Title: **DataBase Support System**

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Synopsis: To describe a simple database support system

1. Overview & License:

This document specifies a proposal for a database package.

1.1. Revision History

0.1	4/26/05	First draft
0.2	5/5/05	First formatting pass, with [DaR] markers for where more work is required
0.3	5/18/05	Test all examples and fix [DaR] markers
0.4	1/15/09	Clean up for release as a VentureForth plug in

1.2. License

2 DATA BASE SUPPORT

The polyFORTH Data Base Support package is a set of tools with which you can design efficient data base applications or components for general applications.

The Data Base Support package includes:

- A simple memory-oriented file manager.
- Commands for defining records within files and fields within records.
- Tools for generating columnar reports.
- Utilities for producing totals and subtotals.
- Techniques for linking sub-files to main files and for chaining records within files, and;
- A set of words for creating ordered indexes (for keeping sorted lists).

2.1 OVERVIEW

polyFORTH presents its Data Base Support package in the form of a "kit," leaving complete flexibility for you, the developer, to create a data base design that reflects the natural organization of the data itself.

Before you begin constructing a data base application, you must understand a few simple premises that underlie the design of the Data Base Support package. First, let's review common data base terminology.
A *data base* is the complete set of organized data that is available to the computer. A data base is divided into related groups of data called *files*. For example, a file might contain the names, addresses, and phone numbers of all your clients.

A file, in turn, is divided into *records*. A record might contain the name, address and phone number for a single client. For every client, there would be one record in the file. A record is itself divided into a collection of *fields*. For instance, one field might be called "STREET."

In a data acquisition environment, a file might contain a set of readings taken during one experiment. Each record could contain the set of measurements taken at a single point in time during the experiment; each field could contain the reading of a different measurement. In this case, you might have numerous files, each containing the data obtained during one run of the experiment; however, the records in each file would be laid out identically.

Many applications require multiple types of files that relate one to another. Suppose you want to record all your invoices, using an "Accounts Receivable" program. In the course of your business, you bill several invoices to the same client. Rather than duplicate the name and address of the clients every time you bill them, it makes sense to have one file for the client data, and another file for invoices. Each invoice record can point to one of the clients in the client file. In this way, one file can "use" another file.

2.1.1 Contiguous Files and Performance

A premise of the Data Base Support package is that you are a knowledgeable programmer concerned about performance. Its approach allows you to design the data base for optimum efficiency.

In contrast, typical data base packages are intended to simplify data base construction for non-programmers. These packages do not require that you think about how your data is organized. On the down side, you lose the ability to structure your data base in the optimal way. The price for greater generality is impaired performance and increased size of compiled code.

In a disk-oriented data base application, the key determinants of performance are:

1. How many physical disk accesses are required to access a logical data item?

2. How much head motion occurs during normal operation?

If you can minimize the number of physical accesses required and the disk head motion, you can maximize performance.

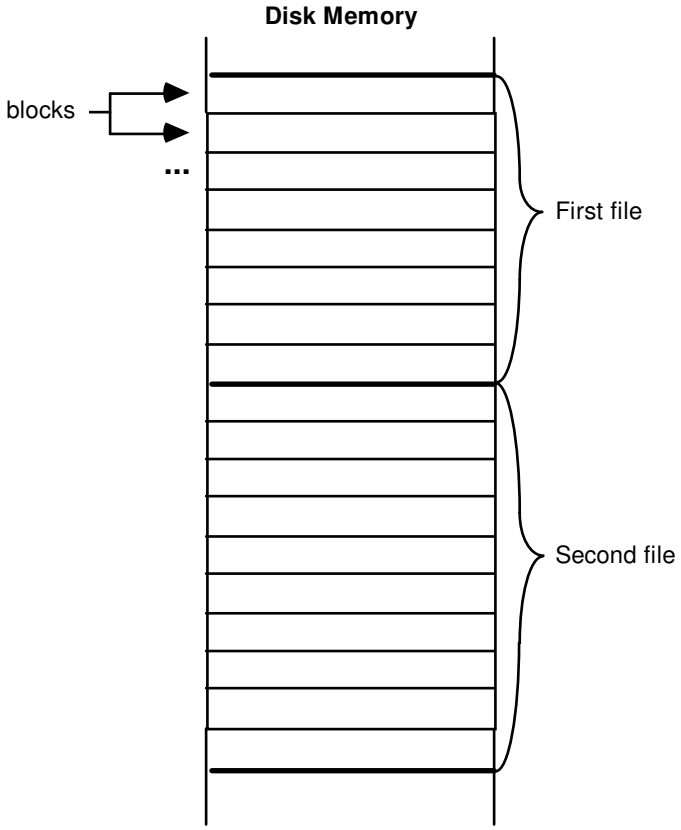


Fig. 2.1

In polyFORTH, a file occupies a contiguous range of blocks on disk. A file may be any size (using whole blocks) up to the capacity of the disk. There is no need for a file allocation table.

The polyFORTH Data Base Support package addresses both issues simultaneously by imposing a single restriction: a file is a contiguous region of data.* This means the system does not automatically "manage" files by interweaving them on disk as they expand and contract. Files are not fragmented across the disk, and there is no need for a file allocation table to point to the fragments.

Instead, you specify the maximum size of each file when you create the file, and assign it a contiguous range of blocks on the disk. Although this requires some thought, there are several advantages:

1. Since files, and therefore records, are contiguous, the exact location of any data element can be calculated. Thus any data element can be accessed in a single physical disk access. In traditional operating systems and file managers, an application cannot know from a record number where that record lies physically. The location must either be looked up in a directory, or found by following a set of chains. Reportedly, one popular operating system requires up to six disk reads to access a single logical record.

2. While accessing various elements within a single file, the disk's magnetic head need only travel within the distance occupied by the file. Head motion is minimized.

3. You have control over the arrangement of multiple files in relation to one another. For instance, if one file serves as an index into another file, you can place these two files adjacent to each other on the disk. Again, head motion is minimized.

These benefits assume that you are running on a native polyFORTH system. If your polyFORTH runs under another operating system, performance depends on the way that O/S treats the disk.

Just as files are contiguous and of fixed length, so too are records and fields. Again, although variable-length fields require less thinking on the part of the user, they necessarily degrade performance. Fixed-length fields do not necessarily imply fixed-length amounts of data, because a variable number of subordinate records may be chained together as necessary. (We'll explore this technique further in Section 2.7.)

Since the primary bottleneck in disk-based file systems is disk-access time, minimizing this bottleneck achieves surprising efficiency. For example, one company sells a data base system which uses the polyFORTH Data Base Support package to handle 300 Mbytes of data and support 64 simultaneous users with under one-second response time even at peak load, on a single 68000 microprocessor.

REFERENCES

Disk Block I/O, Section 1.2.2, 3.2

* This means that the data blocks are physically contiguous on a disk supported by a native polyFORTH. Versions of polyFORTH that are co-resident with another OS use its files to contain blocks, and thus rely on the host OS to manage disk.

2.1.1 Current Files and Records

Another concept that is fundamental to the Data Base Support package is the notion that at any given moment, exactly one file is current and one record is current. Let's first describe what is meant by a file being current.

We mentioned that a file is simply a contiguous, fixed-length range of blocks on the disk. There is no file allocation table on the disk, nor is there any other indicator of which blocks constitute which file. The knowledge of where each file begins and ends resides within the application code, specifically in a small table that you define for each file (using the defining word **`FILE`**, Section 2.3). This table is called a *File Definition Area* (FDA).

The name you give this table is the name of the file itself. The table contains the starting block number, along with sufficient information about the number and size of records for the Data Base Support package to be able to calculate the absolute location of any record in that file.

When you invoke the name of a file, the file definition places the address of its parameter field in a user variable called **`F#`**. All record-accessing operations in the Data Base Support package use this pointer to indicate the current FDA, which in turn points to the blocks where the desired record resides.

Thus, at any given moment, one and only one file is current. Changing files is a simple matter of invoking the file name, which places a new address in **`F#`**, taking only microseconds.

Contrast this with the process of "opening" and "closing" files in traditional operating systems. In these systems, each open and close operation requires noticeable disk activity to read in the file directory and write it out again. For this reason, the question of how many files can be open simultaneously is a concern in such systems. This concern disappears with polyFORTH's Data Base Support package.

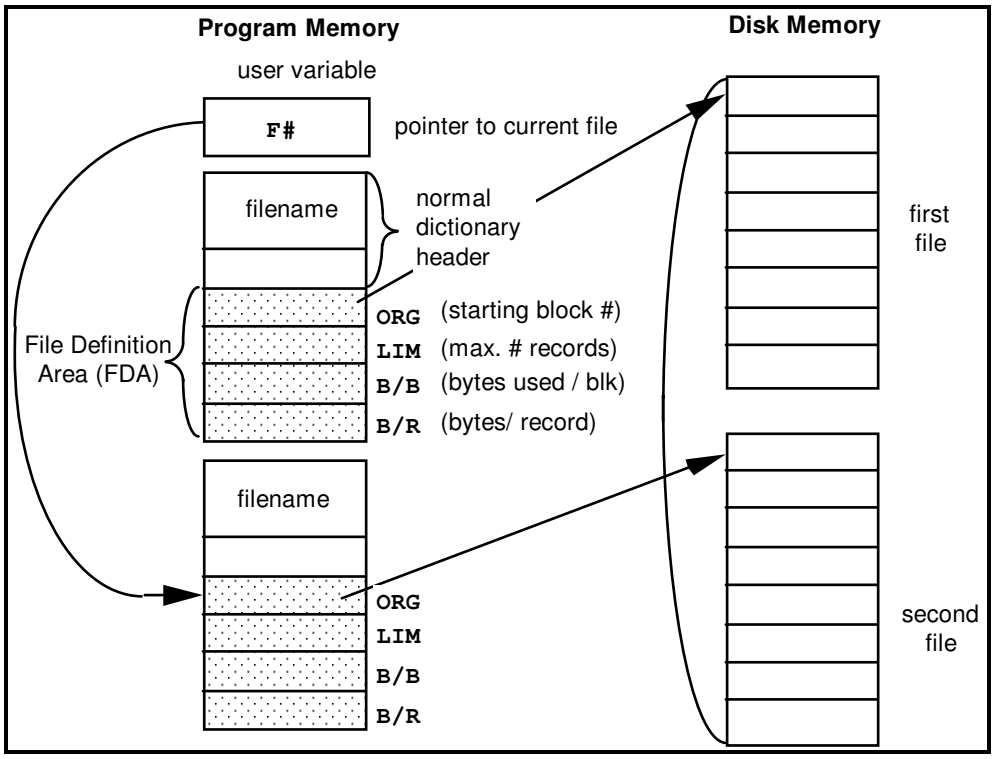


Fig. 2.2

For each file on disk there is a file definition in the dictionary. This definition contains four parameters describing the location and dimensions of the corresponding file. In this figure, the second file is "current."

