low cost keyboards

Flexible, versatile, medium duty, professional quality keyboards are yours for a quarter a key and customized to your particular needs

by DON LANCASTER

WHAT COULD YOU DO WITH A LOW-cost keyboard? Besides such traditional uses as adding machines, ham radio-teletype and automatic Morse-code senders, electronic security locks, etc., there's a whole new world of wonderful new integrated circuits that open the doors to a wide range of new projects. Projects that right now aren't practical because commercial custom keyboards are too expensive and too hard to get in small quantities.

For instance, you can now get MOS calculator chips for less than $16. This and a low-cost keyboard and a display gives you an add-subtract-multiply-store calculator for way under the going price. Or, one keyboard, an encoder, and a coupler buys you one half of a computer terminal you can call up your timesharing service with—at a tiny fraction of commercial unit or rental costs.

Low-cost keyboards also open the doors to programmable calculators, sports car rally computers, computer data entry, and such new blue-sky projects as cable television "answer back" systems, electronic notebook and message centers, communications aides for the deaf, sophisticated electronic security devices, elaborate electronic games, programming for music composers and synthesizers, teaching machines, tape or cassette file search systems, credit card verifiers, inquiry systems, recipe, bibliography or literature data banks, "anti-drunk driver" gadgetry, and many, many others.

But, commercial custom keyboards are expensive. Normally, you pay 80¢ to $2 per key for a 12- or 16-key assembly, and as much as $6 per key for a fully-encoded teletypewriter style keyboard. Surplus is a help, but only if you can use the keyboard as is. And the "Let's use pushbuttons!" route usually ends up with hard-to-read characters, harder operation, and impossible wiring.

Yet, for a few nickles worth of materials, you can build yourself a custom medium-duty keyboard set up for your particular task.

We'll show you how to build two keyboard versions here. The first is a 12-key version for calculators, electronic security locks, Touch Tone systems, or data entry. The second is a full 55-key teletypewriter-style keyboard for computer terminals, communication systems, and deaf listening aides. A later article will show you a low-cost ASCII encoder that converts the contacts of the big keyboard into an eight-bit parallel IC logic-compatible standard computer code. Along with this, we'll show you a 100 word-per-minute adaptor. Together the keyboard, encoder and adaptor can give you a complete sending end of a teletype style computer terminal for a fraction of the usual rental or purchase price.

How it works

Figure 1 is a cross section of one keyswitch. We use a ¼-inch thick soft carbon-urethane sponge contact. The contact is made by pressing the foam against a pair of plated contacts on a printed circuit board. This system generates very little switch noise and bounce, as the sponge particles progressively make and bring about a smooth change from an open circuit to a low resistance. ON resistance is usually under 500 ohms for an operating force of 3 to 5 ounces. This is low enough for the keyboard to talk to virtually any integrated circuit logic system without any buffering or isolation. It is also smooth enough to give "soft start" click-free contacts for electronic music operations. While the key travel is typically 3/16-inch, you can easily make it anything you want. There's also a definite increase in mechanical force well *after* contact is made, so for most applications, you can easily tell when contact has been made, particularly if you have a display alongside you can watch. Optional "clickers" of one sort or another can be added if they are absolutely needed. The assembly is reasonably thin, projecting only 13/16-inch behind the keybottom. I used standard, commercial two-shot molded keytops. These are white on grey and are available in a wide variety of characters, numerals, and punctuation. Blank and oversize keys are also available. The two-shot molding process means the character goes all the way *through* the keytop. It cannot wear off, come loose, or change color. Conventional springs and an optional damping pad return a pressed key to its home position. Optional *Belleville* washers or a snap-action strip of polypropelene can be

