

The most common method of communicating with a microcomputer is via an alphanumeric keyboard. The keyboard assembly described here is principally intended for use with the 'Elekterminal', which will be described next month, however the standard design ensures that it can also be employed with other data terminals.

As its name suggests, an alphanumeric keyboard is one which contains both alphabetic characters and (decimal) numerals as well as the usual punctuation marks. Obviously, for the computer and data terminal to be able to 'understand' one another, they have to speak the same language, and to this end, several standard formats have been devised, which allocate a particular binary code to each alphanumeric character. The most popular and widelyused format is the American Standard Code for Information Interchange, usually referred to by its acronym. ASCII. This is an 8-bit code, in which the most significant bit (MSB) is used as a parity bit for error detection. Since 7 binary digits can be arranged in 128 different combinations, it is clear that a considerable number of the 7-bit codes are left over once all the decimal digits, alphabetic characters and punctuation symbols have been catered for. In the ASCII format the remaining codes are assigned control functions. A complete listing of the ASCII character set, with an explanation of the control characters, is shown in table 1.

Keyboard circuit

Although, in principle, it would be

1a OSCIL LATOR frequency control 11 BIT COMPARATOR CLOCK 11 STAGE RING COUNTER YO SHIFT CON-X1 8 STAGE RING COUNTER INPUT X2 2376 BIT ROM X3 (9 BIT x 88 KEYS **[**35 X4 x 3 MODE) X5 DATA AND STROBE **54 SPST KEYBOARD SWITCHES** TTL/DTL/MOS PARITY INVERT COMPATIBLE AY~5~2376 **OUTPUT DRIVERS** RESET I (optional) DATA OUTPUTS STROBE PARITY 9965 la OUTPUT OUTPUT

AY-5-2376

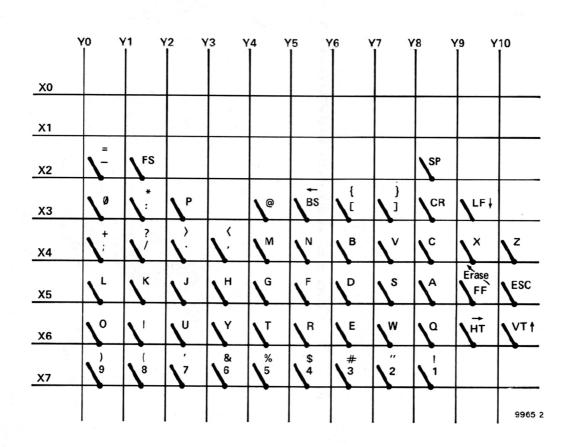
Top View 40 □ Frequency Control A 39 □ X0 Frequency Control B 2 Frequency Control C 3 38 🗆 X1 Shift Input 4 37 🗖 X2 Control Input 4 5 36 🗆 X3 Keyboard Matrix Parity Invert Input 6 35 🗆 X4 34 | X5 33 | X6 32 | X7 31 | Y0 Parity Output 7 Outputs Data Output B8 2 8 Data Output B7 9 Data Output B6 🗆 10 30 DY1 Data Output B5 🗖 11 Data Output B4 🔲 12 29 🗖 Y2 28 DY3 Data Output B3 13 27 DY4 Data Output B2 14 Data Output B1 🗖 15 26 TY5 25 | Y6 24 | Y7 23 | Y8 22 | Y9 21 | Y10 Keyboard Matrix Strobe Output | 16 Inputs -V_{GND}□ 17 O V_{GG} ☐ 18 Strobe Control Input ☐ 19 Data & Strobe Invert Input 20

9965 - 1b

Figure 1. Pin configuration and block diagram of the AY-5-2376 amount to a circuit diagram of the keyboard.

Figure 2. This figure illustrates which elements of the matrix are occupied by keys.

2



parts list to figures 1, 3 and 4

Resistors:

R1 = 100 k

R2 = 680 k

Capacitors:

C1 = 4n7

C2 = 56 p

Semiconductors:

IC1 = AY-5-2376 (General Instruments)

Miscellaneous:

