Eglowstein

REACH OUT AND TOUCH YOUR DATA

Three commercial hand trackers sense your every move

Left: Perhaps the best-known hand-tracking device, the VPL DataGlove relies on fiber optics to track finger motions. Center: The Dexterous Hand Master from Exos uses an intricate exoskeleton, made of lightweight aluminum, that fits over the back of the hand. Right: Mattel's Power Glove shares a common heritage with VPL's DataGlove, but it was designed for the home video market. As such, it's a lot less expensive and a lot more rugged. Nevertheless, you can easily adapt it to work with a PC-compatible computer.

Make a fist and shake it at your computer screen. Nothing happens? That's because you're not wearing a hand-tracking device. Although keyboards and mice convert hand movements into data, they can't capture the sweeping gestures and subtle articulation of a hand moving in space.

Three commercial products purport to do just that: VPL Research's DataGlove, Exos's Dexterous Hand Master, and Mattel's Power Glove. When you wear one of these devices, it measures how much your fingers are flexed. A controlling computer, sampling the instrument's sensors at a rapid clip, can figure out the shape of your hand. Add a way to locate the hand in space, and you've got hand tracking. Imagine literally grabbing a dBASE record or rotating an AutoCAD model with a twist of your wrist. There is a world of possibilities; see "Telltale Gestures" on page 237 for more applications now in development.

It's Not Polite to Point

Each product discussed here uses its own method to track the fingers. Two of them use magnetic field interference to track hand motion, and one uses ultrasound triangulation.

VPL's DataGlove, perhaps the best-known hand-tracking device, relies on fiber optics. When you bend a fiber-optic cable, the light dims in proportion to the amount of flex. The DataGlove uses loops of fiber-optic strands that run up the back of your hand. A part of each loop, which is fixed over the knuckle and first joint of each finger, forms a sensor (see figure 1).

One end of the fiber loop connects to a constant light source, the other to a sensitive photo detector. A microprocessor scans through each of the 10 detectors in turn and takes a light reading. As the light intensity diminishes, the processor records more bend.

After the whole hand has been read, the real fun begins. Calculating the angle of each joint requires knowing a lot about the physical nature of the hand and the makeup of the optical sensors. The microprocessor in the DataGlove controller takes care of managing that model and performing the needed computations.

Precise measurements require that the fibers line up properly over the joint. The DataGlove relies on a snug-fitting Lycra glove that fits, well, like a glove. The fibers, sewn onto the back of each finger, collect at the base of the glove on the back of the hand, as shown in photo 1. A separate unit, the size of a pocket calculator, houses the light source and sensors. A computer interface manages the scanning of the sensors and the communications with the host computer. The DataGlove uses a standard RS-232C serial port, which makes it compatible with most computers.

Somewhere, My Glove

Now the computer can tell what the fingers are doing. The next thing it needs to know is the position of the hand relative to a fixed point. VPL has incorporated the Polhemus Navigation Sciences' 3Space Tracker into the DataGlove. The Tracker measures magnetic interference in three dimensions. Users of Exos's Dexterous Hand Master typically employ the Tracker, too.

Any coil charged with an electrical current generates an electromagnetic field. The field is strong in the direction of the coil's radius, and it is relatively weak in the perpendicular direction. Similarly, a magnetic field passing through a coil of wire generates an electric current proportional to the field's strength.