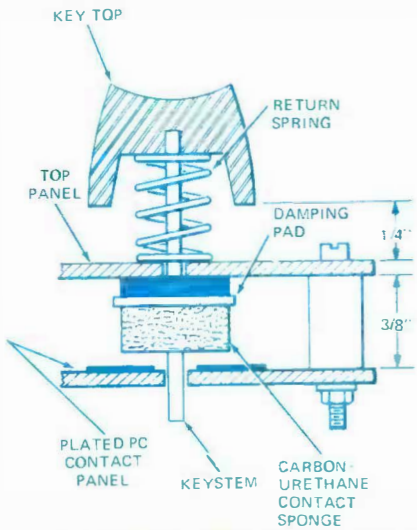
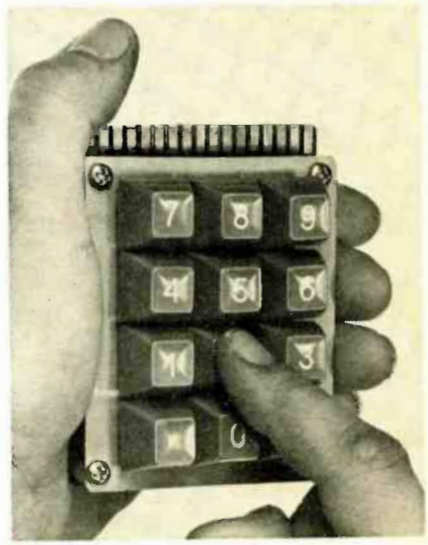


FIG. 1—INDIVIDUAL KEYS are made from a few easily obtained components.



CALCULATOR KEYBOARD ready for mounting. Note the printed-circuit connector.

added for snap-action or tactile feedback, but this only adds to the cost and complexity for most users.

The parts are detailed in Fig. 2. A *keystem* assembly is made up of a piece of 3/64 x 3/16 x 1¼-inch solderable soft steel and a 17/32-inch disc of light gauge solderable steel. Be sure the part of the keystem that goes into the keytop is cut to fit tightly. You should *lightly* centerpunch 4 or 5 "pockmarks" on each side of the very top of the keystem, or else glomp on a small self-grip locking plier-wrench heavy enough to cut in teeth marks. This helps lock the keytop firmly in place during final assembly.

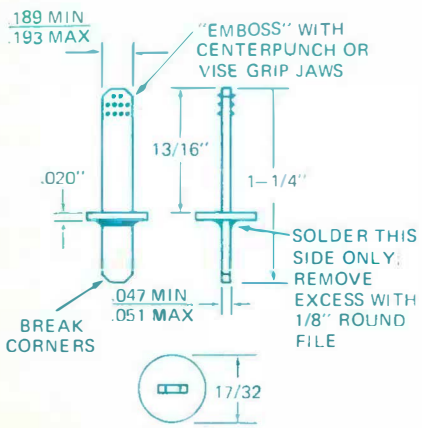
The disc is soldered to the keystem exactly as shown in Fig. 2-a, keeping it positioned exactly 13/16-inch from the keytop end and keeping the solder only on the keypad end. A small wood or other non-heat conducting jig is absolutely essential during soldering. A simple one is shown in Fig. 2-b. The disc *must* be perfectly square with respect to the keystem. Immediately before soldering, carefully clean both pieces with a typewriter style ink eraser to guarantee the solder will smoothly and strongly adhere. Liquid rosin solder flux helps greatly, but isn't essential. As with any electronic assembly, don't use acid core solder or flux.

After soldering, remove all excess solder with a ⅛-inch diameter *round* file, and smooth and polish all edges. Also remove any remaining flux.

Press a slit 0.4 x 0.4 x 0.25 inch piece of carbon urethane onto the keystem. You might like to *optionally* glue it to the keydisc. If you do, use an absolute minimum of adhesive and be sure not to fill any of the sponge voids. The glue really isn't necessary. The carbon-urethane foam may be obtained from the source listed, or you can use the foam many MOS integrated-circuit manufacturers wrap their IC's in for shipment. If you're using the free material, check several companies, for some of the material is more suitable than others. A good material will be soft yet still give 500 ohms or less resistance, and it won't crumble or tear. Be absolutely sure that the keypad sponge is centered and square with respect to the keystem.