We can summarize the above discussion by saying, "Files are pointed to, not opened." Analogously, we can say that "Records are pointed to, not read."

Just as there is always a current file, so there is also a current record, the number of the current record found in the user variable **R#**. All the data-access operators refer to specified fields within the *current record* in the *current file*.
The polyFORTH Data Base Support package is once again unique in this concept. Many data base packages actually read in an entire record from the disk, then allow access to the fields within it. polyFORTH merely makes a record current; disk access only occurs when a field name is invoked in combination with a field access operator.

This design takes advantage of the behavior of **BLOCK** (Section 1.2.2). Whenever a single field is accessed, **BLOCK** reads the entire block in which that field resides. If multiple fields in the record are required in the same operation (such as displaying all fields in the record for a report), it is unlikely that the block buffer will be reused before all the fields can be displayed. (Should this happen, **BLOCK** will automatically read the block again.) Moreover, it is even likely that references to neighboring records in the same block will also not require physical disk accesses.

An important advantage to not reading the record physically is the certainty that at any given moment only one copy of each record exists. Systems that read a record into

memory face the problem of two users accessing the same record, and having different copies of it. Solving this conflict entails various "lockout" schemes, all of which complicate the system and reduce performance.

The file and record pointers are entirely independent of each other. Not only can you select records without re-selecting the file, you can also change files without affecting **R#**.

From time to time in your application you may want to leave your current file and record temporarily (perhaps to examine or display a field from a related file) and return. The following words enable you to "remember" **F#** and **R#** temporarily:

Word	Action
SAVE	pushes **R#** and **F#** onto the return stack.
RESTORE	pops those items off the return stack and places them in **R#** and **F#**.

Naturally, you must use **SAVE** and **RESTORE** as a paired set within the same definition, just as you would use **>R** and **R>**. Similarly, you must use both words within or outside of any **DO ... LOOP** structure in that definition.

Following a **SAVE**, **R#** is on top of the return stack; if you need a copy of it you may get it by using **R@**.

REFERENCES

Return Stack, Section 2.1.3

2.1.2 How Data is Stored

The Data Base Support package allows storage of data in either numeric or alphanumeric form. For instance, a U.S. telephone number, including area code, requires 14 bytes when stored in alphanumeric form:

```
(213) 372-8493
```

This same phone number can be stored in only 6 bytes per record, if it is recorded as a 16-bit area code and a 32-bit local number:

```
213  3728493
```

The appropriate punctuation symbols can easily be inserted when the number is displayed, using pictured numeric output.

The contents of numeric fields travel between the data stack and the disk; the contents of alphanumeric strings travel between the **PAD** and the disk.

For instance, if we have a double-length field named **SALARY**, we can fetch the value of the field (from the current record in the current file) by invoking the phrase:

```
SALARY D@
```

which places its value on the stack in the same way that the word **2@** fetches a double-length value from an ordinary variable. Similarly, the phrase,

```
SALARY D!
```

removes a double-length value from the stack and places it in the current **SALARY** field. Alternatively, the word **B@** fetches the contents of an alphanumeric field, and copies it to the **PAD**. The word **B!** stores an alphanumeric string at **PAD** into a given field.

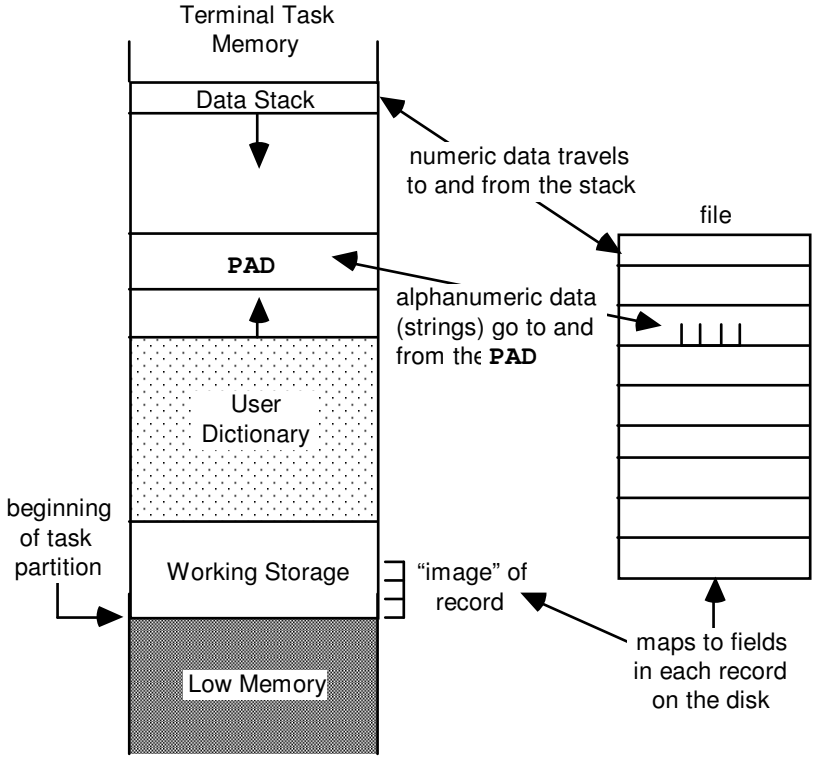


Fig. 2.3

Shows how data travels between disk and memory. Numeric data travels between disk and the parameter stack, and text strings travel between the disk and **PAD**.

REFERENCES

Field Reference Operators, Section 2.5.3
Pictured Numeric Output, Section 2.5.2.1
String Storage in **PAD**, Section 2.3.1

2.1.3 Working Storage

Two features of the Data Base Support package make use of a region of memory called *working storage*. Working storage is allocated at the beginning of a task partition, and serves as a place where record data may remain which is easily accessible, but less volatile than **PAD** or the parameter stack. Since each task has a working storage area, tasks running concurrently may use the same code referring to working storage without conflict.

One use of working storage appears in automatic totaling (Section 2.8.8). Here working storage holds the accumulating registers for each column of data to be added as the report is generated.

The second use of working storage is as an "image" of a record. The same relative positions are maintained both in the record on disk and in working storage. For example, working storage is used to hold the key during a binary search of an ordered index (Section 2.6), in the field in which it will be found in records being searched.

The same field names that let you access fields on disk also may be used to reference the corresponding fields in local working storage. There is only one "record" in the working storage area. This technique lets you map data items as though they were contained in records although they are temporarily in resident memory instead of on the disk.

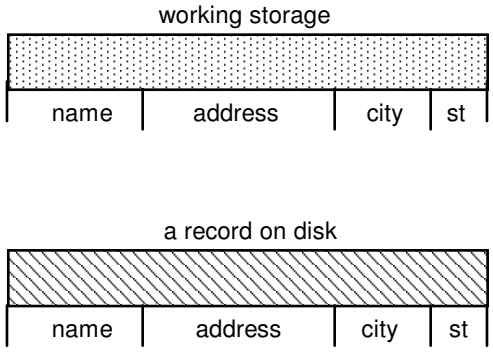


Fig. 2.4

Field names may be used to reference either the individual field in the current record (on disk), or the corresponding field in working storage.

The double use of working storage for both subtotaling and key searches rarely causes a conflict, since the two activities occur at separate times. To be on the safe side, however, the statistics component uses the word **REGISTER** to return the address of the accumulators, which in turn is defined in terms of **WORKING**. If you find that you will encounter a conflict, you may resolve it by simply redefining **REGISTER** to point to some other area.

How much working storage is necessary? If you are using the subtotaling feature, the amount depends on the number of accumulating registers you need. In total, you will need the sum of:

16	register area management
4	header variables for registers
#registers * 8	8 bytes per accumulator
total	

For instance, three accumulators will require 44 bytes* (16 + 4 + 3*8).

* On 32-bit machines these sizes should be doubled.

If you are using ordered indexes, working storage must be as large as the largest record in any ordered index file.

Remember that any task, which performs an application that uses working storage must have sufficient room allotted for it—including the printer task. Section 2.1.6 describes methods for allocating working storage.

REFERENCES

Accessing Fields in Working Storage, Section 2.5.5
Ordered Indexes, Section 2.6
Subtotaling, Section 2.8.8

2.1.4 Installing The Data Base Support Package in polyFORTH

Before you begin to use the Data Base Support package, you must first decide whether you will be using it in your personal task only, or whether other terminal tasks may need to use it simultaneously.

To load the package into a your private terminal task, list its load block with the phrase,

```
FILES LIST
```

The constant FILES return the number of this load block. Make sure that the block begins with the phrase:

```
EMPTY   n ALLOT
```

where n is the amount of working storage required for your files application (see Section 2.1.4).

At the end of the load block, a null definition of **TASK** should appear. This word will be the last word in the dictionary when file applications are loaded, and will mark the point at which overlays will occur.
Now issue the command:

```
FILES LOAD
```

to load the Data Base Support package.
As you create data base applications, each of these should begin with the phrase:

```
FORGET TASK    : TASK ;
```

This makes each application an overlay, which will discard other overlays that use this convention. For instance, if you have an accounts-receivables application, its load block should begin with the above phrase, to forget any other applications without forgetting the Data Base Support package itself.

Finally, if you wish to output a report to your printer, you must allot a working storage area in the printer task. This may be done with the phrase:

```
n TYPIST H HIS +!
```

This phrase advances the dictionary pointer **H** for **TYPIST**—the printer task—by the amount *n*. It is most convenient to edit this phrase into the **FILES** load block.

Alternatively, if several terminals require use of the Data Base Support package, Block 9 should load the package with the system electives. In this case, remove the:

```
EMPTY   n ALLOT
```

at the top of the **FILES** load block; also remove the definition of **TASK** and the word **EXIT** at the bottom (by placing parentheses around them). By allowing the final word **GILD** to execute, the Data Base Support definitions will become available to all tasks. Edit the phrase:

```
FILES LOAD   n TYPIST HIS +!
```

where *n* is the amount of working storage required for your files application (see Section 2.1.4) into the last line of Block 9 (just above the **EXIT**). If you have already loaded the electives before making this addition, type:

```
FLUSH RELOAD
```

then type:

```
HI
```

Using this approach, each files application must begin with the phrase:

```
EMPTY   n ALLOT
```

instead of **FORGET TASK**, where *n* is the amount of working storage needed by that application.