continued

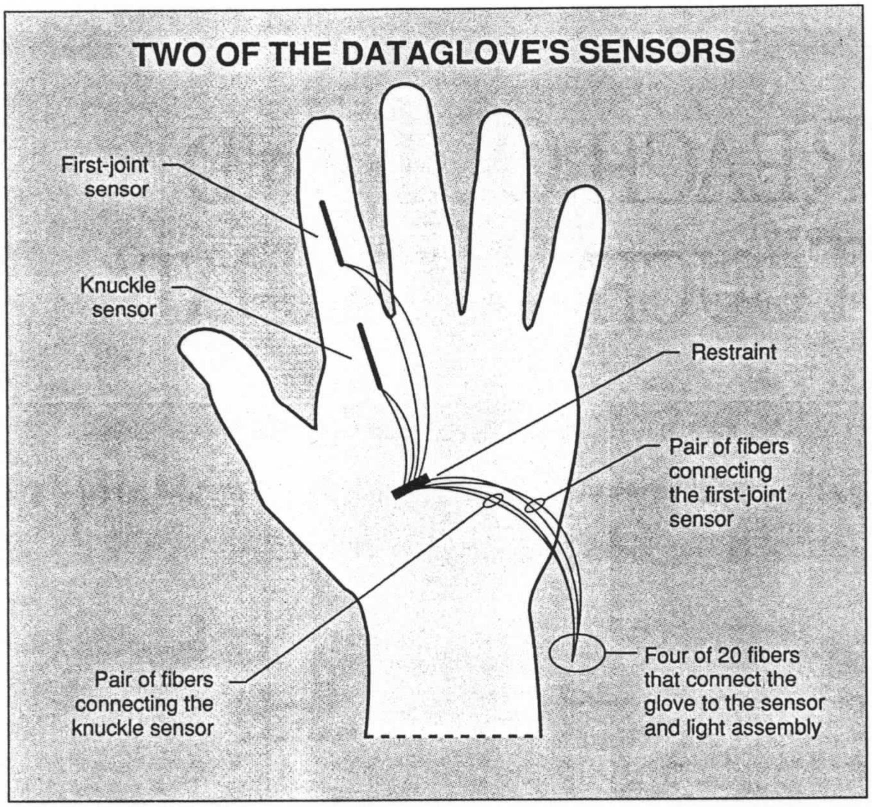


Figure 1: *The DataGlove's sensors are glued to the glove, arranged directly over each joint. Loose fibers connect each sensor to a light source/receiver pair for measurement.*

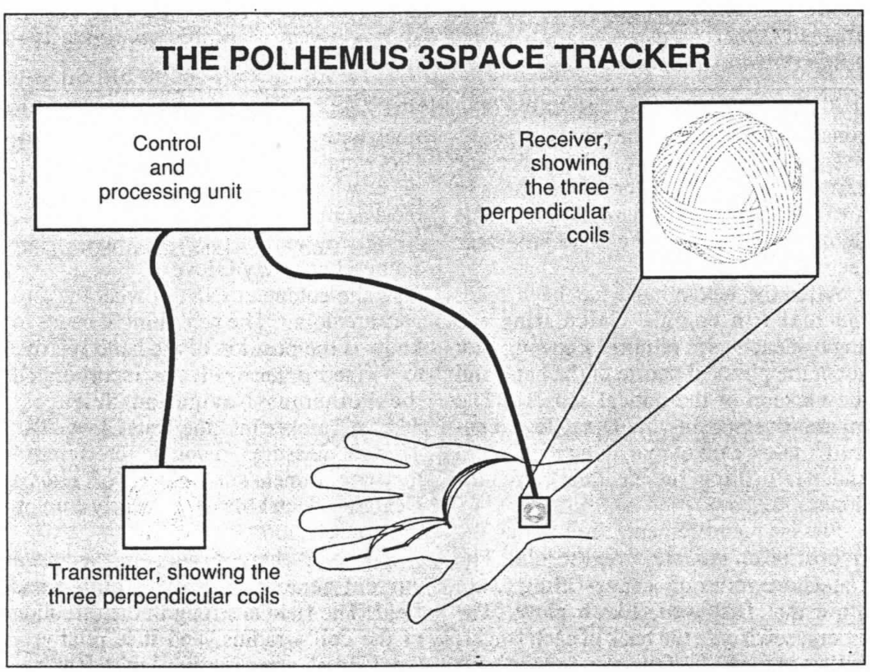


Figure 2: *Designed to report the relative location of the user's hand in space, the Polhemus 3Space Tracker consists of a small cube mounted on the hand, and a slightly larger transmitter that rests on a stationary stand nearby. The cutaway views show the three perpendicular coils in both the transmitter and the receiver.*

The Tracker uses a transmitter with three coils of wire, each perpendicular to the other two. A similar receiver has the same arrangement (see figure 2). The Tracker's controller pulses each of the transmitter's coils in turn and reads the current generated in each of the three receiving coils, for a total of nine readings. Determining the receiver's orientation and distance from the transmitter requires plenty of math—more than you'll need to do your taxes.