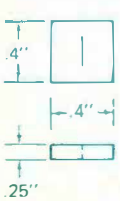
Two 1/16-inch panels support the switches. These are spaced ⅜ inch apart using 6-32 threaded spacers. Since the keystem is a conductor, both panels must be insulators *except* where contact is to be made. Use an ordinary 1/16-inch single-sided printed circuit board for the bottom panel, contact side up; and an etched-off piece of PC material or other 1/16-inch fiber glass for the top panel.

Be sure to follow these guidelines in your PC layout. Keys are normally ¾-inch apart. The contact areas should be 0.4" square total, with enough clearance between both contact halves and the keystem. Conductors between the contact pads should be small enough and centered enough so that a slightly misaligned keypad can't cause an unwanted short. With a calculator or telephone style keyboard, the rows of keys are usually centered on top of each other. With a typewriter style keyboard, the rows are usually offset to allow normal typing. Normally you'll also want to provide a PC edge-card connector on your layout for system interconnection. While you can go to multiple contacts and self-encoding keys, this does add complexity and



(a)

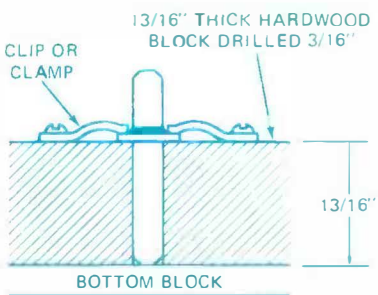
KEYSTEM IS MADE BY SOLDERING A STEEL DISC & STRIP TOGETHER



SLIT WITH X-ACTO KNIFE & SLIDE INTO PLACE ON KEYSYSTEM. A VERY SMALL AMOUNT OF GLUE MAY BE OPTIONALLY ADDED.

(c)

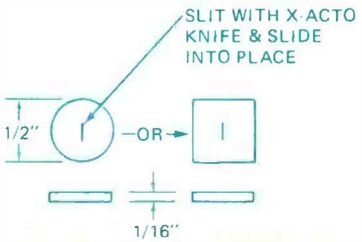
CONTACT PAD IS MADE FROM 1/4" CARBON URETHANE FOAM. SLIT SHOULD BE ACCURATELY CENTERED.



(b)

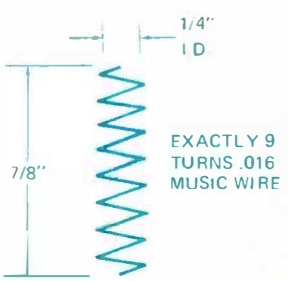
USE A JIG LIKE THIS FOR SOLDERING

FIG. 2—HOW KEY IS MADE. Construction of the keystem is simple and well within the abilities of most technicians and experimenters. Care and precision insure a reliable keyboard.



(d)

DAMPING PAD IS MADE FROM 1/16" THICK INNERTUBE STYLE RUBBER.



(e)

SPRING LOOKS LIKE THIS. START WITH AN EXTENSION SPRING, STRETCH IT & CUT EVERY NINTH LOOP

might be difficult to do on a single-sided board.

Holes for the keystems are moderately critical, and the bottom and top panels must be match-drilled or match-punched in their exact final position. Start with the bottom panel, foil side up and either punch or drill and file rectangular holes for each keystem. The holes should be large enough to allow the keystem to slide freely by, but not so large that the keystem can rotate excessively. Edges should be beveled slightly. After the PC panel is punched, drill the mounting holes and firmly bolt the top and bottom panels together *backwards*, so the drilled panel is on top and the undrilled one is on the bottom. File notch across both panels to indicate their alignment for final assembly. The top panel can then be match-drilled or match-punched to the bottom. This way, all the keystems are perfectly vertical and freely slide after final assembly. If you try to drill top and bottom separately, some of the keystems are sure to bind or be crooked.

The return springs may be chopped out of larger hardware store springs, or wound with music wire. The inside diameter should be somewhat over 0.2 inch. The uncompressed length should be around ¾ inch and the spring should squash beyond ¼ inch without bottoming. Wire diameter is 0.16 inch. The restoring force should be around 3 ounces when compressed ¼ inch and 6 ounces when compressed ½ inch. The ends should be wound or ground so they do not cut into the top panel or keytop when in use.