REFERENCES

ALLOT, Section 2.8.1
EMPTY, Section 3.3.4.1
FORGET, Section 3.3.4.2
HIS (User variables), Section 4.6
LIST, Section 5.1.1
Overlays, Section 3.3.4
Parentheses Used for Comments, Section 1.5.1
System Electives, Section 1.4.2

2.1.5 Installing The Data Base Support Package in gforth

While the previous section described how to install the original Data Base Support Package on the 16-bit polyFORTH block-based system that it was written, the current package has been enhanced to work on 32-bit, file-based systems. It has been tested, at various points in time, on the 32-bit pF32-386/pMSD system using its Text File Support (**TEXTFILE**) Option, on SwiftForth 2.00.2, and of Gforth 0.6.2. However, since each system has its own, unique dependencies, the current system is configured to run on gforth, using an ANS Forth to Open Firmware compatibility layer (**Forth2OF.fth**). The primary compatibility issue these routines solve is the issue of locating the support files in a multi-file application package, such as this.

Starting in the BootROMCVS source folder, the Data Base Support Package can be compiled into gforth using the following commands.

```
INCLUDE Forth2OF.fth
INCLUDE Tools/File/File.fth
```

The Data Base Support Package includes the following files.

```
INCLUDE Tools/File/Support.fth \ DataBase Support System
INCLUDE Tools/File/Reports.fth \ Report Generator
INCLUDE Tools/File/Struct.fth  \ Structured files
INCLUDE Tools/File/Memory.fth  \ Memory based data
INCLUDE Tools/File/Index.fth   \ Ordered Index
INCLUDE Tools/File/Sort.fth    \ Field sorting
```

Once loaded, the following, optional configuration settings may be invoked to cause the system to behave in specific ways.

```
FALSE REVERSE !
```

Causes the system to not store strings with every other byte reversed. This is described in Section 2.6.1 below, regarding Indexed File Records. The default setting is **TRUE**, since most existing Data Base Support files have been constructed that way. However, if you are not concerned with compatibility with existing data files, you will most likely set this flag to **FALSE**.

```
LITTLE-ENDIAN
BIG-ENDIAN
```

These options establish the byte order of values stored in **NUMERIC**, **LONG** and **DOUBLE** fields. The default setting is **LITTLE-ENDIAN**, but you may want to use **BIG-ENDIAN** on systems where that is the native data format. Neither one has any speed benefit, since both are coded using byte fetch operators. However, if you are accessing data in **WORKING** storage, as described in Section 2.5.5, this setting can be essential.

```
' DD-MMM-YYYY DATE-FORMAT !
' MM/DD/YYYY DATE-FORMAT !
```

The format of a date can be adjusted, using this option. The default setting is **MM/DD/YYYY**. The primary usage is in **+PAGE** as is described in Section 2.8.4.

REFERENCES

B!, Section 2.6.1
WORKING, Section 2.5.5
+PAGE, Section 2.8.4

2.1.6 Installing The Data Base Support Package in Open Firmware

Since the Data Base Support Package was originally written to run on polyFORTH, there are dependencies, above and beyond simple ANS Forth requirements. These have all been bracketed with the following:

```
[UNDEFINED] <name> [IF] <definition> [THEN]
```

Here is a list of the non-ANS Forth words that this system requires:

Word		Description
GET	(a --)	Multi-tasking means to get ownership of a facility.
GRAB	(a --)	Multi-tasking means to get ownership without pausing.
RELEASE	(a --)	Multi-tasking means to release ownership of a facility.
#USER	(-- a)	Multi-tasking variable containing the size of the user area.
+USER	(o n _ -- o')	Multi-tasking means to define new user variables.
c@-le	(a n -- …)	Little endian fetch of a multi-byte value.
c!-le	(… a n --)	Little endian store of a multi-byte value.
c@-be	(a n -- …)	Big endian fetch of a multi-byte value.
c!-be	(… a n --)	Big endian store of a multi-byte value.
LINKS	(a – a')	Finds the end of a linked list.
>LINK	(a --)	Add to the top of a linked list.
<LINK	(a --)	Add to the bottom of a linked list.
UNLINK	(a a' -- a)	Remove an entry from a linked list.
CALLS	(a --)	Call routines in a linked list.
append	(a1 n a2 --)	Add a string to a counted string.
place	(a1 n a2 --)	Place a counted string.
,string	(a n --)	Compile a counted string.
$c,	(a n --)	Compile a string.
,"	(string" --)	Compile a parsed string.
spin	(--)	Show activity.
-spin	(--)	Stop showing activity.
FILLER	(o n _ -- o')	Defines an unreferenced field (Section 2.5.2)

In addition, Open Firmware does not presently contain the following ANS Forth words:

```
SAVE-INPUT RESTORE-INPUT M+ ALLOCATE FREE RESIZE
```

Additionally, the **BYTE-LOAD** method is used to conditionally compile support for Open Firmware specific features. For example, the 1275 tokenizer does not directly support defining words, so extensions to the tokenizer must be defined every time one of these words is defined. The disk based file support words are also not directly supported, so they are not loaded into the Open Firmware package.

The Data Base Support Package is compiled with the rest of the Open Firmware kernel, so there may be other dependencies, beyond the 1275 specified words, which have not been identified at this point. The package is optionally byte-loaded into the **/packages** node and it optionally byte-loads the applications which use it. This creates a compile time binding (i.e. early binding) between the kernel, this package, and the applications,

which is required at the present time. Future work will be needed to remove this dependency.

Systems that use this package should compile their applications in **THE-FILES.of**, following the compile of the **database.of** file

```
\ The following modules rely on the Database operators

-1 -1 tokenize-list OF/OFSources/Common/Database.of
      Encode-Driver BuildResults/"{Build}/Obj/Database.lzss
-1 -1 tokenize-list OF/OFSources/IO/smu/sdb-parser.of
      Encode-Driver BuildResults/"{Build}/Obj/sdb-parser.lzss
```

Add their applications to **The-Drivers.fo**:

```
LoadDriver  Database
LoadDriver  sdb-parser

AddDriver   Database
AddDriver   sdb-parser
```

And the byte load of their applications to **Database.of**:

```
" sdb-parser" ['] byte-load-driver CATCH IF 2DROP THEN
```

Then, their application interfaces can be called as needed:

```
0 0 " database" $open-package ?dup
if    >r  [char] B " distribute-sdb-properties" r@ $call-method
      r> close-package
then
```

2.2 CREATING A SIMPLE FILE

This section introduces the procedures for creating a simple file by way of an example, and provides a contextual framework for the detailed sections that follow.

In this section we are assuming that we already know how to structure our data; we are concerned here only with the mechanical aspects of file creation and field layout. For a more general discussion of data base design, see Section 2.9.

Our simple example will be a file of names and addresses. To avoid extra detail, we will only use alphanumeric fields. No attempt will be made at keeping a sorted file (ordered indexes are discussed in Section 2.6).

Step 1
Define the fields:

```
0  20 BYTES NAME   20 BYTES STREET
   14 BYTES CITY    2 BYTES STATE
    6 BYTES ZIP    14 BYTES PHONE   DROP
```

In the above lines we have defined six Forth words, which will reference the individual fields in each record. The initial zero is the relative position within the record. The defining word **BYTES** creates an alphanumeric field of the specified width (the width must be an even number on cell-aligned processors). The final **DROP** is necessary to discard the final relative position within the record (see Section 2.5.1).

In addition to **BYTES**, several other defining words are available for creating different types of fields (see Section 2.5.2).

Step 2
Determine how many records and blocks the file will need. Two words that are not generally resident are available in the "file initialization block."* **#R** computes the number of records of given size that would fit in a given number of blocks; **#B** computes the reverse: the number of blocks needed to hold a given number of records of given size (see Section 2.3.1).

Step 3
Define the file:

```
FILE People.dbf   FILE= Tools/File/People.dbf

74 500 400 BLOCK-DATA PEOPLE
```

This statement defines a file called **PEOPLE,** which contains records that are each 74 bytes in length. The file will hold a maximum of 500 records. The starting block will be 400 (see Section 2.3.1).

Invoking the filename **PEOPLE** makes this file current.

Step 4
Initialize the file. Load the file initialization block (if it's not already loaded) and execute the phrase:

```
PEOPLE INITIALIZE
```

to fill all blocks in the file with zeroes (see Section 2.3.3).

Step 5
Enter data.

Here is the definition of a word that will allow data entry for a single record (person):

```
: enter   PEOPLE  SLOT READ
    CR ." Name? "     NAME ASK
    CR ." Address? "  STREET ASK
    CR ." City? "     CITY ASK
    CR ." State? "    STATE ASK
```

* This block is not generally resident, because it is used only in the initial creation of the data base. It may usually be found at **FILES 5 +**.

```
CR ." Zip? "       ZIP ASK
CR ." Phone? "     PHONE ASK ;
```

By invoking **PEOPLE**, we select the **PEOPLE** file as the current file.

The word **SLOT** allocates a new record in the current file, and leaves its number on the stack (see Section 2.4.3). The word **READ** sets the current record according to the number on the stack (see Section 2.4.1).

Next, the definition prompts the user to enter the "name" field. The word **ASK** is like **EXPECT**, except that it places the expected text in the given field. The same process is followed for the remaining five fields.

Step 6
Display the data.

We define the following word to display the current record:

```
: person   CR NAME B?  CR STREET B?  CR
   CITY B?  STATE B?  ZIP B?  PHONE B? ;
```

The word **B?** displays the contents of the given **BYTES** field (see Section 2.5.3).

To display the contents of all records that have been entered, we define:

```
: everyone   PEOPLE RECORDS DO CR
   I READ  person  LOOP ;
```

Invoking **PEOPLE** makes the **PEOPLE** file current. The word **RECORDS** returns the appropriate arguments for a **DO ... LOOP**, including all records that have been allocated by **SLOT** in the current file (see Section 2.4.3).

Within the **DO** loop, **READ** makes each record current in turn, and **person** displays the information for that record.

Here is a sample of the output of **everyone**:

```
Andrews, Carl
1432 Morriston Ave.
Parkerville PA 17214 (717) 555-9853

Boehning, Greg
POB 41256
Santa Cruz CA 95061 (408) 666-7891

Chapel, Doug
75 Fleetwood Dr.
Rockville MD 20852 (301) 777-1259

Cook, Dottie
154 Sweet Rd.
Grand Prairie TX 75050 (214) 642-0011
```

To produce columnar output, we would use the "Report Generator" (Section 2.8).