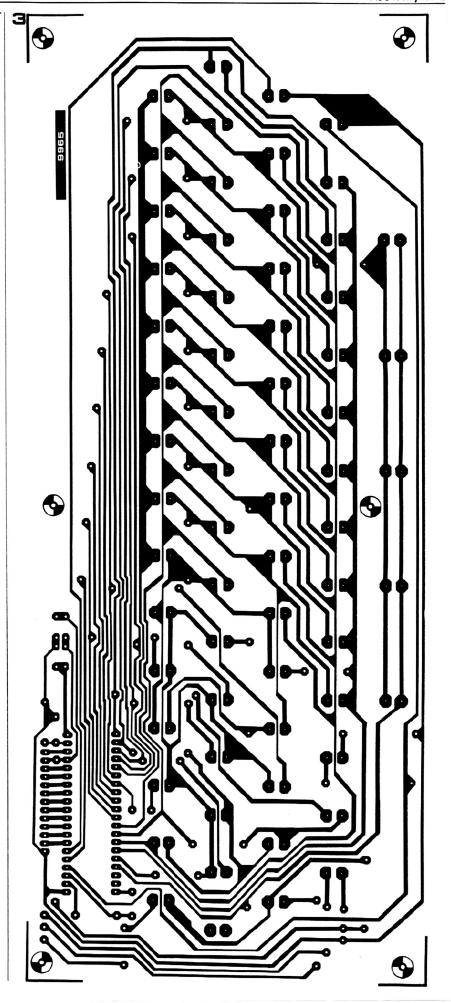
62 keyboard switches: TKC type MM9 - 2

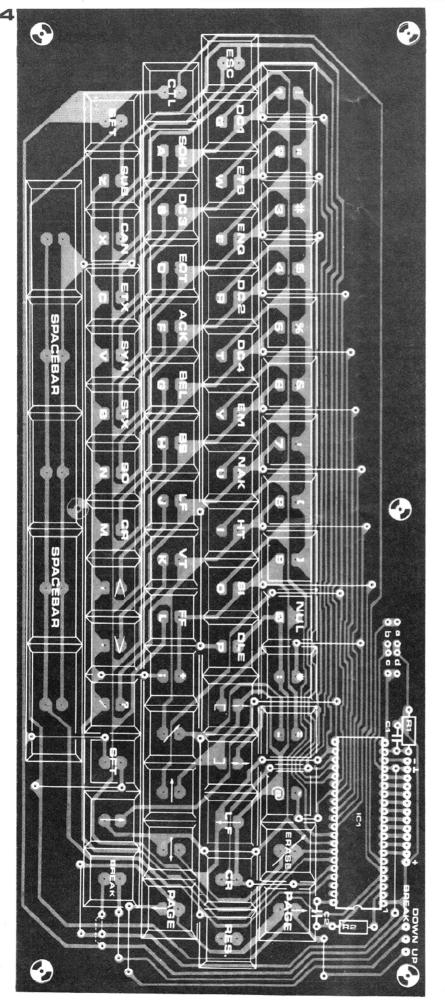
We have been informed that the TKC switches are to be supplied in the UK by the following companies (see advertisement section for further details): A stee Europe Ltd., Windsor De Boer Electronics, Eindhoven Marshall's Ltd., London

Figure 3. Track pattern of the keyboard p.c.b. (EPS 9965).

Figure 4. Component overlay of the keyboard p.c.b.

Note that the copper layout and component overlay are reproduced here at 90% of actual size.





possible to design a keyboard which had a separate key for each of the 128 characters, it would obviously be not only extremely expensive, but rather unwieldy. Thus, as is the case with typewriters, each key is normally assigned a double (or triple) function, with a shift key to determine which of the codes which correspond to a particular key is in fact generated.

The key closures are converted into ASCII code by means of an encoder IC; this is basically little more than a ROM in which the complete ASCII code is stored, and which is addressed by the keyboard. There are several IC encoders currently available, the one used here is the AY-5-2376 from General Instruments. Pin-out details and internal block diagram of the IC — which constitutes virtually the entire circuit diagram of the keyboard — are shown in figure 1.

In order to keep the wiring of the keyboard as simple as possible, the keys are arranged in a matrix as shown in figure 2. For reasons which will become clear, not every point in the matrix requires a key. In addition to those keys in the matrix, several additional keys are shown in figure 1, namely a break key, two page keys, a reset key, a shift key and a control key. The break- and page keys are intended for the Elekterminal (to be described next month), whilst the reset key is optional. The shift- and control keys are used to select the different functions of each key in the keyboard matrix. This is illustrated in table 2, which lists the characters obtained when the 'N' (normal), 'S' (shift) and 'C' (control) keys are depressed. As can be seen, a large number of characters occur more than once in the table, which is the reason why not all the points in the matrix need be occupied by keys.

A number of ASCII characters are assigned non-standard functions in the Elekterminal. These are listed in table 3, along with an explanation of their new function. If the keyboard is used with other data terminals, then the characters can, of course, retain their original significance.