The bare copper contacts on the PC board must be protected against long term corrosion that will raise the contact resistance. Gold, nickel, or tin plating is ideal, but you can use ordinary silver ink "PC Repair" paint provided you thin it properly and bake it on. A better product is *Sel-Rex SILPAINT* 2065-01. It is thinned with denatured alcohol and brushed on. You then bake it in a kitchen oven at 200 degrees for two hours. The resultant carbon on silver contact is almost as good as gold plating and is far easier to do with limited equipment. Commercial keyboard kits are already plated.

During final assembly, you might like to add an optional damping disc that goes below the top panel and above the steel disc on the keystem. This pad can be about 1/16 inch thick and can be made of innertube rubber or most anything similar. The pad quiets the keyboard operation, and shortens the keystroke. Changing the pad thickness lets you control the keystroke.

Be sure to polish, smooth and clean everything during final assembly. A rough edge or a thumbprint can cause long term wear or contact resistance problems. Also check to be sure each keypad seats flat on its contacts. Assembly starts with the bottom panel and threaded bushings, followed by the keystems, the damping pads, and the top panel. These are all bolted together and operation is carefully checked. Once smooth operation is obtained, the springs are added, followed by the keytops which are pressed on till they firmly seat. A tiny amount of silicone grease may be optionally added to the keystems. Keep

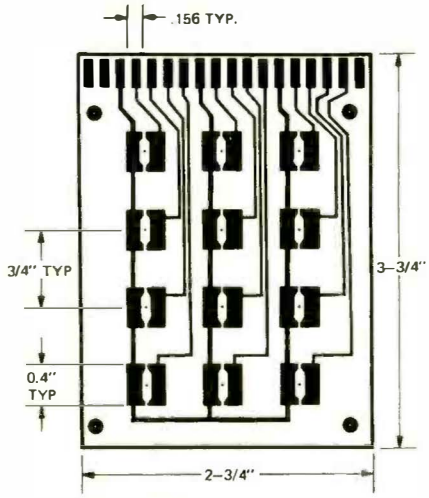
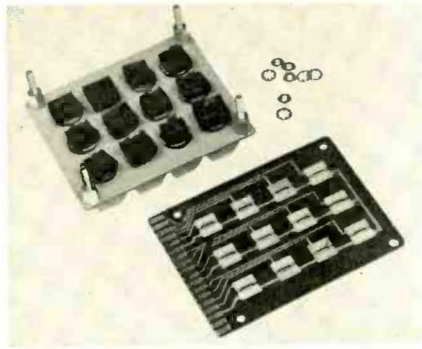


FIG. 3—PC PATTERN for a keyboard. Use extreme care when drilling holes for keystems.



DISASSEMBLED KEYBOARD showing keystems and the carbon-urethane sponge contacts.

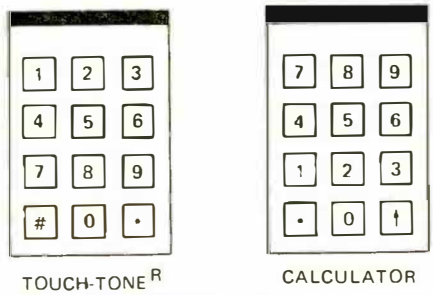


FIG. 4—TWELVE-BUTTON KEYBOARDS in the standard Touch-Tone and calculator formats.