For deleting records, we would use the word **SCRATCH** (see Section 2.4.3).

2.3 FILE DEFINITION AND ACCESS

A polyFORTH file is a contiguous region of Forth blocks. On native versions of polyFORTH this means that the file will be physically contiguous, and that you can arrange for files that are accessed together to be physically near one another. This can significantly speed up a data base application.

Versions of polyFORTH that are co-resident with a "host" operating system (such as MS-DOS or RSX) are identical from the point of view of the programmer, but since allocation of physical disk space is performed by the host operating system you haven't the actual level of control you do on the native versions.

This section discusses how files are defined and referenced on all polyFORTH systems.

2.3.1 The FILE Definition

The word **FILE** is used to group a collection of Data Bases under a single name. Each Data Base within the group will use the same access operators. Presently, there are 2 types of access operators, disk based (**>FILE**) and memory based (**>MEMORY**). The disk based operators can not be used within Open Firmware, since the creation of files has not been fully developed yet. However, in gforth, they are used extensively by passing the pathname string to **>FILE**. The word **FILE=** simply parses the input stream for the pathname string before passing it to **>FILE**. In Open Firmware, the Data Base groups are typically created at compile time and compiled into Open Firmware with **encode-file**. Since this puts the data into the dictionary, the word **HERE>MEMORY** is used to put the data into the buddy memory manager which can be used by the **>MEMORY** access operators.

The words **BLOCK-DATA** or **STRUCTURE** are used to define files, given the attributes of the file. The format is:

```
length limit origin BLOCK-DATA name
```

where:

Word	Description
length	is the length of each record in bytes (maximum 1024 using **BLOCK-DATA**);
limit	is the maximum number of records (on 16-bit processors the limit is 32767 records per file);
origin	is the first block number, and
name	is the user-assigned name of the file.

The defining words **BLOCK-DATA** and **STRUCTURE** create a new name (dictionary entry) that, when invoked, will make this file current. The dictionary entry contains the **F**ile **D**efinition **A**rea (FDA) for the file being defined. **BLOCK-DATA** will make sure that

records do not overlap across 1K boundaries, while **STRUCTURE** does not impose this additional overhead.

We recommend that you define all your files in a single source area, making it easy to see which ranges of blocks have been allocated for other files. If a disk will contain source or other data along with files, it's a good idea to indicate these other uses in comments on the same block.

Here is an example of good file definition layout in a block:

```
( Bytes   Records   Origin          Name)
     26       801      500 STRUCTURE (GLOSSARY)
    340       800      522 STRUCTURE GLOSSARY
      4        10      795 STRUCTURE HITS
     24        42      799 STRUCTURE SECURITY
     38      2600      800 STRUCTURE TESTS
```

Note that the number of blocks may be computed from the number of bytes/ record and number of records. Generally you will choose an appropriate maximum number of records, based on a reasonable estimate of the needs of the application and allowing for expansion. You will also have worked out the approximate size of each record based on the width and type of fields needed. Then derive the number of blocks from the number of records and size of each record. The word **#B** in the file initialization block is a helpful tool for computing the number of blocks. After loading this block, type:

```
#records #bytes/record #B .
```

For instance, if your application requires 2000 records, and each record is 42 bytes wide, type:

```
2000 42 #B .      84 ok
```

Alternatively you can compute the number of records based on the number of blocks. The word **#R** in the file initialization block does the arithmetic. Type:*

```
#blocks #bytes/record #R .
```

For example:

```
84 42 #R .      2016 ok
```

This shows that you can actually fit an extra sixteen records in the same number of blocks.

By using these tools, you can iterate on various sizes until you get the optimal combination. Sometimes you can increase the size of a record without increasing overall file size. For instance, if your record width is 94 bytes, it takes 200 blocks to store the same number of records; however 200 blocks will store 2000 records even when each record is 102 bytes wide:

```
2000 94 #B .      200
2000 102 #B .     200
```

---

* Responses shown in light type.

It's a good idea to leave extra space in records, in case you need to add fields later. Beware, however, of grossly over sizing either your record width or file length, as both of these will increase head motion. Strive for generous but reasonable estimates.

2.3.2 File Definition Area and Access

The word **STRUCTURE** establishes a File Definition Area (FDA) for each file in the system. The user variable **F#** always points to the current FDA. Execution of the filename sets **F#** to address the associated FDA.

Each file's FDA contains four values to specify the file. Each of these values may be accessed by the following names, each of which returns the address of the associated value in the current FDA.

Name	Description
ORG	Starting disk-block number of the first disk block allocated to the file (Forth logical block number as a double-precision number).
LIM	Number of records, of declared record length, that the file can contain.
B/B	Number of bytes used per block.
B/R	Number of bytes per record.

While these words are used by the Data Base Support package, they are rarely referenced directly in applications. **ORG** and **LIM** can be useful in debugging, however. For instance, the phrase:

```
ORG 2@ D.
```

indicates which file is current; in case of an abort, you can tell which file you were in at the time.

2.3.3 File Initialization Utility

A file that has just been created must be initialized before it can be used. A special utility is available for this purpose.

To initialize a file, type:

```
filename INITIALIZE
```

The word **INITIALIZE** performs the following functions:

1. Writes binary zeros throughout the entire file (including **AVAILABLE**).

2. Writes -1 in the entire data area of Record 1 of the file. This serves as a "stopper" for the binary search in an index file. In other kinds of files this has no effect.

Two other words also defined—**#R** and **#B**—are useful when designing file layouts.

2.3.4 Shared Files

In polyFORTH files may be either shared or unshared. Shared files are those that are defined in the common dictionary available to all users (loaded by the electives load

block). If a file is defined in an overlay, it will be available only to the task or tasks in whose partition it is defined.

As we discussed in Section 2.1.3, all users may freely access the file without having to worry about simultaneous access problems, as long as standard polyFORTH accessing methods are used. This is because **BLOCK** ensures that there will be only one copy of a record at a time, and each task does not have its own private copy.

Certain situations require an extra measure of control. For example, one terminal might delete a record that is needed for processing at another terminal at a later point. In such as case, you may use a "status" byte in the record to control access.

REFERENCES

BLOCK, Section 3.2
Installing the Data Base Support Package, Section 2.1.5

2.4 RECORD MANAGEMENT

The process of record management includes selecting records, finding the next free record when a new record is needed, and marking deleted records as available for future use.

Not all applications require special record allocation techniques. For instance, if a file contains 100 records and each record contains information on a permanent piece of equipment, which is identified by a two-digit number, there is no need to allocate or deallocate records. You may just use the equipment number as the record number. This is called "direct access."

In an application in which the number of active records changes dynamically, it may be appropriate to use the record allocation techniques described here.

2.4.1 Record Selection

Field reference operators (Section 2.5.3) access fields in the current record. The word **READ** makes a record current.

READ (n --) Makes record n current, having verified that *n* is a valid record within the current file.

The name **READ** is slightly misleading, in that it doesn't perform an actual disk operation, but merely sets a pointer to the current record. **READ** checks that n is not less than zero and not greater than the value of **LIM**. If *n* fails this range test, **READ** aborts.
READ stores the number of the current record in the user variable **R#**.

REFERENCES

Current Files and Records, Section 2.1.2

2.4.2 Available Records

To distinguish allocated records from available records, the Data Base Support package uses the convention that if the first four bytes in a record contain binary zeroes, the record is available for use. When a file is initialized, all records are filled with zeroes.

Thereafter, active records may keep any non-zero data in the first four bytes; when a record is released, zero is stored in this area.

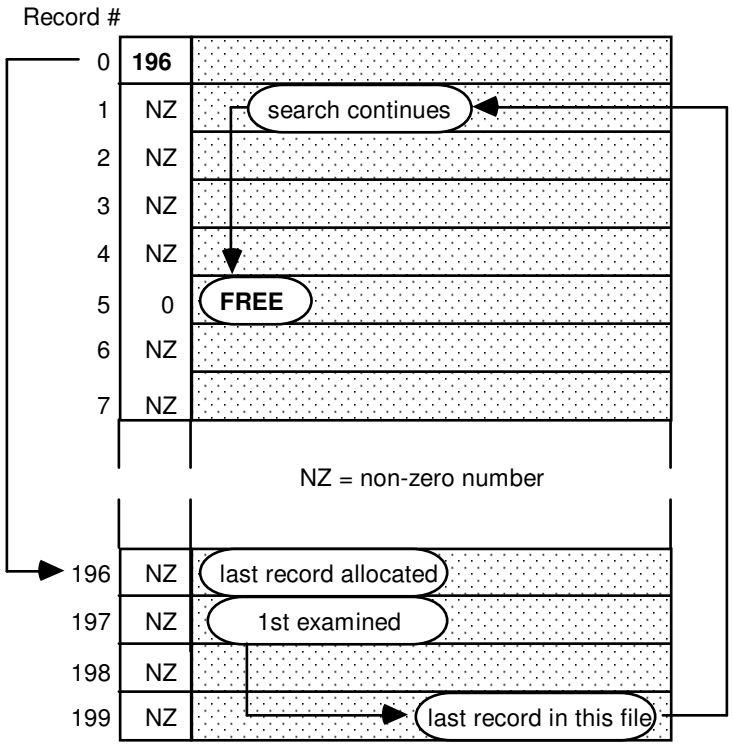


Fig. 2.5

The search for an available record performed by **SLOT** "wraps around" if necessary at the end of the file.

Record 0 of each file contains, in its first four bytes, the record number of the most recently allocated record in that file. The word **AVAILABLE** returns the address of this pointer. When the file is initialized, **AVAILABLE** is zero.

To allocate a new record, the system begins with the record immediately following the "available" record and searches forward for the first free record.

If the search should reach the end of the file without finding a free record, it "wraps" around to the beginning again, so that deleted records will be used. For instance, in Fig. 2.5, **AVAILABLE** points to Record 196; however, there are no more free records between there and the end of the file. But Record 5 is free. By "wrapping around" to the beginning of the file, the search finds the available record.

2.4.3 Record Allocation/Deallocation Operators

Only two words are required for allocating and deallocating records:

Word	Stack	Description
SLOT	(-- n)	Allocates a new record in the current file and returns the number of the allocated record.
SCRATCH	(n)	Deallocates record *n* from the current file, making it available.