Knowing that the strongest readings come from coils that lie on the same plane as the transmitter, the microprocessor can determine the orientation of the receiver in space (relative to the transmitter), as well as the distance in *x*, *y*, and *z* directions. The system works amazingly well. It can determine the relative positioning to the nearest tenth of an inch and to within half a degree, anywhere within a 3-foot radius.

The receiver is a small, lightweight plastic cube, about the size of a sugar cube, that mounts on the back of your wrist. The transmitter, a slightly larger cube, rests near the DataGlove wearer on a stationary stand. Both the receiver and the transmitter connect to a control unit that handles the pulsing and sensing; the control unit connects to the host computer by way of a standard serial or parallel interface.

Double-Jointed

The DataGlove emphasizes comfort with a good degree of precision. However, unless you are an alien from the planet Zambodia, your fingers have three joints, not two. Exos's Dexterous Hand Master (see photo 2) delivers precise measurements at the expense of form.

The Hand Master uses an intricate exoskeleton that fits over the back of your hand. Velcro bands and finger pads attach this framework to the midpoint of each finger segment, and a hinged joint connects each of the finger pads. Figure 3 shows the arrangement of the joints. Make no mistake—this thing looks bizarre; it's not really a glove at all. But it's considerably more comfortable than it looks.

The skeleton is made of lightweight aluminum. Each of the joints contains a small magnet and a Hall-effect sensor to measure the bending angle. The sensor, built into the hinge assembly, responds with a voltage that is proportional to the strength of a nearby magnetic field. A small magnet bound to the sensor moves closer to or farther from it as the joint bends. The Hand Master connects to any standard AT-bus (Industry Standard Architecture) PC compatible through a custom data-acquisition board. The PC software reads the voltage from each of the sensors in turn to measure the position of the fingers.

Thumb Fun

Oops—I almost forgot about the side-to-side motion. Happily, Exos didn't. Fingers can do more than go up and down; they go left and right, too, especially the thumb. Extra sensors on the Hand Master take care of the left and right motions, while allowing for measuring the full range of thumb motion.

Like the DataGlove, the Hand Master can't detect the position of the entire hand. Hand Master applications typically use the same Polhemus Tracker that DataGlove applications use.

Mattel's Power Glove is a completely different animal than the DataGlove, yet the two share a common heritage.

Clearly, the Hand Master uses a different approach to hand sensing than the DataGlove does. However, both cost as much as a new car. The DataGlove in its standard configuration will set you back about $8800. If you prefer the added precision of the Hand Master, plan on handing over $15,000. But if you need that level of precision and reliability, both are cheap at the price.

The same can be said of computers. Not everyone needs megabytes of memory and a hard disk drive, as the home video game manufacturers have known for years. Case in point: that Nintendo Entertainment System you bought for your kids. Did you know it has the same processor that the Apple II uses? Did you know that Mattel makes a hand-sensing glove for the Nintendo? One that you can buy for about $100?

Mattel's Power Glove is a completely different animal than the DataGlove, yet the two share a common heritage. The Power Glove's basic design derives from the DataGlove's, with a few obvious modifications for the home video market. Most notably, it's a lot more rugged (see photo 3).