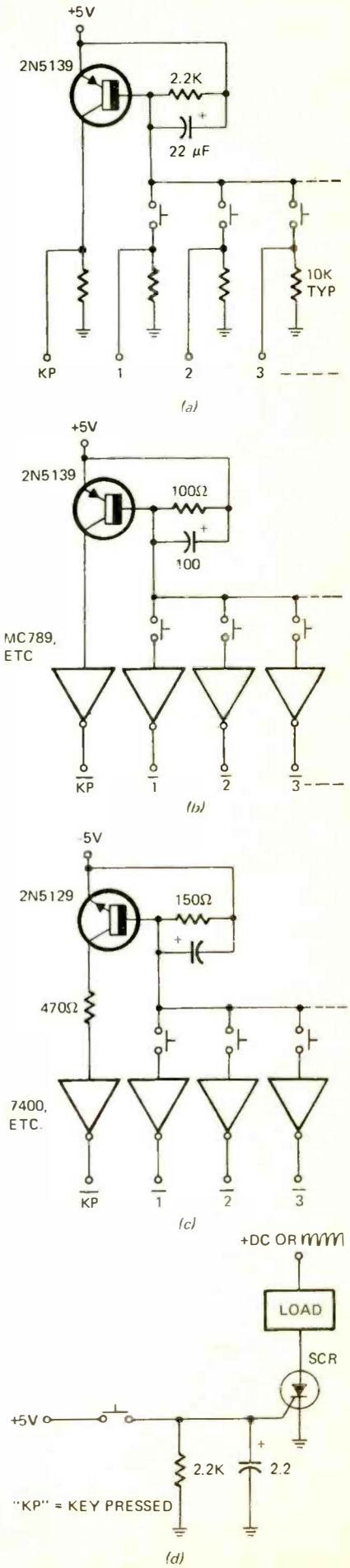


FIG. 5 (right)—WHEN A KEY IS PRESSED collector current flows in the transistor.

all grease well away from the contact areas.

12-key keyboard

The printed circuit pattern for the 12-button keyboard is shown in Fig. 3 and in the photo below it. One common connection is provided, but you can easily break this if you are using your contacts in a matrix form. You can arrange your keys any way you like, but two "standard" formats are the "calculator" and "Touch-Tone® " arrangements shown in Fig. 4.

Several "key pressed" systems are shown in Fig. 5. All are based on detecting a key being depressed by pulling base current through a common transistor. The large capacitor delays the key-pressed command long enough to insure a settled contact. Since the key lets go before the "key pressed" output does, be sure you use only the *leading edge* of your "key pressed" command. Should a second key be depressed before you let go of the first one, it will not be entered, giving you a form of "2-key-rollover" protection. If desired, an external speaker, solenoid, or Sonalert clicker may be added to the basic keyboard to provide additional operator feedback.

A standard 18-connector PC edge card socket fits the keyboard. One suitable mating connector is the Amphenol 143-018-03.

55-key typewriter keyboard

The full typewriter or teletype style keyboard is shown in Fig. 6, and in the head photograph. This particular keyboard is modeled more or less after the ASR-33 teletype, the "standard" computer entry device used in conjunction with the American Standard Code for Information Interchange (ASCII). The key arrangement of Fig. 7 can be used, or you can set up your own. A cross-section of the keyboard is in Fig. 8.

The big keyboard is slightly more complex than the little one. Mechanically, extra spacers are needed to provide a "honeycomb" type of support all the way across the keyboard. Two aluminum angles run the length of the bottom panel for added rigidity. The progressive rows of keys are offset from each other just as an office typewriter is. A long spacebar is also provided. It is really *three* switch contacts to allow realiable operation from the middle or either end. Enlarge the end spacebar slots slightly. Electrically, we have to provide for keys that don't