SLOT searches the file for the first free record, starting with the record following the one pointed to by **AVAILABLE**. If a free record is found, **SLOT** sets the file's **AVAILABLE** to point to it. **SLOT** then stores a -1 into the first cell of the record to indicate that it is no longer free, and clears the remainder of the record to zeros. If the file is full, an error message occurs and processing is terminated.

SLOT does not make the new record current, it only returns the selected record number on the stack. The reason for this factoring is that you often want to do something with the record number before consuming it with **READ** (which makes this new record the current record). For example, we may wish to cause a link in the current record to point to the new record, as in the phrase

```
SLOT  DUP LINK L!  READ
```

Here the phrase **LINK L!** must come first because after the **READ** we'll be in a different record.

SCRATCH does not change the contents of the record beyond the first two bytes.

REFERENCES

N!, Section 2.5.3
READ, Section 2.4.1

2.4.4 Accessing Files Sequentially

The following words return appropriate stack arguments for a loop, which will access the records in a file sequentially:

Word	Stack	Description
RECORDS	(available+1 1)	Typically used before **DO**, returns the content of **AVAILABLE** (the record number of the last record allocated) incremented by one and starting index (1) for a file that has never wrapped around.
WHOLE	(limit 1)	Typically used before **DO**, returns the content of **LIM** and starting index (1) for the entire file.

Since these words return the parameters for the *current file*, it's a good habit to invoke the name of the file just before them, as in **PEOPLE RECORDS**.

When using **WHOLE**, you will probably want to check inside the loop whether each record is currently active. This is normally done by the phrase:

```
LINK L@ IF ...
```

where **LINK** is the generic long field comprising the first four bytes of each record. If these bytes contain zero, the record is available for use.

REFERENCES

Available Records, Section 2.4.2
DO Loops, Section 2.4.4
LIM, Section 2.3.2

2.5 FIELD DEFINITION AND ACCESS

A record description is the list of defined fields that appear in the record. Each field is an entry in the Forth dictionary, containing the displacement of the field from the beginning of the record in its parameter field.

A record description is not formally associated with any particular file (unless **BIND-FIELDS** contains **TRUE**). It is more like a mask, which is used whenever it is appropriate to access data.

There are several kinds of fields: numbers of various sizes and byte strings of specified length. The following sections discuss the various types of fields and the related operators that are used to access the data stored in them.

2.5.1 Record Description

A record description defines the fields that make up each record in a file. A record description has the following general format:

```
0    field-type field-name
     field-type field-name
     ...
DROP
```

The various field types are described in Section 2.5.2.

A value is carried on the stack throughout the above process to give the relative displacement of the beginning of a record. This value is initialized by the zero at the beginning of the record description, incremented appropriately by each field definition, and finally discarded at the end.

In a complex application the fields in a record description may be defined vertically, like this:

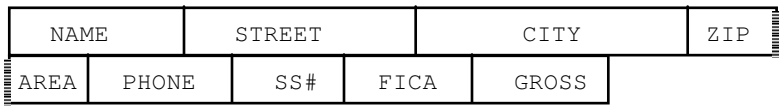
```
( PEOPLE file records)

24 BYTES NAME          ( Last name first)
24 BYTES STREET        ( Street address)
10 BYTES CITY,STATE
  DOUBLE ZIP           ( zip code, US only)
 NUMERIC AREA          ( area code)
  DOUBLE PHONE         ( phone number )
 NUMERIC >DETAIL       ( link to DETAIL file)
                ( For employees:)
  DOUBLE SS#           ( Social sec. number)
  DOUBLE FICA
  DOUBLE GROSS         ( Gross income ytd)
DROP
```

As a quick check to verify that the number of bytes used for each record matches the expected value (as specified in the file definition), replace **DROP** with **.** ("dot") use it to define a **CONSTANT**. This format allows you to use the shadow block for a general discussion of the file and record.

The field-names defined in the example above—**NAME**, **STREET**, etc.—are now entries in the Forth dictionary. When executed, these words return an address, except for field-names defined with **BYTES**, which return a count and address (see Section 2.5.2).

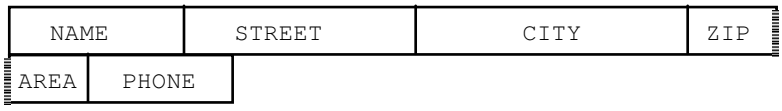
A record description is not formally attached to a particular file and has no name. Use of a field name references the relative location given by that field name in the current record of the current file.

A record in **EMPLOYEES**:



Thus it is possible to use the same field names for two different files, even if the record size used in each file varies. For instance, all the above-defined field names could be used with a file called **EMPLOYEES**, while the first six could be used with another file called **CUSTOMERS**.

A record in **CUSTOMERS**:



NOTE: Due to the Data Base Support package's record-allocation scheme, the first field of an active record may never contain a zero in its first four bytes. In our example, this is

not a problem because the first field is alphanumeric (even blanks are stored as decimal 32's). Otherwise, we would have to rearrange the order of the fields so that one, which will never contain zero, is first.

REFERENCES

Available Records, Section 2.4.2
Field Types, Section 2.5.2

2.5.2 Field Definitions

The following field types are defined:

Word	Description
1BYTE	This field is for an 8-bit value (range 0-255). On processors that do not tolerate odd byte addresses (such as the PDP-11 and 68000), **1BYTE** fields must be used in pairs to avoid wasting space. Example: **1BYTE AGE** Words that are defined by **1BYTE** return an address, suitable for use with the one-byte memory access operators **1@**, **1!**, **1?**, and **?1**.
NUMERIC	**NUMERIC** fields occupy two bytes of storage (on 32-bit systems also). Example: **NUMERIC WEIGHT** Words defined by **NUMERIC** return an address, suitable for use with the numeric field access operators **N@**, **N!**, **N?**, and **?N**.
LONG	**LONG** fields occupy four bytes of storage (only available on 32-bit systems). Example: **LONG WEIGHT** Words defined by **LONG** return an address, suitable for use with the numeric field access operators **L@**, **L!**, **L?**, and **?L**.
DOUBLE	This field is for a 64-bit (8-byte) value. Example: **DOUBLE SALARY** Words defined by **DOUBLE** return an address, suitable for use with the double field access operators **D@**, **D!**, **D?**, and **?D** .
BYTES	This field is for alphanumeric text. A count is required to specify the number of bytes in the field. Example: **24 BYTES NAME** Words defined by **BYTES** return a length and address, suitable for use with the byte field access operators **B@**, **B!**, **B?**, and **?B**. The width of a **BYTES** field must be even.
FILLER	This field reserves space in the record, typically used for future expansion or to skip regions of a record that are to be accessed by other means. **FILLER** requires the number of bytes to be reserved. Example: **6 FILLER <any name>** **FILLER** creates no dictionary entry, but simply discards the word that follows.

At compile time, the numeric field defining words (**1BYTE**, **NUMERIC**, **DOUBLE**) expect the current displacement in the record on the stack. A copy of the displacement is compiled in the parameter field of the definition, and its value on the stack is incremented by the size of the field in bytes. A **BYTES** field also expects the size of the field on the stack. This value is compiled along with the displacement, and used to increment the displacement accordingly.

When a field-name defined by one of these words is *executed*, it pushes onto the stack the address of working storage, incremented by the displacement of the field to give the address of the field in the record image in working storage. In the case of **BYTES** fields, the size of the field is beneath the address on the stack. The working storage address (and size, in the case of **BYTES** fields) is the appropriate input to the field access operators described in the next section.

REFERENCES

Access to the Record Image in Working Storage, Section 2.5.5
Available Records, Section 2.4.2
Direct Access to Fields, Section 2.5.4
Field Reference Operators, Section 2.5.3
Working Storage, Section 2.1.4

2.5.3 Field Reference Operators

Fields in files are referenced with special words. The following operators assume that the desired file and record have been selected. They refer to fields in the current record (as indicated by the value of user variable **R#**; see Section 2.4.1). In all cases, the name of the field precedes the operator; the field-name returns the appropriate address (and length, in the case of **BYTES** fields) to be used by the access operator.

Word	Stack	Action
1@	(a - b)	Fetches the contents of a **1BYTE** field to the top of the stack.
1!	(b a -)	Stores a byte into the **1BYTE** field whose address is on top of the stack.
1?	(a)	Fetches and displays the contents of a **1BYTE** field.
?1	(a)	As for 1?, except the results are right-justified by the report generator.
N@	(a - n)	Fetches the contents of a **NUMERIC** field to the top of the stack.
N!	(n a -)	Stores a number into the **NUMERIC** field whose address is on top of the stack.
N?	(a)	Fetches and displays the contents of a **NUMERIC** field.
?N	(a)	As for **N?**, except the results are right-justified by the report generator.
L@	(a - n)	Fetches the contents of a **LONG** field to the top of the stack.
L!	(n a -)	Stores a number into the **LONG** field whose address is on top of the stack.
L?	(a)	Fetches and displays the contents of a **LONG** field.
?L	(a)	As for **L?**, except the results are right-justified by the report generator.
D@	(a - d)	Fetches the contents of a **DOUBLE** field to the top of the stack (two cells).
D!	(d a -)	Stores two cells into the **DOUBLE** field whose address is on top of the stack.
D?	(a)	Fetches and displays the contents of a **DOUBLE** field.
?D	(a)	As for **D?**, except the results are right-justified by the report generator.
B@	(n a)	Reads a **BYTES** field, according to the declared length, into **PAD**.
B!	(n a)	Stores a **BYTES** field, according to the declared length, from **PAD**.
B?	(n a)	Fetches and displays the contents of a **BYTES** field, according to the declared length. **PAD** is used as intermediate storage of the field data.
?B	(n a)	As for **B?**, except the results are right-justified by the report generator.

Example of usage:

GROSS D@	Fetches the contents of the **DOUBLE** field **GROSS** onto the stack.

Two other words are included for storing data into **BYTES** fields:

Word	Stack	Action
PUT	(n a)	Copies the remainder of the input stream into a **BYTES** field. For example: **NAME PUT Fred Ferguson ok** A string that is too long will be truncated when it is stored. If it is shorter than the field size, it will be blank-filled. A copy of the entire string is left in **PAD**.
ASK	(n a)	Awaits (via **EXPECT**) input from the keyboard, and copies it into a **BYTES** field using **PUT**.

The word **ENTIRE** may be used in place of a field name:

Word	Stack	Action
ENTIRE	(-- n a)	Returns parameters for the "pseudo-field" that occupies the entire record in **BYTES** format. For example: **ENTIRE B?** types the contents of the current record as though it were a single **BYTES** field.