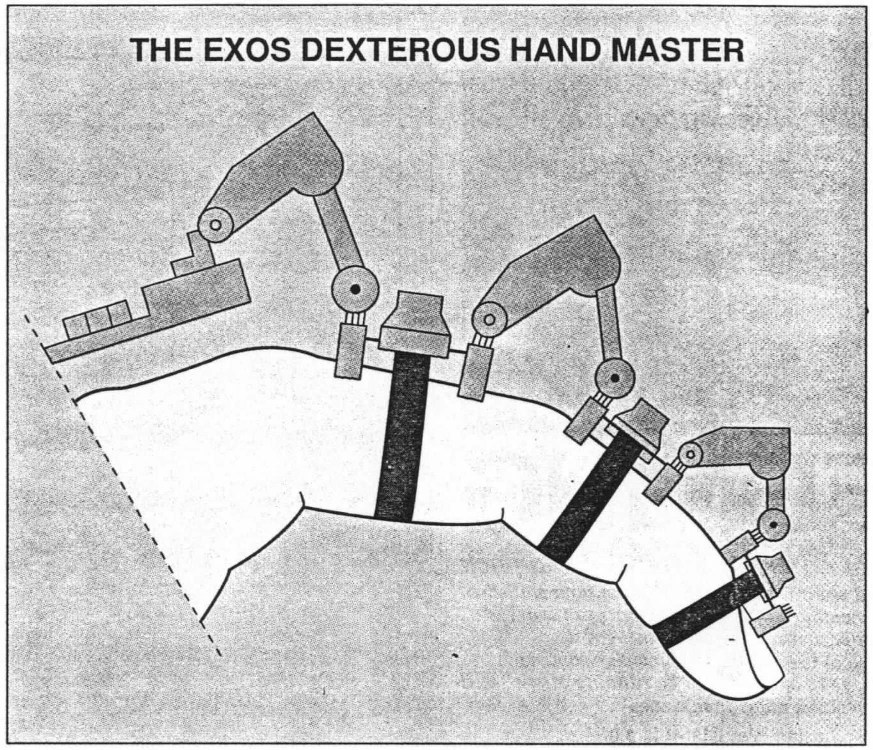


Figure 3: *The Hand Master consists of an exoskeletal arrangement of sensors. The sensors are held over each finger joint by lightweight pads and Velcro straps. Each sensor houses both a Hall-effect magnetic pickup and a magnet.*

Glove at First Sight

The optical fibers on the DataGlove are fully exposed, glued to a lightweight Lycra glove. Not only is that construction expensive, but video-gaming kids would destroy the thing in 10 seconds flat. Mattel replaced the delicate fibers with a flat plastic strain gauge.

The strain gauge has a convoluted history. In the early 1980s, engineers developing the Koala touchpad needed a tough, flexible plastic with a constant resistive surface. During development, there were a number of rejects—one of which changed resistance as it was bent. That material, which is now manufactured by Amtec, forms the basis of the sensor technology that the Power Glove uses in its fingers.

The sensors are 3½-inch strips of polyester, coated with 0.6 mils of a specially formulated ink. As the sensor bends over the normal range of finger movement, the resistance changes. One sensor in each finger measures all the joints at once. This precludes measuring the individual joints, but does Mario really care if you bent your first or second joint? For Nintendo games and many PC applications, it's reasonable to measure the whole finger with some degree of precision and make assumptions about the individual joints.

So, you've got five sensors, one for each finger. That means you also need an A/D converter to read the sensors, and some kind of processing power. The Power Glove uses an 8-bit processor to watch the fingers, communicate with the host computer, and handle the ultrasonics. Ultrasonics? What for?

You Don't Know Where That Hand Has Been

Polhemus's Tracker technology would be far too expensive to include in a $100 retail product, so Mattel had to come up with something else.

The solution that Mattel chose was an ultrasonic ranging system similar to that on modern Polaroid cameras. A small transducer located on the back of the Power Glove sends out a short click. Three receivers, one each to the left top, right top, and right bottom of your monitor, receive the click. They all hear the same sound, so the time it takes them to

