THE LOW-COST KEYBOARD, LIKE THE
majority of other typewriter style key-
boards, provides only a single "make"
contact for each key depressed (see
Computer terminals, teaching ma-
chines, etc., cannot directly use a
single-contact operation, and a device
called an encoder must be placed be-
tween the keyboard and the computer.
The encoder converts the single con-
tact closure into a seven- or eight-bit
IC logic compatible parallel code, usu-
ally following the ASCII encoding
scheme, and allowing for shift and
target key operations. After parallel
encoding, there may follow a parity
generator for error detection, and a
100-word-per-minute parallel to serial
converter that allows the signals to be
sent down a single wire or phone line.
The keyboard encoder described
here costs only a tiny fraction of com-
mercial equivalents. It uses three "dol-
lar" integrated circuits and a small
handful of surplus computer diodes.
While this encoder was designed as a
companion to the low-cost keyboard,
it may be used with any keyboard,
provided the make contacts are less
than 2000 ohms when on and pro-
vided that the keys do not have a
common ground terminal. The en-
coder generates all the codes shown in
Table 1. This includes all the capital
letters, all the often used punctuation,
umerals, and all of the trans-
parent or control functions. Often
used control functions such as DELETE,
SPACE, LINE FEED, ESCAPE (ALT MODE),
CARRIAGE RETURN, etc. are brought
out to separate keys. The output is
RTL, TTL, DTL and MOS com-
patible, and a single 10-volt, 25-mA
power source is needed. If an ASCII
code is not desirable, the same en-
coder may be used, through suitable
rewiring, to generate BAUDOT, SELECTRIC,
HAUDOT or MORSE codes. Parity and
the 100-wpm (words-per-minute) serial
converter are easily added to the basic
encoder.

What is the ASCII code?

Many years ago, the American
Standards Association decided to
adopt a standard code that computers
could use to talk to each other, to
their input/output devices, and to al-

dow standardized connections between
different brands of computer ma-

The resultant industry wide
code is called ASCII, short for Ameri-
can Standard Code for Information
Interchange. This code is a sequence
of six, seven, or eight bits (ones or
zeros). It may be sent either in serial
(bit by bit, least significant bit first)
form, or in parallel (all bits at once,
on 6, 7, or 8 lines) form. Usually par-
allel words are used inside machines,
while serial words are used between
machines. Serial words are obviously
slower, but they take far less wire and interconnections.

The basic code consists of seven
bits. If we look at all possible combi-
nations of seven ones and zeros from
000-0000 to 111-1111, we'd find a total of 128
different sequences. Each of these may
be used to represent something dis-
tinct. 64 of these code sequences are
used for alphanumeric capital letters,
umerals, a blank, and punctuation. 32
more sequences are used for trans-
parent or control commands that never
appear on a screen or in print. These
commands tell the machinery on the
other end what to do—things like re-
turning carriages, clearing, line feeds,
bell ringing, and other control func-
tions. A final 32-code sequences are
reserved for lower case alphabet and
some little used punctuation. This last
group is very seldom used as most
computer communications can be han-
dled with only capital letters, numer-
als, control commands, and common
punctuation.

The complete code appears in
Table II. It is arranged in a matrix
form to make it compact and easy to
read. For instance, the transparent
command "Carriage Return", or "CR"
has a code of 000-1101, starting with
bit 7 on the left and going to bit 1
(the least significant) on the right. A
numeric "6" has the code 011-0110.
Note the right half of this code is the
same as a binary or a binary-coded-
decimal six. A capital L has the code
100-1100, while the lower case L is
a 110-1100.

There are several ways to use the
code, depending on how much you
want the code to do. If we are only
interested in upper-case alphabet, nu-
merics, and punctuation, we can use
the middle of the code and get by
with a six-bit code, sometimes called
ASCII-6. This is useful in character
generators and displays that do not
need transparent commands or lower

case alphabets. Many MOS integrated
circuits are now available that convert
the six-bit subset into a recognizable
bunch of dots on a TV screen or a
line printer; these are called ASCII
Character Generators.

Or, we can use all seven bits, ei-
ther with or without the lower case
stuff, picking up both alphanumeric
and control commands. This is often
called the ASCII-7 code. Finally, if we

by DON LANCASTER

build an ASCII
keyboard encoder

Here is what you need to couple the key-
board you built in February to a computer,
teletype, or teaching machine.

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TABLE 1 OUTPUT CODES

The output codes below are shown in HEXADECIMAL notation to conserve space. Thus "3D" is an ASCII 011-1101, or output $a_1 = 1, a_2 = 0, a_3 = 1$, etc. The "Key Depressed" output does NOT appear for the shift or control buttons depressed separately. All other keys, whether or not they are used with shift or control, produce a Key Depressed output.