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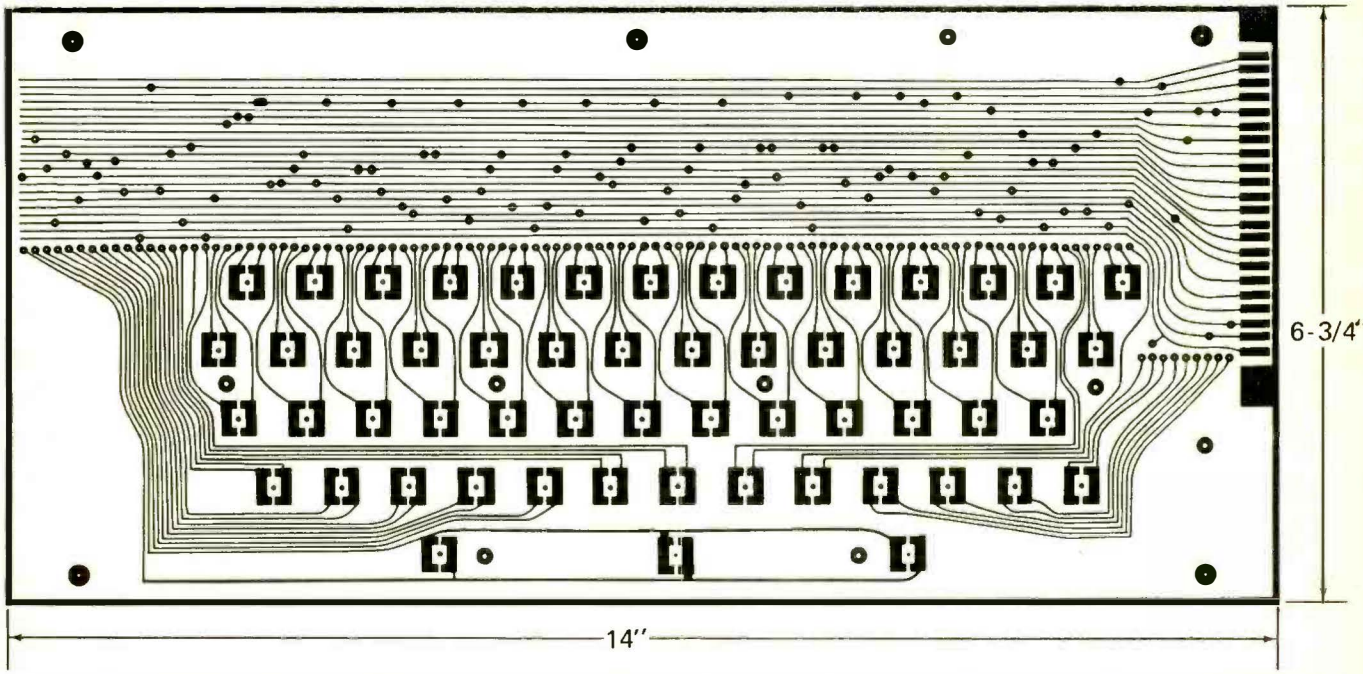


FIG. 6 (above)—PRINTED-CIRCUIT PATTERN for full 55-key typewriter or teletype keyboard. Each key has two contact pads connected to PC lands. Add a jumper vertically from each key-contact land to the land that is directly above it in one of the 22 horizontal rows.

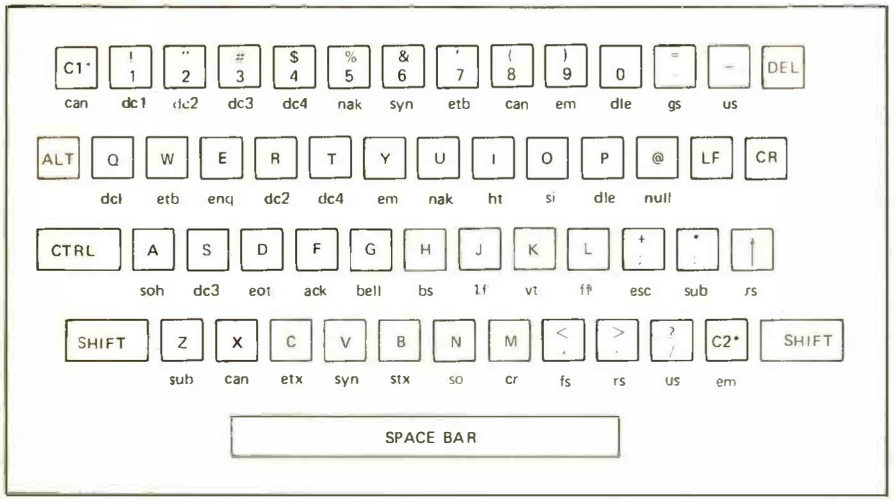
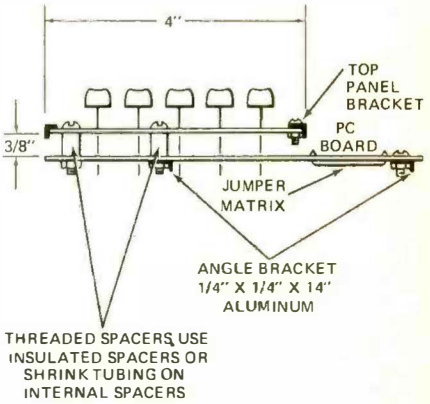


FIG. 7 (left)—TELETYPE KEYBOARD for ASCII computer code. Make yours anyway you wish. Fig. 8 (below)—CROSS-SECTION OF A COMPUTER KEYBOARD. Extra spacers provide stiffening.