continued

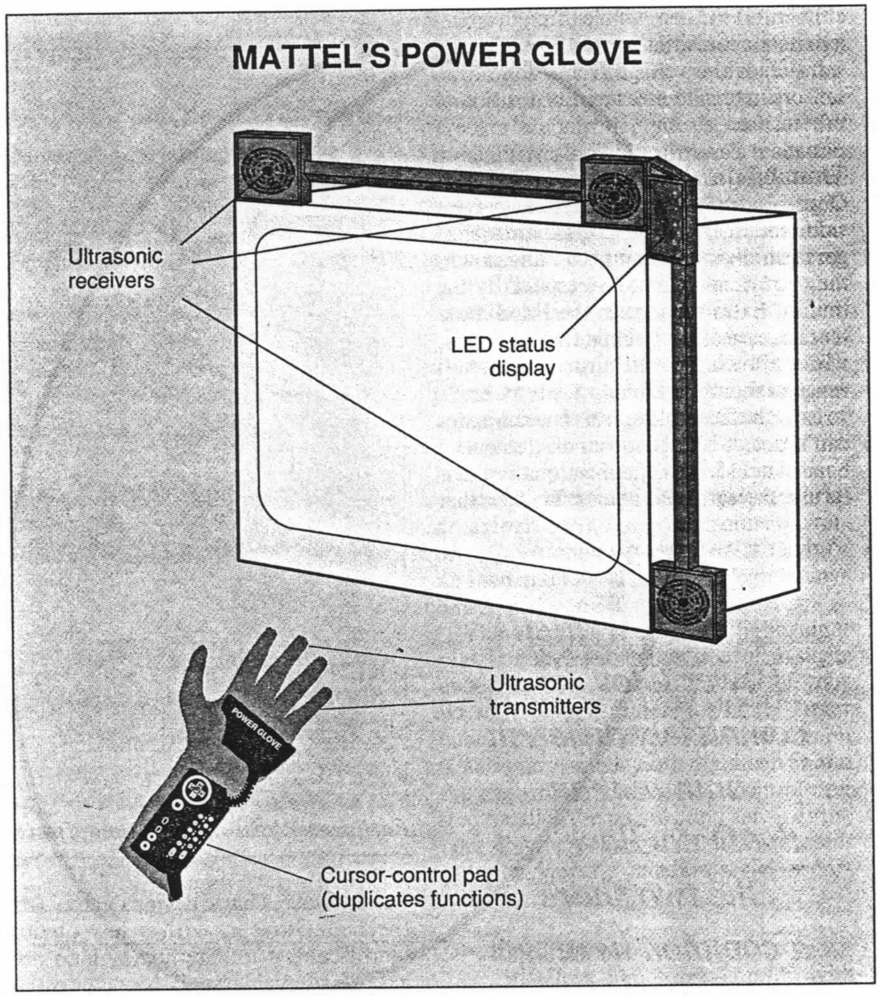


Figure 4: *The Power Glove uses two ultrasonic transmitters and three receivers to triangulate the position and orientation of the hand. The cursor keypad duplicates the sensory functions and allows for somewhat more precise input.*

register the click will determine the absolute distance to the glove as well as the relative distance.

A second transducer, which is located a few inches from the first, does the same. From there, the processor, which knows the speed of sound and the spacing between the transmitters and receivers, can use triangulation to compute the distance of the glove from the sensor array as well as the glove's roll and pitch (see figure 4).

Ultrasonics, however, suffer from one inherent disadvantage: They require an unobstructed line of sight. If the transmitters don't point directly at the receivers, the Power Glove simply can't track. Other than that, though, it's a very sound design.

OK, I'm Game

As long is you're facing the receiver array, and you are within the normal range of the ultrasonics (about 5 feet), the Power Glove can track your hand motion to within a quarter of an inch and measure the flex of your fingers to some fair degree of accuracy.

For the personal computer user, the most significant drawback of the Power Glove is that it will work only with the Nintendo system. To that end, the unit comes with a proprietary Nintendo connector that plugs directly into the game unit.

Even worse, the Power Glove takes all its detailed information and converts it into an emulation of the standard game controller pads. Although there is a special high-resolution mode, the standard mode will give you the A fire button (flexing the thumb), the B fire button (flexing the index finger), Start, Select, and the up/down/left/right motion from center. Notice that it can't tell you how

continued

Can We Talk?

Because the Power Glove is designed for the Nintendo Entertainment System, attaching it to your computer may take some doing. I'll describe how to connect it to a PC compatible, although the same method should work for almost any computer.

The good news is that the Power Glove runs off 5 volts and is therefore electrically compatible with the printer port of a PC compatible. The bad news is that you'll have to find a way to supply the 5 V; that's something a printer port normally doesn't do.

Connecting the Power Glove requires three data lines, a ground, and 5 V. It's probably best to connect the glove to an unused printer port; you can get 5 V from any of a number of sources.

