. Each transition of the data "refreshes" the tuned circuit.

The diagrammatic input processor of Fig. 7 shows that the data is first passed through a serial-in, parallel-out store — the shift register, which is clocked at data rate. The register is 8 bits long and can contain one word, complete with its parity bit (4 parity bits in the case of Hamming-protected words). The 8 bits, in parallel, are examined by the framing-code detector for coincidence with the 11100100 "start" sequence which, when detected, resets a "divide-by-eight" counter to zero. The

Fig. 4. A row of data. It is seen that each group of 8 bits (1 byte) has a separate function. Clock run-in and Control and Row address each have two groups.

output of the counter is a pulse at one-eighth the rate of the clock and is used to identify correctly-framed words of 8-bit words in the shift register. In other words, framing-code detection indicates a reference point and the counter produces a pulse every eighth clock period which transfers the group of eight bits currently in the shift register, through latches, to the data lines. The output if the latch only changes when the counter indicates that the eight bits being presented to it are, in fact, a word. Complete characters are therefore presented on the eight, parallel data lines in serial form, reducing the 6.9375MHz rate to 867kHz.

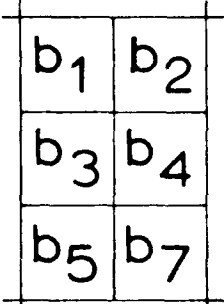
The parallel data presented to the latches are also examined by the Hamming-code checker which, as was seen, can correct one error and detect 2, 4 or 6 errors in address and time information. Following this block, an 8-bit latch finds and holds the 3-bit magazine address and 5-bit row address, referred to in Fig. 4, after a two-character holding time, inserted to allow the two four-bit words (or one three-bit word and a five-bit word) to be assembled.

Parity checks on character words are performed by the parity block, operating from the main data line, its output determining the acceptability or otherwise of a word.

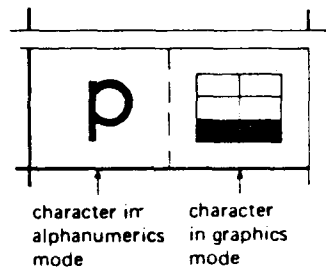
The rest of the input processor is concerned with the selection of a page by the viewer, who will be provided with three thumbwheel switches or a keyboard with ten number keys and keys for several other functions. A page having been "dialed in", the row address latch block examines the row address words until row zero is detected — the page header — when the selector will examine the following address information to compare it with the required page keyed in by the viewer. On detection of the required page code,

Bits					0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1	
b7	b6	b5	b4	b3	Column	0	1	2	3	4	5	6	7
b4	b3	b2	b1	Row									
0	0	0	0	0			SP	0	@ <sup>②</sup>	P	P <sup>③</sup>	p	
0	0	0	1	1	Graphics Red	I	1	A	A <sup>③</sup>	Q	Q <sup>③</sup>	a	q
0	0	1	0	2	Graphics Green	"	2	B	B <sup>③</sup>	R	R <sup>③</sup>	b	r
0	0	1	1	3	Graphics Yellow	£ <sup>②</sup>	3	C	C <sup>③</sup>	S	S <sup>③</sup>	c	s
0	1	0	0	4	Graphics Blue	\$	4	D	D <sup>③</sup>	T	T <sup>③</sup>	d	t
0	1	0	1	5	Graphics Magenta	%	5	E	E <sup>③</sup>	U	U <sup>③</sup>	e	u
0	1	1	0	6	Graphics Cyan	&	6	F	F <sup>③</sup>	V	V <sup>③</sup>	f	v
0	1	1	1	7	Graphics White	'	7	G	G <sup>③</sup>	W	W <sup>③</sup>	g	w
1	0	0	0	8		(	8	H	H <sup>③</sup>	X	X <sup>③</sup>	h	x
1	0	0	1	9	Alpha <sup>n</sup> Red	)	9	I	I <sup>③</sup>	Y	Y <sup>③</sup>	i	y
1	0	1	0	10	Alpha <sup>n</sup> Green	*	:	J	J <sup>③</sup>	Z	Z <sup>③</sup>	j	z
1	0	1	1	11	Alpha <sup>n</sup> Yellow	+	;	K	K <sup>③</sup>	[ <sup>②</sup>	[ <sup>③</sup>	k	{ <sup>②</sup>
1	1	0	0	12	Flash Alpha <sup>n</sup> Blue	,	<	L	L <sup>③</sup>	\ <sup>②</sup>	\ <sup>③</sup>	l	<sup>②</sup>
1	1	0	1	13	Steady Alpha <sup>n</sup> Magenta	-	=	M	M <sup>③</sup>	] <sup>②</sup>	] <sup>③</sup>	m	<sup>②</sup>
1	1	1	0	14	End Box Alpha <sup>n</sup> Cyan	.	>	N	N <sup>③</sup>	↑ <sup>②</sup>	↑ <sup>③</sup>	n	~ <sup>②</sup>
1	1	1	1	15	Start Box Alpha <sup>n</sup> White	/	?	O	O <sup>③</sup>	— <sup>②</sup>	— <sup>③</sup>	o	DEL

control characters (columns 1 and 2) to be displayed as spaces



Graphics display rectangle showing the allocation of bit numbers to the individual cells



- Notes**
- ① This character code (position 0/3) is reserved for internal use by broadcasters
  - ② UK version of national use character in the ISO-7 code
  - ③ In the graphics mode when bit 6 = 0 the corresponding alphanumeric-mode character should be displayed
  - ④ All character rows start in the 'Steady', 'Alphanumeric White' and 'unboxed' condition, without control characters.

Fig. 5. Characters possible in a Teletext display. Graphics are not in the ROM, being produced directly by the data bits.

the data which follows is written into the store, assuming that the parity checker is in agreement.

The outputs of the input processor are taken to the store and are (a) the 7-bit data (b) the "write" or "reject" command to the store (c) the row address and (d) the character address.

**Store.** Storage can take many forms, but the most convenient way to store the data while the page is assembled is the random-access memory, which is an

array of semiconductor devices, often bistable circuits, set to "1" or "0" by input signals and which can be interrogated non-destructively when required by examining any desired location in the memory. No "order" is entailed; data can be lodged at any part of the memory.

Data are stored in 7-bit code as received from the 7-bit latch driving the data line in Fig. 7.

**Display.** The display of characters depends on the use of a large-scale integrated circuit — another form of store called a read-only memory. This is again an array of memory cells, but this time the pattern of bits read out of a given address in the memory is not under the control of the user. The form of the data is decided at the time of

manufacture to perform a variety of functions, but the one in a Teletext decoder is a character generator, arranged to contain the characters shown in Fig. 5. Bits 1-7 in the configurations shown on the left, control the selection of display at the output. Bits 1-4 determine which row of character bits should be read out, while bits 5-7 indicate the column. For example, if the seven bits from the store were 0011010, bits 7, 6 and 5 (001) indicate that one of the undisplayed control characters in column 1 should be generated and bits 4, 3, 2 and 1 show that ROW 10 — alphanumeric, green — is required. The use of this invisible control character means that the visible, succeeding character shall be a green alphanumeric one, as opposed to the graphics alternative in columns 2, 3, 6 and 7. The next group of