REFERENCES

EXPECT, Section 3.7.1
Fetching Input to **PAD**, Section 2.3.6.3
PAD, Section 2.3.1
Report Generator, Section 2.9

2.5.4 Direct Access to Fields

The Data Base Support package is set up so that field names may be used with field access operators in a transparent way, although in fact more is going on with these words than meets the eye. In the event that you need to directly access fields in a file (for instance, if you wish to use **MOVE**, **ERASE**, etc. instead of **N!**, etc.), you should understand the details explained in this section.

The addresses returned by user-defined field names are intended to be consumed by the field reference operators (Section 2.5.3). These addresses, however, are not the addresses of the actual data in a block buffer, but rather addresses within working storage (Section 2.1.4). The field reference operators perform the necessary offset correction, call the appropriate block and access the data. In the case of "fetch" operators, the operators move the data elsewhere (numbers are pushed onto the stack; strings are moved to **PAD**). This allows the field-name words, which return the address, to be used transparently with either working storage or the file data itself; the difference depends solely upon the operator that fetches or stores the data.

Each field reference operation can be an implied disk access, since it may call file I/O operators. It is important not to carry the address of a field in an I/O buffer on the stack across any I/O operation (such as displaying the content of a field or accessing another field), since in a multitasking environment another task may perform disk activity that changes the content of the I/O buffer.

Occasionally it may be useful to bypass the protection of the field reference operators, and determine the actual address of a field in a disk buffer. This can be done by the following phrase:

```
field-name ADDRESS
```

This phrase places the actual memory address of the field on top of the stack. For example, the following phrase will move an array of 100 2-byte data elements from working storage to disk much faster than it would take to calculate addresses repeatedly using **N!**:

```
DATA  DATA ADDRESS  200 MOVE  TOUCH
```

The first use of **DATA** returns the address of the image of the field in working storage. The phrase **DATA ADDRESS** returns the location of the field in virtual memory. **200 MOVE** moves the image in working storage to the disk buffer. **TOUCH** is necessary after writing to a disk buffer.

For **BYTES** fields (since invoking the name of a **BYTES** field pushes both the location and length onto the stack), the phrase:

```
field-name ADDRESS
```

returns the length and virtual memory address (note that the order is reversed from the standard "address, count" order).

If direct addressing is used, you must remember that the content of the buffer can change at any time the task either requests I/O from any source or causes execution of **PAUSE** or **WAIT**. Furthermore, if you modify the contents of any field directly (without using **N!**, **B!**, etc.), you must invoke **TOUCH** after the modification.

REFERENCES

Disk Buffer Management, Section 3.2.1
MOVE, Section 2.3.4
Multitasking Overview, Section 1.2.3

2.5.5 Access to the Record Image in Working Storage

Because field names return addresses within local working storage, you can directly access the working storage image of a record. This lets you map data items as though they were contained in records, although they are kept in resident memory instead of on the disk. There is only one "record" in the working storage area.

Using ordinary memory-access operators in conjunction with field names provides access to working storage locations:

Word	Action
C@	Fetches an 8-bit number. Example: **AGE C@**
C!	Stores an 8-bit number. Example: **39 AGE C!**
@	Fetches a single-length number. Example: **LINK @**

!	Stores a single-length number. Example: **16 LINK !**
2@	Fetches a double-length number. Example: **PRICE 2@**
2!	Stores a double-length number. Example: **196.75 PRICE 2!**
S@	Fetches a string from working storage to **PAD**. Example: **NAME S@**
S!	Stores a string from **PAD** into working storage. Example: **NAME S!**

The word **WORKING** returns the address of the beginning of the task's working storage. Note that there is no common standard for manipulating half-cell quantities (i.e. 16-bit values on a 32-bit system), so it is best to avoid using them within this context.

REFERENCES

Memory-Stack Operations, Section 2.1.2
PAD, Section 2.3.1
Working Storage, Section 2.1.5

2.6 ORDERED INDEX FILES

An ordered index file is one in which the records are kept in ascending order depending upon the ASCII values of a *key*. A key is an item of data that is used in a match or comparison.

There are two purposes for an ordered index file. First, it greatly speeds up searches based on the key data. Second, it allows you to display the main file alphabetically without having to sort it.

Each record in the index file contains a key together with a link address to an associated main file. This link resides in a 32-bit field called **LINK**. In Fig. 2.6, the index file **(NAMES)** contains the names of people, ordered alphabetically, along with links to the main file.

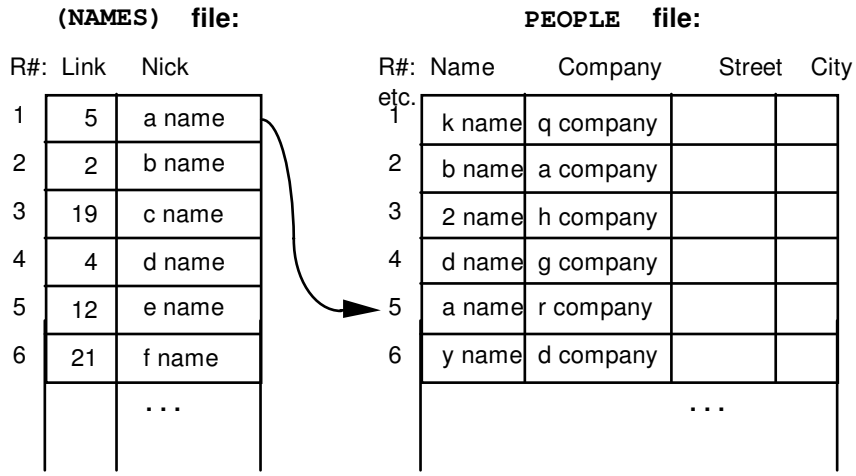


Fig. 2.6

An ordered index file (on the left) showing links to the corresponding records in the main data file (right).

You may have several index files addressing the same main file. For example, both sample name and observation number, using two separate index files, could index a file of scientific data. In Fig. 2.7, a second index file (**COMPANIES**) points to the same main file **PEOPLE**, but uses the company field as a key, and keeps the records ordered alphabetically by company.

Searches on an ordered index are performed using a "binary search," which locates a record (or the place that it should go if it is not in the file) with only $\log_2 n$ steps rather than n/2 (which is the average for a "brute force" or sequential search).

A binary search works by taking the occupied part of the file and dividing it by two, then comparing the desired key with the field in the middle record. If the key is larger, then the high half of the file is halved again. This process is repeated until the size of the remaining set of records is one. This remaining record must match the key, if the key is in the file; otherwise, it is the record *before* which the key would be inserted. For a file of 128 records, a binary search requires only seven comparisons, as compared with an average of 64 for a sequential search.

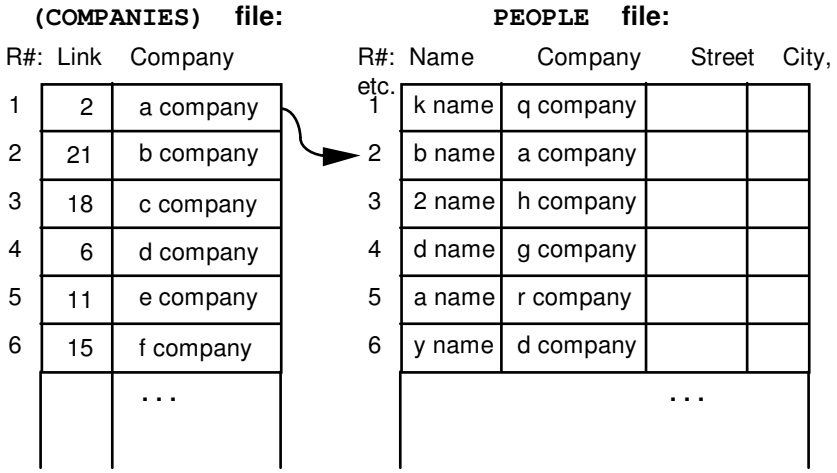


Fig. 2.7

Another index to the same main file shown in Fig. 2.6, this time using the company name as key.

An ordered index is a "dense file." That is, there are no gaps between active records. Therefore, **AVAILABLE** always reflects the number of records in the index file, and all records in the index file can be accessed with a **DO LOOP** with the knowledge that all records are active. With files maintained using **SLOT** and **SCRATCH**, you must check the **LINK** field (first four bytes of every record) to see whether each record is active.

2.6.1 Index File Records

At minimum, an ordered index file must contain the key and the link that associates the key with its main data record. The link is a 32-bit record number residing in the first two bytes of the record, and the key field immediately follows.

You can keep data other than keys in an index file and process this data in the same manner as data in other types of files. Such a technique should be avoided, however, if more than one user will have simultaneous access to the file, because record numbers may change due to insertion or deletion by other users.

The time required to search an index depends upon the length of each record as well as the number of records, because longer records will require more blocks to store the file, and hence more disk accesses to search it. Therefore, you should keep these records as small as possible.

The first four bytes of each record in an index file contain the link to the associated record in the main file. polyFORTH ISD-4 predefines this field as **LINK**. The phrase:

```
LINK L@
```

reads the link field of the currently selected record and returns it on the stack.

When creating the record description (Section 2.5.1) for an index file, you must skip over the **LINK** field by using the phrase **4 FILLER <name>** at the beginning of the layout, or by starting with a displacement of four rather than zero. For example:

```
0  4 FILLER LINK        ( Link to PEOPLE file)
   10 BYTES NICK        ( Last name key)
DROP
```

The key may be ASCII or binary. In order to make it possible to use binary integers as keys, as well as to speed up the search, the comparison made in the search routine compares *word-by-word*, rather than byte-by-byte. To accommodate this, you must make your key fields an even number of bytes in length. To allow the exchange of data with machines which use a byte order that would render the most significant byte the second one in a string, the operators **B@** and **B!** reverse bytes when fetching and storing from disk such that the data on disk is in a compatible order. The can be defeated by setting **REVERSE** to **FALSE**.

Be aware that the order of the records in the index file is subject to frequent change as a result of file insertion or deletion. Because the record number of an index record may change, it should not be used directly for any purpose.

You must also take special care when sharing ordered files. We suggest you limit the index file to keys, and keep all other data in an associated main file record. Otherwise, a task may be pointing at a current record in an index, but before it accesses the data in the record the index record changes position.