EQUIPMENT REPORT

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straightforward with the exception of the subtraction function. This operation is done the same as addition except a special equal sign reserved for this purpose is used. This quirk soon becomes second nature. Entering a number with too many digits lights the overange indicator as does a calculated result outside of the -99,999,999 to +99,999,999 range. When this indicator lights further calculations are locked out since they would lead to erroneous results. The keyboard worked well with a sensitive touch despite the lack of tactile and audible feedback.

Anyone purchasing the kit should seriously consider the charger/ac power option. Some of the components for this option are added to the clock/power supply board.

If you are an experienced kit builder the Aries calculator kit will give you a cache of arithmetic power that you can conveniently carry in your jacket pocket with its 3 13/16 × 4⅝ × 1¼ inch dimensions. Sold by B & F Enterprises for $75 the recommended charger/ac power option is $17.50 including the four nickel cadmium AA cells. **R-E**

LOW COST KEYBOARDS

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the pattern you want, a double-sided PC board may be used, but this freezes your design and ups the cost.

Assembly of the big keyboard is pretty much the same as the smaller ones. Two blank keys are provided; they are ASCII encoded as "can" and "em". This lets you transparently pass two special commands on for the rest of your system without needing to press the CONTROL button. You can make it do anything you like on the other end.

PARTS LIST *(12-key keyboard)*

12 Keytops, two shot molded plastic, 0-9, (.), and (†)
12 Contact stems per Fig. 1 & Fig. 2
1 2" x 2" contact pad material, carbon urethane sponge ¼" thick. Cut into 0.4" square keypads
1 2" x 2" damping pad material, 1/16" soft rubber cut into a dozen ½" round damping pads
1 Extension spring, ¼" i.d. x 3" long x .016 music wire. Stretch to Fig. 2-e and cut every 9th turn, forming a dozen keysprings
1 Top panel per Fig. 3 and text 3½" x 2⅞" x 1/16" fiberglass or other insulator
1 Bottom panel, 1/16" plated PC material per Fig. 3 and text 3¾" x 2⅞" x 1/16"
4 6-32 x ⅜" threaded spacers
4 6-32 x 1" machine screws
4 6-32 nuts
4 No. 6 shakeproof washers
MISC: solder and rosin flux; optional adhesive; template for contact stem assembly

PARTS LIST *(55-key keyboard)*

55 Keytops, two shot molded plastic, standard ASCII characters and spacebar
57 Contact stems per Fig. 1 & Fig. 2
1 4" x 4" contact pad material; cut into 57 0.4" square contacts
1 4" x 4" damping pad material, cut into 57 0.5" round damping pads
4 Extension springs, cut into 57 springs after extending
1 Top panel, insulated PC material, 4" x 4"
1 Bottom panel, per Fig. 6; 6¾" x 14"
2 Support brackets, 14" long
MISC: Threaded spacers, shrink tubing, and mounting hardware; No. 24 solid wire; solder; optional glue or epoxy; keystem soldering template.

Contact material is available from Custom Materials, Inc., 279 Billerica Rd., Chelmsford, Mass. 01824. It's their #7611 Velofoam ¼" thick, and runs around ½¢ per keytop, but is only available in large sheets.

Keytops are available from Mechanical Enterprises, 5249 Duke St., Arlington, Va. 15¢ each, any reasonable callout. Space bars are 35¢ each. $2 service charge on orders under $25.

Other configurations

You can easily work up other arrangements for this low cost keyboard. Even if you only need a few pushbuttons for an electronic lock, music synthesizer or game, this system easily adapts itself and its real beauty is that you can custom design your own. **R-E**