For my prototype, I used an external regulated power supply. No external supply? The red and black wires on a spare disk drive power connector will give you 5 V, or you might tap 5 V from the keyboard connector using an extension with a tap on the keyboard's 5-V supply. Pin 5 of the five-pin DIN plug is the keyboard power, and pin 4 is ground (see figure A). With a pair of male and female five-pin DIN connectors, make a short keyboard extension cable, with all five lines. However you get power, check that the voltage is correct and fairly spike-free before you go any further.

Now for the tricky part. The glove connects to a small box that controls the ultrasonics. It's that short cable with the goofy seven-pin connector that you have to modify. Make sure you don't cut off the nine-pin connector from the glove itself!

You'll be removing the game unit connector, so you might want to find a Nintendo controller extension cable and make the modifications to that. Curtis

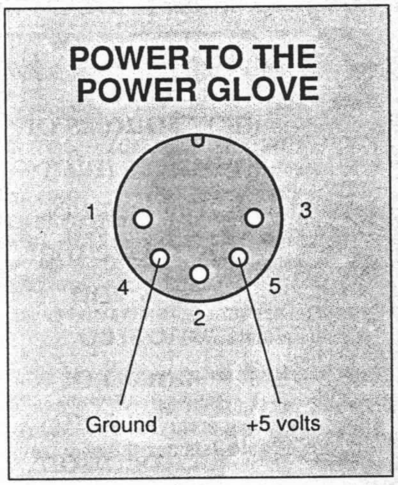


Figure A: *To connect a Power Glove to your PC compatible, you need a 5-V power source. Pins 4 and 5 of a standard five-pin keyboard connector provide 5 V to the keyboard and can also be used to power the Power Glove.*

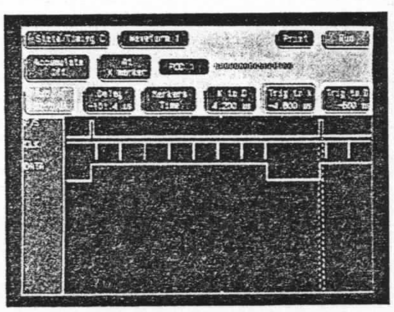
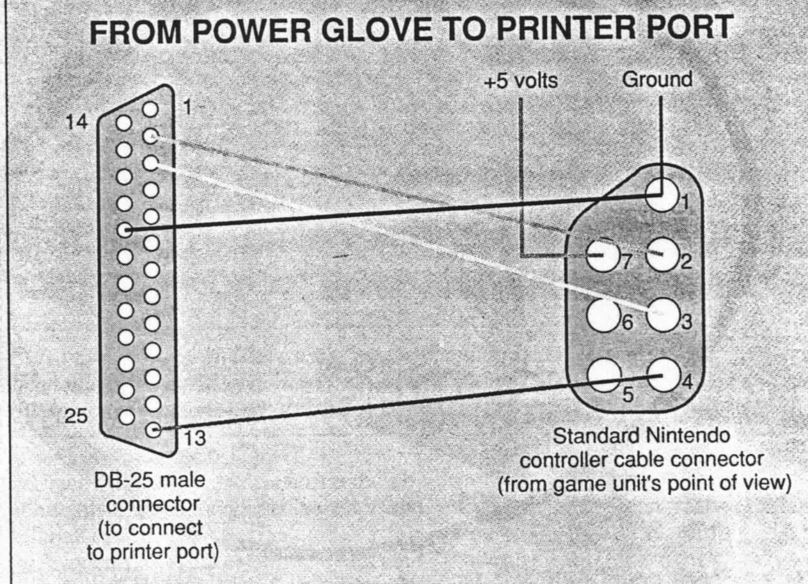


Figure C: *Shown here are the timing pulses required to retrieve data from the Power Glove. P/S is the reset pulse to set the glove's shift register back to bit 0. CLK moves the register from bit to bit. After pulsing the P/S line, you sample bit 0, pulse CLK, and then sample and pulse seven more times for bits 1–7.*



Pin	Function	Pin	Function	Color	Curtis NC-1
2	Data clock	1	Ground	Black	Orange
3	Latch	2	Data clock (to controller)	Orange	Red
13	Data in	3	Latch (to controller)	Yellow	Brown
18	Ground	4	Data out (from controller)	Green	Black
		5	(No connection)		
		6	(No connection)		
		7	+5 volts (to controller)	Red	White