All mechanical switches are prone to a certain amount of contact bounce. In order to eliminate the effects of this the IC contains a delay network which can be controlled externally. The length of delay is determined by the time constant R1/C1. Via wire links a, b, c and d, pins 6 and 20 of the IC can be connected either to a '0' or '1' voltage level. In the latter case, the data outputs, strobe-output and parity output are inverted. In normal use these pins are grounded, i.e. only links c and b are made.

Construction

In order to facilitate construction of the keyboard a printed circuit board was designed, which is intended to accomo-

Table 1.

Character	Binary Bit 7 to Bit 0	Hexadecimal	Character	Binary Bit 7 to Bit 0	Hexadecimal
NUL	00000000	00	@	01000000	40
SOH	00000001	01	Α	01000001	41
STX	00000010	02	В	01000010	42
ETX	00000011	03	С	01000011	43
EOT	00000100	04	D	01000100	44
ENQ	00000101	05	E	01000101	45
ACK	00000110	06	F	01000110	46
BEL	00000111	07	G	01000111	47
BS	00001000	80	н	01001000	48
HT	00001001	09	1	01001001	49
LF	00001010	0A	J	01001010	4A
VT	00001011	OB	K	01001011	4B
FF	00001100	0C	L	01001100	4C
CR	00001101	OD	M	01001101	4D
SO SI	00001110	0E	N	01001110	4E
DLE	00001111 00010000	0F 10	O P	01001111	4F 50
DC1	00010000	11	Ω	01010000 01010001	50 51
DC2	00010001	12	R	01010010	52
DC3	00010010	13	S	01010010	53
DC4	00010100	14	T	01010100	54
NAK	00010101	15	Ù	01010101	55
SYN	00010110	16	V	01010110	56
ETB	00010111	17	w	01010111	57
CAN	00011000	18	×	01011000	58
EM	00011001	19	Y	01011001	59
SUB	00011010	1A	Z	01011010	5A
ESC	00011011	1 B	[01011011	5B
FS	00011100	1C	\	01011100	5C
GS	00011101	1D]	01011101	5D
RS	00011110	1E	Λ	01011110	5E
US	00011111	1 F	_	01011111	5F
SP	00100000	20	,	01100000	60
!	00100001	21	a	01100001	61
	00100010	22	b	01100010	62
# \$	00100011 00100100	23 24	C	01100011	63
%	00100100	25	d	01100100 01100101	64 65
% &	00100101	26	e f	01100101	66
,	00100110	27	g	01100111	67
(00101000	28	h	01101000	68
ì	00101001	29	i	01101001	69
*	00101010	2A	i	01101010	6A
+	00101011	2B	k	01101011	6B
,	00101100	2C	1	01101100	6C
	00101101	2D	m	01101101	6D
,	00101110	2E	n	01101110	6 E
/	00101111	2F	0	01101111	6F
0	00110000	30	р	01110000	70
1	00110001	31	q	01110001	71
2	00110010	32	r	01110010	72
3	00110011 00110100	33 34	s	01110011	73
4	00110100		t 	01110100	74 75
5 6	00110101	35 36	u v	01110101 01110110	75 76
7	00110110	36 37	w	01110111	76 77
8	00111000	38	×	01111000	77 78
9	00111001	39	ý	01111001	79
:	00111010	3A	Z	01111010	7A
;	00111011	3B	<u>-</u>	01111011	7B
<	00111100	3C	Ī	01111100	7C
=	00111101	3D	}	01111101	7D
>	00111110	3E		01111110	7E
?	00111111	3F	DEL	01111111	7 F

NUL - null, or all zeros SOH - start of heading STX - start of text ETX - end of text EOT - end of transmission ENQ - enquiry ACK - acknowledge BEL - bell BS backspace HΤ horizontal tabulation LF line feed VT vertical tabulation FF form feed CR carriage return SO shift out shift in SI DLE - data link escape DC1 — device control 1 DC2 — device control 2 DC3 - device control 3 DC4 - device control 4 NAK - negative acknowledge SYN - synchronous idle ETB - end of transmission block CAN - cancel EM — end of medium SUB — substitute ESC - escape FS file separator GS group separator RS record separator US - unit separator SP space DEL - delete

Table 1. This table lists the complete ASCII character set, along with the corresponding binary and hexadecimal values for each character.

Table 2. This table illustrates the relationship between the keyboard matrix and the corresponding set of characters. It is apparent that, since several characters appear more than once, a key is not required for every element of the matrix.

Table 3. A number of ASCII characters are assigned non-standard functions in the Elekterminal. This table indicates which characters are involved and also their new significance.