<table>
<thead>
<tr>
<th>KEY</th>
<th>NORMAL CODE</th>
<th>SHIFTED CODE</th>
<th>CONTROL CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>@</td>
<td>40</td>
<td>40</td>
<td>00 (null)</td>
</tr>
<tr>
<td>A</td>
<td>41</td>
<td>41</td>
<td>01 (soh)</td>
</tr>
<tr>
<td>B</td>
<td>42</td>
<td>42</td>
<td>02 (sta)</td>
</tr>
<tr>
<td>C</td>
<td>43</td>
<td>43</td>
<td>03 (ets)</td>
</tr>
<tr>
<td>D</td>
<td>44</td>
<td>44</td>
<td>04 (eot)</td>
</tr>
<tr>
<td>E</td>
<td>45</td>
<td>45</td>
<td>05 (eng)</td>
</tr>
<tr>
<td>F</td>
<td>46</td>
<td>46</td>
<td>06 (ack)</td>
</tr>
<tr>
<td>G</td>
<td>47</td>
<td>47</td>
<td>07 (bell)</td>
</tr>
<tr>
<td>H</td>
<td>48</td>
<td>48</td>
<td>08 (bs)</td>
</tr>
<tr>
<td>I</td>
<td>49</td>
<td>49</td>
<td>09 (ht)</td>
</tr>
<tr>
<td>J</td>
<td>4A</td>
<td>4A</td>
<td>0A (LF)</td>
</tr>
<tr>
<td>K</td>
<td>4B</td>
<td>4B</td>
<td>0B (vt)</td>
</tr>
<tr>
<td>L</td>
<td>4C</td>
<td>4C</td>
<td>0C (FF)</td>
</tr>
<tr>
<td>M</td>
<td>4D</td>
<td>4D</td>
<td>0D (cr)</td>
</tr>
<tr>
<td>N</td>
<td>4E</td>
<td>4E</td>
<td>0E (so)</td>
</tr>
<tr>
<td>O</td>
<td>4F</td>
<td>4F</td>
<td>0F (ps)</td>
</tr>
<tr>
<td>P</td>
<td>50</td>
<td>50</td>
<td>10 (dle)</td>
</tr>
<tr>
<td>Q</td>
<td>51</td>
<td>51</td>
<td>11 (DC1)</td>
</tr>
<tr>
<td>R</td>
<td>52</td>
<td>52</td>
<td>12 (DC2)</td>
</tr>
<tr>
<td>S</td>
<td>53</td>
<td>53</td>
<td>13 (DC3)</td>
</tr>
<tr>
<td>T</td>
<td>54</td>
<td>54</td>
<td>14 (DC4)</td>
</tr>
<tr>
<td>U</td>
<td>55</td>
<td>55</td>
<td>15 (NAK)</td>
</tr>
<tr>
<td>V</td>
<td>56</td>
<td>56</td>
<td>16 (SYN)</td>
</tr>
<tr>
<td>W</td>
<td>57</td>
<td>57</td>
<td>17 (ETB)</td>
</tr>
<tr>
<td>X</td>
<td>58</td>
<td>58</td>
<td>18 (CAN)</td>
</tr>
<tr>
<td>Y</td>
<td>59</td>
<td>59</td>
<td>19 (EM)</td>
</tr>
<tr>
<td>Z</td>
<td>5A</td>
<td>5A</td>
<td>1A (SUB)</td>
</tr>
<tr>
<td>0</td>
<td>30</td>
<td>20</td>
<td>10 (dle)</td>
</tr>
<tr>
<td>1</td>
<td>31</td>
<td>21</td>
<td>11 (DC1)</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>22</td>
<td>12 (DC2)</td>
</tr>
<tr>
<td>3</td>
<td>33</td>
<td>23</td>
<td>13 (DC3)</td>
</tr>
<tr>
<td>4</td>
<td>34</td>
<td>24</td>
<td>14 (DC4)</td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td>25</td>
<td>15 (NAK)</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>26</td>
<td>16 (SYN)</td>
</tr>
<tr>
<td>7</td>
<td>37</td>
<td>27</td>
<td>17 (ETB)</td>
</tr>
<tr>
<td>8</td>
<td>38</td>
<td>28</td>
<td>18 (CAN)</td>
</tr>
<tr>
<td>9</td>
<td>39</td>
<td>29</td>
<td>19 (EM)</td>
</tr>
</tbody>
</table>