Figure B: *This diagram details the wiring necessary to connect the Power Glove to a standard PC-compatible printer port. The colors shown are for the Mattel unit. They may vary from unit to unit, so be sure to verify them. If you choose to use the Curtis NC-1 Super Extendo cable, go by the colors listed for it.*

Listing A: *A portion of the source for PG.COM, showing the 8088 implementation of the timing in figure C. The bit assignments on the printer port assume that the printer port is wired as shown in figure B.*

```
LPT1_addr      equ     0378h      ; LPT1
LPT2_addr      equ     0278h      ; LPT2
Mono_addr      equ     03BCh      ; LPT1 on mono cards
Clock_HI       equ     01h        ; data clock is low bit
Latch_HI       equ     02h        ; data latch is bit #1
Clock_LO       equ     0
Latch_LO       equ     0
Data_in        equ     10h        ; from port (Printer_addr+1), mask with this
                                  ; for current data bit
Printer_addr   dw      LPT1_addr
Glove_byte     db      0
delay_val      dw      1          ; empty loops to delay after an OUT
speed_constant equ     800h       ; delay=loops/speed_constant
; Power Glove cursor emulations (bit assignments in "Glove_byte")
PG_rt          equ     01h
PG_left        equ     02h
PG_dn          equ     04h
PG_up          equ     08h
PG_start       equ     10h
PG_select      equ     20h
PG_B           equ     40h
PG_A           equ     80h
PG_fist        equ     PG_A+PG_B
;
outdx   macro
        local   delayloop
;
        out     dx,al
        push    cx
        mov     cx,delay_val
delayloop:
        loop    delayloop
        pop     cx
        endm

; This is the only Power Glove-specific part of the code, from here to HANDLE_TSR
; talks to the glove. From that point on, the code merely does the keyboard buffer
; management and any mapping of glove functions -> keyboard functions.
;
; The RESET pulse.  An L-H-L pulse, a minimum of 4 µs long.
        mov     dx,Printer_addr
        mov     al,Latch_LO+Clock_HI
        outdx
        mov     al,Latch_HI+Clock_HI
        outdx
        mov     al,Latch_LO+Clock_HI
        outdx
        mov     cx,8             ; # of bits
        mov     bl,0             ; BL will collect the data bits
bit_loop:
        shl     bl,1             ; make a place for the new bit
        mov     dx,Printer_addr
        inc     dx
        in      al,dx            ; read the LPT status
; The bit is now in bit 5 (on the select line)
        and     al,Data_in       ; isolate it
        shr     al,1             ; move it to bit 0 (low)
        shr     al,1
        shr     al,1
        shr     al,1
        add     bl,al            ; and store
; strobe in next bit - pulse the clock line from H-L-H
        mov     dx,Printer_addr
        mov     al,Latch_LO+Clock_LO
        outdx
        mov     al,Latch_LO+Clock_HI
        outdx
        loop    bit_loop         ; back, a total of 8 times
; We've got all 8 bits. Invert them.
        mov     al,bl
        xor     al,0ffh
        mov     Glove_byte,al    ; Now, 1='pressed'
```

sells the NC-1 Super Extendo set (a pair of game controller extension cords) for around $10. One end will mate perfectly with the Power Glove's connector. On the glove or extension cable, remove the end that normally plugs into the Nintendo unit, leaving a couple of inches of wire. Now, strip off some insulation from each strand and confirm the color coding. The Mattel wiring on the glove I worked with used the color scheme shown in figure B. If you use a Super Extendo cable, you may find the colors shown in the second color chart.

Connect the glove end of the wire to the 25-pin connector, as shown in figure B. The +5-V wire (formerly from pin 7) and ground (pin 1) should be connected to the 5-V supply that you chose earlier.

Serial for Breakfast

The Power Glove speaks a form of serial communications that is more like the PC keyboard than the RS-232C port. The 8 bits of data are presented one at a time on a TTL-level data line. Since there's no built-in clock rate, the computer has to provide the clock, so a second TTL line serves as the clock to advance from one bit to the next.