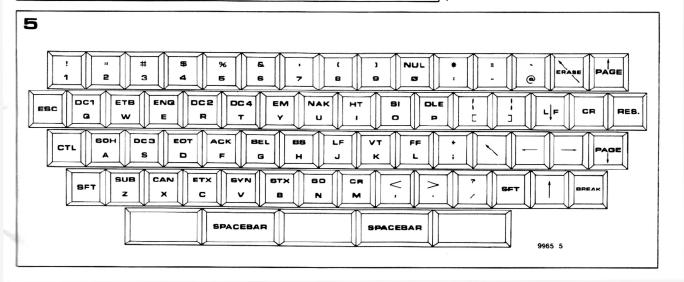
Figure 5. Keyboard layout.

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Table 2.
 C: control
 S: shift
                                                                      y 10
                                               y 6
 N: normal
             NUL SOH
                        STX
                              ETX
                                    EOT
       C
                                         ENQ ACK
                                                           DC1
                                                                      SI
                                                     BEL
                                                                DLE
                                         ENQ ACK
       S
             NUL SOH
                        STX
                              ETX
                                    EOT
                                                     BEL
                                                           DC1
       Ν
             NUL SOH
                              ETX
                                                                      0
                        STX
                                   FOT
                                         ENQ ACK BEL
                                                           DC1
       C
             DLE
                  VT
                        FF
                              so
                                    CR
                                                     ETB
                                                                      SUB
                                         NAK SYN
                                                           CAN
                                                                ΕM
       s
             DLE
                                         NAK SYN
                                                                      SUB
 x 1
                              1
                                                     ETB
                                                          CAN
                                                                ΕM
       N
             DLE
                  K
                                         NAK SYN ETB
                              N
                                    м
                                                          CAN
                                                                EM
                                                                      SUB
       С
                  FS
                        GS
                              RS
                                    US
                                                           SP
                                                                      US
                                    US
 x 2
                  FS
                        GS
                              RS
                                                           SP
                                                                      \leftarrow
       N
                  FS
                                    US
                                         <
                                               >
                                                           SP
                        GS
                              RS
       С
                                         BS
                        DLE
                              US
                                               ESC
                                                     GS
                                                           CR
                                                                LF
                                                                      RUB
 x3
                              DEL
                                         BS
                                                           CR
                                                                LF
                                                                      OUT
       N
             Ø
                                                                LF
                                    ര
                                         BS
                              ←
                                                           CR
       С
                                    CR
                                         so
                                               STX
                                                     SYN
                                                          ETX
                                                                CAN
                                                                      SUB
 x 4
                              <
                                    М
                                         N
                                                           С
                                                                Х
                                                                      Z
       N
                                    m
                                         n
                                               b
                                                           C
                                                                 x
                                                                      z
       С
             FF
                  VT
                              BS
                                         ACK
                                                                FF
                        1 F
                                    RFI
                                               FOT
                                                     DC3
                                                          SOH
                                                                      FSC.
                  Κ
                                                                      ESC
 x 5
             L
                                    G
                                               D
       Ν
            ı
                  k
                                         f
                                                                FF
                                                                      ESC
                        i
                              h
                                    g
                                               d
                                                           а
                                         DC2
       C
             SI
                  HT
                        NAK EM
                                    DC4
                                               ENQ
                                                     ETB
                                                          DC1
                                                                HT
                                                                      VΤ
 x 6
             0
                                    т
                                                                HT
                                                                      VT
                                                     W
                                                           Q
            0
                                                                HT
                                                                      VT
                        u
                              v
                                                     w
                                                           q
       С
                                                                      FS
                                                                RS
 x 7
       S
            )
                              æ
                                                                ESC
                                                                      1
                              6
                                               3
```

date all the necessary hardware (i.e. including the keys). Figures 3 and 4 show the copper track pattern and component overlay respectively. The board layout is designed to take TKC type MM9 keyboard switches. The keyboard layout is illustrated in figure 5. A certain amount of care should be used when mounting the keys. Since they are only held in place by their terminal pins one must be careful to ensure that the keys are correctly positioned, otherwise there is the danger that the key tops may touch one another and a key will remain depressed after being hit. The best solution is to mount the keys row by row, using a jig or template to hold the keys in place.

The connections between the keyboard and receiver section of the terminal are best made using ribbon cable, via which the keyboard can simultaneously be provided with the necessary supply voltages of +5 and -12 V. The current consumption of both supplies is a maximum of 10 mA.