2.6.2 Ordered File Maintenance

An "ordered index" file in polyFORTH is one in which the keys are maintained in ascending ASCII sequence. For instance, an index to a file of records of people might be ordered by last names.

An ordered file allows quick searching on key fields. For instance, given a name, we can search the index file looking for a match. From the index record where the match was found, we can obtain the link to the main file.

2.6.2.1 SEARCHING AN ORDERED INDEX

In polyFORTH, this routine is called **BINARY** (named because it performs a binary search). Here's how it works:

As we've seen (Section 2.5.5), field names return the address of the field in the "image" of the record in working storage. **BINARY** expects to find the match criteria for the desired field in this image (Fig. 2.8).

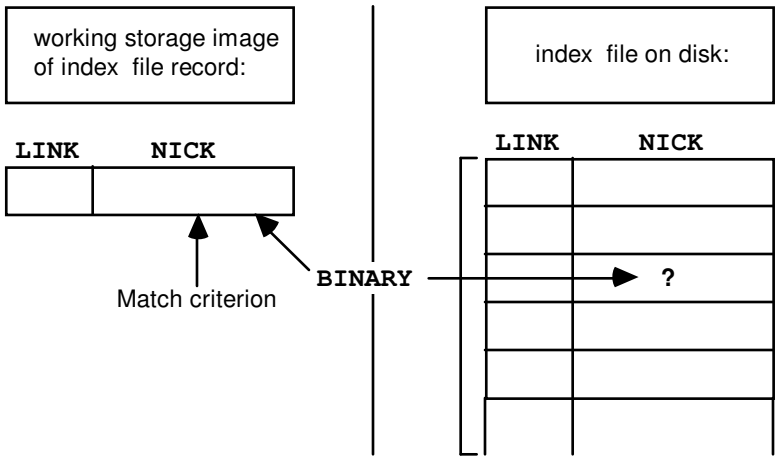


Fig. 2.8

BINARY searches the ordered index for a match to the key in working storage. It returns the content of the **LINK** field of the matching record, and aborts if there is no match.

Make sure that you have allocated enough room in working storage for all tasks (including the printer task) to hold the image of any record on which you use this technique (Section 2.1.6).

For instance, suppose we want to take a name from the input stream, then search for it in the **NICK** (short for "nickname") field of our **(NAMES)** file. The phrase:

```
1 TEXT  nickname NICK S!
```

captures the name from the input stream and stores it into the image of the **NICK** field in working storage.

Now we use **BINARY** to search the index file for this name, first ensuring that the index file is current. **BINARY** expects on the stack the arguments returned by a **BYTES** field:

```
(NAMES)  NICK BINARY
```

Here's what **BINARY** does:

Word	Stack	Action
BINARY	(n a - n)	Searches the current file looking for a match between the criteria in working storage and the given field in the data. Issues a system abort if it cannot find the record requested. On the stack is the record number of associated record in the main field (that is, the contents of the link field of the matching index record). The matching index record number is in **R#**.

(A related word, **-BINARY**, is discussed in Section 2.6.2.2.)

REFERENCES

Access to the record image in working storage, Section 2.5.5
Binary search principles, Section 2.6
R#, Section 2.4.1

TEXT, Section 2.3.6.3
Working Storage, Section 2.1.4

2.6.2.2 INSERTING A RECORD IN AN ORDERED INDEX

Inserting a new record in an ordered file involves two steps. First, we must determine the location in the index file for a new key to be inserted. This ensures that the index file will always be properly "sorted."

Second, we must be able to insert the new key into the file at the appropriate place, moving all subsequent records one notch down in the file.

Using the example in Fig. 2.6, let's consider what must happen when we add a new person to our database. First, must insert a new index record into the **(NAMES)** file in the appropriate place, and then allocate a new record in the **PEOPLE** file for the data itself. Finally, we must point the **LINK** field in the index record to the data record in the main file.

We've already seen in Section 2.4.3 that the word **SLOT** is used to allocate new records in data files. Adding a record to the index file is more complicated, because we must insert the new record at the appropriate place to keep the keys ordered. For this purpose, we use the words **–BINARY** and **+ORDERED**.

Word	Stack	Action
–BINARY	(n a - t)	Searches the current file looking for a match between the criteria in working storage and the given field in the data. A zero result ('false') means that a match was found; a non-zero flag means that no record in the file contains the indicated key. On exit, if a match is found **R#** contains the number of the first matching index file record; otherwise **R#** contains the number of the index record before which an insertion will be made. Pronounced "not-binary," because it returns 'true' if a match is not found.
+ORDERED	(-)	Inserts the record whose image is in working storage into the current record in an ordered index. Subsequent records in the index file are advanced one position relative to the start of the file.

–BINARY expects the same conditions as **BINARY** (Section 2.6.2.1):

1. The current file is the ordered index to be searched.
2. The match criterion is in the key field in working storage.
3. The arguments produced by a **BYTES** field name are on the stack.

+ORDERED expects the following conditions:

1. The current file is the index to be modified.
2. The record before which the insertion is to take place has been previously selected by **–BINARY**.
3. The key and **LINK** fields to be inserted are in their respective fields in working storage.

Using our example, then, the standard procedure is:

```
1 TEXT              (scan the input stream for the name)
NICK S!             (store it into the image of NICK)
NICK -BINARY        (search the index file, using the NICK field as the key)
IF                  (no match:)
  SAVE PEOPLE SLOT RESTORE        ( obtain available record number in
                                    main file)
  LINK !            (store the record number into working storage)
  +ORDERED          (insert the new index record)
ELSE                (duplicate entry)
  ORDERED RELEASE
  1 ABORT" Already in file "
THEN  ...
```

Because your code must provide the location into which the insertion will take place (using **-BINARY**), you have the option of determining how to handle duplicate keys if **-BINARY** returns a false (zero) indication. This is normally handled as an abort condition, as shown above.

During execution of the **-BINARY ... +ORDERED** sequence, the index file should not be accessed by any other task, since the record numbers of all records following the insertion point are changing.

To prevent conflicts, the Data Base Support package includes a facility management variable called **ORDERED**. **-BINARY** issues an **ORDERED GET**. This phrase protects the file from being accessed by other tasks on the system until the current task releases it. In this way, file integrity is maintained. **+ORDERED** issues an **ORDERED RELEASE**. If you exit from the operation in any other way, you must do this yourself. The intent is for the task that performed the search to retain control of the file from the moment when the insertion point has been found until the expected insertion has taken place, or until it has decided not to do one.

The word **BINARY** also performs an **ORDERED GET**, so that searches cannot be performed while another task is using this facility. **BINARY** performs an **ORDERED RELEASE** immediately after the search, however, so it "holds" the facility only during the period of the search itself.

REFERENCES

Binary Searches, Section 2.6.2.1
Facility Variables (**GET** and **RELEASE**), Section 4.7
SAVE and **RESTORE**, Section 2.4.2
TEXT, Section 2.3.6.3

2.6.2.3 DELETING A RECORD FROM AN ORDERED INDEX

-ORDERED is used to delete a record from an index file. It may only be issued immediately after the record has been selected (normally by a prior use of **BINARY**).

Word	Stack	Action
-ORDERED	( )	Deletes the current record (**R#**) from an ordered index which is the current file. Subsequent records move back one position, relative to the start of the file.

Because the record that until now followed it will occupy the actual space that was occupied by the deleted record, the record is completely obliterated by this operation (unlike **SCRATCH**, which only changes the first two bytes of the record).

Here is an example using **-ORDERED**.

1 TEXT	(scan the input stream for the name)
NICK S!	(store it into the image of **NICK**)
NICK BINARY	(search the index file, using the **NICK** field as the key; return main file record number)
ORDERED GRAB	(regain control of **ORDERED**, which **BINARY** released)
-ORDERED	(delete the index record)
PEOPLE SCRATCH	(de-allocate the record in the main file whose number is on the stack from **BINARY**.)

In this example we had to **GRAB** the facility variable **ORDERED** to prevent another task from accessing the file during the moving of records that will occur during the **-ORDERED** operation. **GRAB** is used instead of **GET** because **GET** releases the CPU so other tasks can run (and potentially alter the file). **-ORDERED** performs an **ORDERED RELEASE** when it is finished.

REFERENCES

Binary Searches, Section 2.6.2.
Facility variables (**GRAB**, **GET**, and **RELEASE**), Section 4.7
SCRATCH, Section 2.4.3

2.6.3 An Example — A Simple Mailing List

The following pages show an example of a simple mailing list application. It demonstrates the use of an ordered index to provide easy access into a file based on a key, such as last name and first initial, and a report, which is in alphabetic order based on that key.