| 3A  | 3A          | 2A ($)       | 1A (SUB)      |
| 3B  | 2B (+)      | 1B (ESC)     |
| 2C  | 2C          | 3C ($)       | 0C (ff)       |
| 2D  | 2D          | 3D ($)       | 0D (cr)       |
| 2E  | 2E          | 3E ($)       | 0E (so)       |
| 2F  | 2F          | 3F ($)       | 0F (ps)       |
| -   | 5E          | 5E           | 1E (rs)       |
| SPACE | 20 | 20 | 00 (null)     |
| LINEFEED | 0A | 0A | 0A (LF)      |
| C. RETURN | 0D | 0D | 0D (cr)      |
| ESCAPE (ALT) | 1B | 1B | 1B (esc)     |
| DELETE | 7F | 7F | 1F (si)      |

ASCII ENCODER PARTS LIST

R1—390 ohms, ½ watt (sets operating force—see text)
R2, R3, R4—100,000 ohms, ½ watt
R5, R7, R10, R16—4700 ohms, ½ watt
R6, R8, R9, R11, R12, R13, R14—9100 ohms, ½ watt 5K
R15—470 ohms, ½ watt
R17, R18, R19—100 ohms, ½ watt
R20—2200 ohms, ½ watt
R21, R22, R23—10,000 ohms, ½ watt
C1—0.1-uF disc ceramic capacitor
C2, C3—100-uF 10V electrolytic
C4 thru C26—1N914 or similar silicon computer diode
D27—1N4393 or similar 6.8-V Zener diode
IC1, IC2, IC3—MC 9818P mWrt hex inverter
Q1, Q5, Q6, Q7—2N5139 npn transistor
Q2, Q3, Q4, Q8—2N5129 npn transistor
Misc. PC board, jumpers, sleeving, solder, hardware
in use. Finally, ESC is called Escape or Alternate mode. This lets you break out of the ASCII code if you ever need a longer sequence or something else special. The technique is called code extension. One common use is on a timesharing terminal, where you can switch back and forth between BASIC, FORTRAN, and EXECutive Mode languages using the ESC or exactly equivalent ALT key.

DEL is a 111-111 code that’s used to delete a previous command or fill a paper tape full of holes.

Construction steps

The schematic and parts list is shown in Fig. 1. The keys are arranged electrically to form an “8 x 8” array, and PNP transistors translate the positive end of the array back down to logic levels. This technique requires far fewer diodes than a direct encoding does. The control and shift keys suitably alter the code of only those keys they’re supposed to change.

A printed circuit board is used for

---

**FIG. 1—SCHEMATIC DIAGRAM OF THE ENCODER** shows how simple the device can be when three inexpensive IC’s are used.
assembly. It's available commercially (see Fig. 1 parts list) or you can make your own using the pattern in Fig. 2 and following the drilling and assembly guides of Figs. 3 and 4. Use a small iron and fine solder for assembly, and be careful to observe the code match and dot on the IC's and the polarity bands on the diodes and capacitors.

Resistor R1 determines the operating force required on the keyboard. It is chosen to be low enough in value that each key's output code is set up and correct at ½ to ¾ the pressure required to get the "key pressed" output command. This way the code is set up and stable before it is sent. Capacitor C3 further delays the "go" command to insure reliable operation. Be sure you use only the leading edge of the "key pressed" command, for it lasts longer than the rest of the code does. Should a second key be pressed before the first one is released, it will not be sent, giving a form of "2 key rollover" protection.

The PC board mounts on short spacers directly below the keyboard, and connects to the keyboard with a double connector, a flat cable, or direct jumpers. An Amphenol 143-012-01 connector may be used as an output. A 12-volt supply may be used by going to an 8-volt Zener diode. Operation at 5 or 6 volts may be obtained by lowering all the resistors, but the required keyforce will be

---

**TABLE II COMPLETE ASCII CODE**

<table>
<thead>
<tr>
<th>Bits</th>
<th>Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_0$</td>
<td>0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>$b_1$</td>
<td>0 0 0 0 0 1 1 1</td>
</tr>
<tr>
<td>$b_2$</td>
<td>0 0 1 1 0 0 1 0</td>
</tr>
<tr>
<td>$b_3$</td>
<td>0 1 0 0 0 0 1 1</td>
</tr>
<tr>
<td>$b_4$</td>
<td>1 1 0 0 0 0 1 1</td>
</tr>
<tr>
<td>$b_5$</td>
<td>0 0 1 1 0 0 1 0</td>
</tr>
<tr>
<td>$b_6$</td>
<td>0 0 1 1 0 0 1 0</td>
</tr>
<tr>
<td>$b_7$</td>
<td>1 1 1 1 1 1 1 1</td>
</tr>
</tbody>
</table>

Each control function has a specific meaning. For instance "LF" stands for a line feed. "CR" is a carriage return, "BEL" is a bell to attract an operator's attention. "ESC" is an escape for complicated control instructions, etc.