```
Table 3.
   CTL
                   FF
                         (FORM FEED)
                                                   home cursor + page clear
   CTL
                   LF
                         (LINE FEED)
                                                   LF + cursor ↓
   CTL
                   HT
                         (HORIZONTAL TAB)
                                                   cursor →
   CTL
             K
                   VT
                         (VERTICAL TAB)
                                                   cursor 1
   CTL
             М
                =
                   CR
                         (CARRIAGE RETURN)
                                                  CR = erasure to end of line
   CTL
             H =
                   BS
                         (BACK SPACE)
                                                  cursor ←
   CTL
                =
                   FS
                         (FILE SEPARATOR)
                                                  home cursor
   SFT
                   ESC
                         (ESCAPE)
                                                  scroll up
   CTL
             Z
                                                  erasure of current line
```



```
ASCII keyboard
November 1978, page 11-06.
The parts list should read:
R1 = 680 \text{ k}: R2 = 100 \text{ k}. The
keyboard switches are listed as
type MM9; the full type number
is MM9-2. In Table 3, the last few
lines are incorrect. The corrected
section of the table is given below.
CTL + M = CR (CARRIAGE RETURN) = CR + erasure to end of line
CTL + H = BS (BACK SPACE)
                                      = cursor ←
CTL + [ = ESC(ESCAPE)
                                      = scroll up
CTL + 1
                                      = CR (carriage return)
                                        without erasure
CTL + Z = SUB
                                      = erasure of current line
       = FS (FILE SEPERATOR) = home cursor
```

CAPITALS from the ASCII keyboard

BASIC made easy

1978) is more versatile than may appear at first sight. Some readers have commented that a 'shift-lock' would be useful, particularly when it is used for programming in BASIC. In actual fact, we can go one stage further: an 'uppercase lock'!

In the ASCII code, capitals and lowercase letters are distinguished by the value of the sixth bit (S6 on the charac-

The ASCII keyboard (Elektor, November

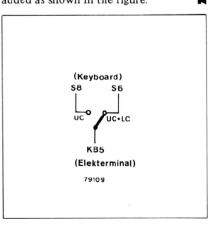
ter generator). For capitals, this bit is logic 'Ø'; for lower-case letters it is logic '1' (see table 1 in the original article). The character generator used, the AY-5-2376, not only provides the usual 7-bit ASCII code: it has an eighth output (S8). Although this is not made clear in the data sheet, S8 can be used instead of S6. The result is all that could be desired: the shift key operates normally for

numerals, punctuation marks etc. — but only CAPITALS are printed when a letter key is operated!

This facility can be extremely useful — for instance, when programming in NIBL. The 'shift' key need only be used when special symbols are required; it is no longer required for printing text.

no longer required for printing text.

A single-pole change-over switch can be added as shown in the figure.



SHIFT-LOCK for ASCII keyboard

The following SHIFT-LOCK circuit should prove a useful addition to the ASCII keyboard published in Elektor 43 (November '78). The circuit is also suitable for use with most other types of keyboard which are not already provided with this facility.

There is no need for an extra key to be mounted on the keyboard, since the original SHIFT key performs both the SHIFT and SHIFT-LOCK functions; the length of time for which the key is depressed determines which function is selected. If the SHIFT key is held down for longer than 0.2 seconds, the shift output will go low (inactive) as soon as the key is released. If, however, the key is only depressed briefly (i.e. for less than 0.2 sec), the shift output is held high (active) until pressed a second time, i.e. the key functions as a SHIFT-LOCK.

The timing for the circuit is provided by the RC constant of R3 and C2. As soon as the voltage across C2 reaches approximately 45% of the supply voltage, N2 will change the input conditions of the JK flip-flop, IC2. Assuming that the $\overline{\mathbb{Q}}$ output is initially high, the circuit functions as follows:

Momentarily depressing the SHIFT key has no effect upon the output of N2. The J input of the flip-flop therefore remains high, and the K input low. Shortly after the key is

pressed, the output of N1 goes low, taking the SHIFT output (via T2) high. When the SHIFT key is released, a positive going edge triggers the flip-flop, so that, given the state of the J and K inputs, the $\overline{\Omega}$ output goes low, taking the K input high, and ensuring that the SHIFT output is held high (via T1, T2). The next time the SHIFT key is held down briefly, the flip-flop is reset, i.e. the $\overline{\Omega}$ output is returned high, taking the SHIFT output low.

If the SHIFT key is originally depressed for longer than 0.2 seconds, the output of N2 goes low and takes the K input high, thereby holding the

Q output high. The SHIFT output will go low as soon as the key is released. R1, C1 and R2 eliminate the effects of contact bounce, whilst LED D2 provides a visual indication of when the SHIFT-LOCK function is selected.

If the circuit is used in conjunction with the Elektor ASCII keyboard, the track to pin 4 of the AY-5-2376 should be broken and the circuit connected between the SHIFT key and the IC.