To keep everything synchronized, a third line serves as a master reset, to clear the glove's interface and reset it back to the first bit. Figure C shows the relative timing of the reset line, the data line, and the clock line. In the figure, the glove is completely at rest: No directions or "fire" buttons are in effect.

Pulses should be kept between 3 and 8 microseconds, and the bit sampling should be packed as tightly as possible. In figure C, the reset pulse is about 4 µs, and the clock pulses are about 3 µs. Unfortunately, the printer port on the PC has a finite response time somewhat longer than that, so you need to add some delay. The exact amount depends on the speed of your machine and the makeup of your particular printer port.

Listing A is a code snippet from the source for PG.COM, a sample TSR cursor-key driver that uses the glove output to drive the cursor keypad. If you're not working with a PC compatible, you'll need to write a piece of code that does something similar. [Editor's note: *The source code for PG.COM is available on disk and on BIX. See page 5 for details.*]

COMPANY INFORMATION

Amtec International
(Strain gauges inside the Power Glove)
3653 West 1987 South
Salt Lake City, UT 84104
(801) 977-0359
Inquiry 988.

Curtis Manufacturing, Inc.
(NC-1 Super Extendo)
30 Fitzgerald Dr.
Jaffrey, NH 03452
(603) 532-4123
Inquiry 989.

Exos, Inc.
(Dexterous Hand Master)
8 Blanchard Rd.
Burlington, MA 01803
(617) 229-2075
Inquiry 1185.

Mattel, Inc.
(Power Glove)
Consumer Affairs
5150 Rosecrans Ave.
Hawthorne, CA 90250
(213) 978-5150
Inquiry 1186.

Polhemus Navigation Sciences
(3Space Tracker)
P.O. Box 560
Colchester, VT 05446
(802) 655-3159
Inquiry 1187.

VPL Research, Inc.
(DataGlove)
656 Bair Island Rd., Suite 304
Redwood City, CA 94063
(415) 361-1710
Inquiry 1188.

far from the center you are, just that you're off-center.

The Power Glove's low price makes it a fascinating device for folks who are interested in experimenting with hand trackers. I created crude but usable gesture-recognition software using only the cursor pad emulation. The text box "Can We Talk?" on page 288 describes the communications protocol and the cabling that are required to connect the glove to an unused printer port on your PC compatible.

Give Your Computer a Hand?

After getting my hands on these three products, it's evident that none in its present form could ever replace the mouse. The Dexterous Hand Master measures the anatomical motions of the hand with more precision than today's applications could exploit. The DataGlove would be more practical for mainstream applications, but the fibers mounted on it seem too delicate to withstand the rigors of everyday use. And the price tags of these two products clearly put them out of reach as a replacement for your computer's mouse.

What about the Power Glove? Maybe. Mattel implemented it beautifully for the home video market. It's priced right and has more-than-adequate resolution for its intended purpose. The appearance is less than professional, but then, it wasn't designed to be used in the boardroom. The Power Glove is one rugged puppy, built for hard use by kids playing Nintendo games.

Being so new, no one really knows how long the Power Glove will hold up under actual use. The unit I worked with was connected to a PC compatible for several weeks. It looked haggard after being crunched under piles of books and papers, but it never failed to work. Still, the Power Glove will probably never become a popular accessory for Macs or PCs. We need something else.

All three vendors agree that some yet-undeveloped product would fill that need nicely. A product with the Hand Master's precision, the DataGlove's ease of use, and the Power Glove's affordability and rugged construction would be just the ticket. In the meantime, don't sell these products short. Many applications—most obviously, CAD—are just crying out for a good three-dimensional input device.

The Dexterous Hand Master and the DataGlove are here today, and they are priced within the budgets of those who really need them. If you're just curious, you might want to try experimenting with a Power Glove. I've navigated Lotus 1-2-3 spreadsheets, logged onto BIX, and scrolled through hours of Prodigy screens without ever touching my keyboard. The Power Glove is just downright fun, and it's a good way to get your hand on (or in) a piece of the future. ■

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Your questions and comments are welcome. Write to: Editor, BYTE, One Phoenix Mill Lane, Peterborough, NH 03458.