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**FIG. 3 (left)—DRILL GUIDE for the PC board. Solid-wire jumpers are on the component side.**

**FIG. 4 (right)—COMPONENT SIDE of the encoder board. Jumpers are shown here as well as in Fig. 3 at left.**

**FIG. 5—PARITY GENERATOR for the eighth bit (all) needs only one IC for odd or even parity.**

---

**100-WPM ADAPTOR PARTS LIST**

<table>
<thead>
<tr>
<th>Part</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>10000 ohms, 1/4 watt</td>
</tr>
<tr>
<td>R2</td>
<td>2200 ohms, 1/4 watt</td>
</tr>
<tr>
<td>R3</td>
<td>10 ohms, 1/4 watt</td>
</tr>
<tr>
<td>R4</td>
<td>10000 ohms, 1/4 watt</td>
</tr>
<tr>
<td>R5</td>
<td>Potentiometer, 1000 ohms, linear</td>
</tr>
<tr>
<td>C1</td>
<td>0.1-μF 10V disc ceramic</td>
</tr>
<tr>
<td>C2</td>
<td>0.1-μF 6V electrolytic</td>
</tr>
<tr>
<td>C3</td>
<td>100-μF 10V tantalum, 10%</td>
</tr>
<tr>
<td>D1</td>
<td>1N4002 silicon power diode or equal</td>
</tr>
<tr>
<td>IC1</td>
<td>MC4024 TTL multivibrator</td>
</tr>
<tr>
<td>IC2</td>
<td>SN74165 TTL 8-bit shift register, 8-bit, 8-bit</td>
</tr>
<tr>
<td>IC3</td>
<td>SN7474 TTL dual-type-D flip-flop</td>
</tr>
<tr>
<td>Q1</td>
<td>2N1613 npn silicon transistor</td>
</tr>
<tr>
<td>MISC</td>
<td>PC board, jumpers, sleeving, mounting adapter hardware</td>
</tr>
</tbody>
</table>
greater and less uniform from key to key. TTL (Transistor Transistor Logic) fanout is 1 standard load. RTL (Resistor Transistor Logic) fanout is one medium-power gate.

The unit is tested by noting the proper codes in Table I. It's particularly important to watch all the bits at once with lamp drivers, IC testers, or something similar during initial checkout to be sure the code is up and stable before the keypressed command is sent for each and every key.

An optional parity generator for the eighth bit is shown in Fig. 5 and may be used for even or odd parity. A 100 word per minute teletype adaptor is shown in Fig. 6. The 100-wpm adaptor consists of an oscillator whose period must be exactly 9.09 ms. Upon the Key Pressed command, an ASCII code, a START bit and a SYNCHRONIZING bit are loaded into a parallel-load shift register. After loading is completed, the oscillator marches out the code bits in proper sequence to be teletype and computer compatible. The circuit may accept a second character anytime after the 110-ms transmission time. The output consists of a transistor that normally shorts the teletype line. It breaks the line anytime a "1" is to be transmitted. The proper polarity must be observed on the output, and the 20 or 30 mA loop current source is located elsewhere.

CIRCUIT BREAKER SUBSTITUTION BOX

A substitution box with circuit breakers selected by a switch is one of the handiest gadgets on my service bench. With breakers of different ratings, I'm ready to check radios, amplifiers and TV's with blown fuses and questionable circuit breakers.

Generally, I can clip onto the fuse or circuit breaker if the chassis has been pulled. I've rigged up a handy adapter that lets me jump fuses without pulling the chassis when the fuse holder is a post type on a panel or chassis skirt. The drawing shows its construction.

Drill a 1/8 inch hole through the center of a spare fuse-holder cap. Drill small holes slightly off center in the ends of a blown cartridge fuse. Drill a second hole, just large enough to pass a piece of thin insulated hook-up wire, in the center of one end of the fuse. Strip about 1/8 inch of insulation off one end of a piece of hook-up wire and pass it through the center of the fuse so the short exposed wire goes through the hole in the far end. Solder. Solder a second piece of hook-up wire to the other end and then thread both leads through the fuse-post cap and then add clips for connecting to the breaker substitution box.—Arthur M. Padmore

FIG. 5—TELETYPE FEED is through a special adapter circuit. This one handles up to 100 words per minute. A precision oscillator controls the storage and output from the shift register.