This application is a good example of the layout of a Data Base application, with a "help screen" at the top, followed by the relevant file definitions. The help screen may be displayed any time by the command **HELP**.

```
INCLUDE Tools/File/File.fth  FALSE REVERSE !  BIG-ENDIAN

: Help ( -- )
      CR ." HELP          Display these PERSONNEL instructions."
      CR ." enter name    Enter a new person into the file with"
      CR ."                   access key of 'name'."
      CR
```

```
      CR ." remove name   Delete 'name' from the data base."
      CR
      CR ." fix name      Enter new information replacing all"
      CR ."                   current data for 'name'."
      CR
      CR ." see name      Display a person whose key is 'name'."
      CR
      CR ." s             Display current person."
      CR
      CR ." all           Display all records in the file."
      CR ;

FILE Personnel.dbf   FILE= Tools/File/Personnel.dbf

( Bytes  records   origin           name   )
    16      300         0 BLOCK-DATA (PERSONNEL)
   128      300  +ORIGIN BLOCK-DATA  PERSONNEL

\ The record layout for both the PERSONNEL and (PERSONNEL)
\    files.  The LINK is predefined, and subsequent
\    fields are offset from the previous 4 fields.
\    For example, the NICK name is 14 bytes long
\    starting in the 5th byte.

\ ZIP  is a 32-bit number, as is PHONE.

\ AREA  code is single precision.

  4 ( LINK)
 12 BYTES NICK     ( Nickname, used as the key.)
 32 BYTES NAME     ( Full name, first name first.)
 32 BYTES STREET   ( Street addr. or PO Box, etc.)
 32 BYTES CITY
    LONG ZIP       ( Note:  can only handle US zips)
    NUMERIC AREA
    LONG PHONE

\ The offset for the field types is carried on the
\    stack so that it may be either displayed or
\    dropped at the end of the load.  We use it in
\    this case to display the record size.

CR .( Main file: ) .  .( Bytes )

( Data storage)

\ PERSON  parses the input stream following it for the
\    NICK field.  It leaves us pointing at the NICK
\    field in the (PERSONNEL) file.

: PERSON ( - n a)   1 TEXT  NICK S!  (PERSONNEL) NICK ;

\ DIGITS  Prompts the terminal for input and converts
\    it to binary on the stack.
```

```
: DIGITS ( - n)   QUERY  32 WORD COUNT  0 0 2SWAP
      BEGIN  >NUMBER  DUP
      WHILE  1 /STRING
      REPEAT  2DROP DROP ;

\ !LABEL  Prompts for each field in order.

: !LABEL   CR ." Name: "   NAME ASK
    CR   ." Street: "   STREET ASK
    CR   ." City, State: "   CITY ASK
    CR   ." Zip: "   DIGITS ZIP L!
    CR   ." Area: "   DIGITS AREA N!
         ." Phone: "   DIGITS PHONE L! ;

( Record management)

\ enter  creates a new entry for the person whose
\    nickname follows in the input stream, prompting
\    for entry of additional data. If there is already
\    an entry for that nickname, an error message is
\    issued.  In either case, the record remains the
\    current one for future editing.

: enter   PERSON -BINARY IF  SAVE  PERSONNEL SLOT DUP
      READ  NICK S@ NICK B!  RESTORE  DUP LINK !
      +ORDERED  PERSONNEL READ !LABEL
      ELSE  ORDERED RELEASE  ABORT" Already known "
   THEN ;

\ fix  accepts new data for the pre-existing entry
\    whose nickname follows in the input stream.

: fix   PERSON BINARY  PERSONNEL READ !LABEL ;

\ remove  deletes the person whose nickname follows
\   from the data base.

: remove   PERSON  BINARY -ORDERED  PERSONNEL SCRATCH ;

( Data Display)

\ .PHONE  displays the AREA and PHONE numbers as one
\    would expect to see them.

: .PHONE   AREA N@ 0  <# 41 HOLD # # #  40 HOLD #>
   TYPE SPACE  PHONE L@ 0 <# # # # #  45 HOLD ( -)
   # # # #> TYPE ;

\ .ZIP  forces the zip code to be displayed in
\    nnnnn format.

: .ZIP   ZIP L@ 0 <# # # # # # #>  TYPE ;
```

```
\ n .PERSON  displays the data from the nth record in
\    the PERSONNEL data file.

: .PERSON ( n)   PERSONNEL READ  CR  NAME B?  5 SPACES
   ." (" SPACE   NICK B?  ." )"  CR   STREET B?
   CR  CITY B? CR   .ZIP  10 SPACES  .PHONE  SPACE ;

\ see  Parses the input stream and displays the proper
\    record.  s does the same thing using R#
\    (the current record).

: see   PERSON BINARY  .PERSON ;

: s   R# @ .PERSON ;

\ all  uses the RECORDS word which returns the
\    initial value and number of records+1 in the
\    data file.  The loop counter is used to access
\    each record in the ordered index (PERSONNEL),
\    where the LINK field points to the data in the
\    PERSONNEL file.

: all   (PERSONNEL) RECORDS DO  I (PERSONNEL) READ
   LINK L@ .PERSON  CR  LOOP  SPACE ;

0 [IF] \ Here is a sample of the output of all:

Andrews, Carl      ( Carl )
1432 Morriston Ave.
Parkerville, PA
17214          (717) 555-9853

Cook, Dottie      ( Dot )
154 Sweet Rd.
Grand Prairie, TX
75050          (214) 642-0011

Chapel, Doug      ( Doug )
75 Fleetwood Dr.
Rockville, MD
20852          (301) 777-1259

Boehning, Greg      ( Greg )
POB 41256
Santa Cruz, CA
95061          (408) 666-7891

[THEN]
```

2.6.4 Hierarchical Ordered Files

polyFORTH's ordered indexes have the property than whenever a record is inserted or deleted all records following the point at which the action occurs are physically moved to

accommodate the change. Although this form of maintenance is somewhat slower than maintaining order by updating chains or pointers (as some data bases do) it is substantially more reliable.

The assumption is that in most applications an index is searched frequently, and insertions and deletions occur relatively infrequently. As a result, we have optimized search time and reliability above maintenance time.

The actual time an insertion or deletion will take depends upon the position in the file at which the action occurs (if it is near the beginning of the file more records must be moved), the number of records in the file, and the size of each index record. In practice, indexes of several thousand records may be maintained on a hard disk without unacceptable delays.

Some applications, however, involve tens of thousands of records that must be searched and maintained in order. In order to deal with such applications, the recommended approach is to divide the total index into several sub-indexes, each of which will be a manageable size. For example, a company with 40,000 employees might separate them into departments. The department code can index a table in memory giving the appropriate origin block number for the index of employees in each department. This block number may be put into the ORG field of the FDA of a private copy of a generic file definition for the index. Or, the first letter of the employee's last name may be used to select one of 26 indexes.

Such a multi-layered approach is called a *hierarchy*. If you are designing a hierarchical file structure, the important considerations include keeping the decision-making process simple and independent of any frequently changing conditions. If possible, try to base the initial choice on something that can be evaluated without need for a special file search. Above all, you should avoid keeping record numbers of records in an ordered index in a higher-level index, as ordered index record numbers are subject to change.

REFERENCES

File Definition Areas, Section 2.3.2

2.7 CHAINING

Chaining is the linkage of one record to another, whether in the same or a different file. Generally, chaining is appropriate when an unknown amount of data must be associated with a piece of information.

There are as many ways to chain records as there are varieties of applications. In this section, we'll cover most of the situations that require chaining, and present general solutions to each case.

2.7.1 Chaining Techniques

Before you begin coding, make sure that you study the exact requirements carefully. Reviewing this section for considerations will be helpful.

Here are some design considerations to take into account:

1. Will the chaining occur within the same file, or to an auxiliary file?

2. Must there always be at least one auxiliary record chained to a main record, or may a main record have no auxiliary records?

3. When you traverse the chain, should it be in the order in which its elements were added (first-in, first-out), or in reverse (last-in, first-out), or should the chain be maintained in order by a key (such as date and time)?

Let's explore these issues one by one.

In some applications, it is possible to chain records within a single file. Naturally, this is easier than chaining to another file.

For example, suppose that we have a file of customer names and addresses. Some of our customers have several addresses: one for invoicing, one for shipping, and so on. Because multiple addresses are the exception, not the rule, and because address fields are large, we'd prefer not to allow room for multiple address fields within each customer record.

So, we use chaining instead. At this point, we must examine how much information each auxiliary record must contain. It turns out that each auxiliary record must contain almost as much information as the main record. If we create a separate file for the auxiliary records, each record would need to be nearly as large as a record in the main file. If there is relatively little in the main record (the one all customers have) beyond the primary address, you may as well use additional records in the same file to contain additional addresses. As Fig. 2.9 shows, this approach lets us re-use the field layout structure that we created for the main file records, even though there are some fields in the primary record that we don't use in the auxiliary records.

For another example of chaining within a single file, we turn to the **`Glossary`** application included with polyFORTH ISD-4 (see Section 2.10). This application lets you enter descriptions of the commands in your applications and produces alphabetized glossaries.

For each word that you enter into the system, the **`Glossary`** saves its name, vocabulary, stack effects (before and after) as text strings, the source block, the date this entry was created or updated, plus as many lines of descriptive text as you care to include.

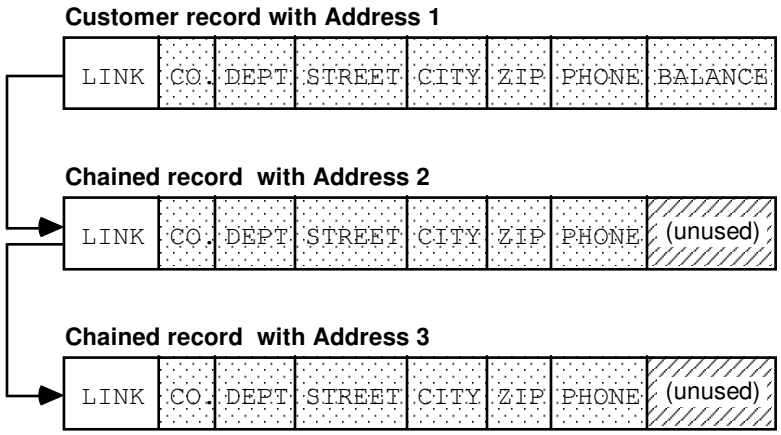


Fig. 2.9

Example of a chain with all records in the same file.

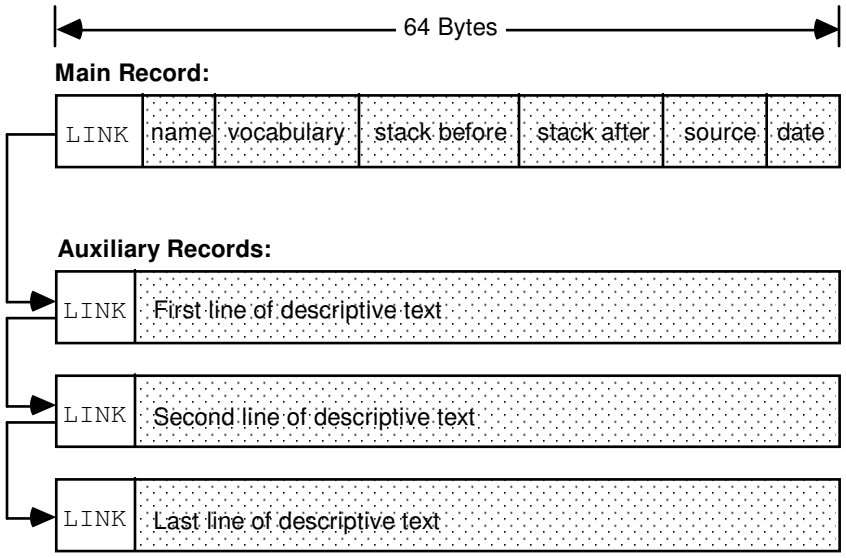


Fig. 2.10

Record chaining in the polyFORTH **`Glossary`** utility.

Fig. 2.10 shows the record structure for the **`Glossary`**. All data except the text is stored in the main record for each command. This record points to an auxiliary record that contains the text description. This record may in turn point to a second text record, and so on. A separate index file contains the alphabetized keys that point to main records in this file.

Although the main records and auxiliary records share *no* fields in common (except **`LINK`**), they are the same size. Thus it is most efficient to keep both types of records in the same file.

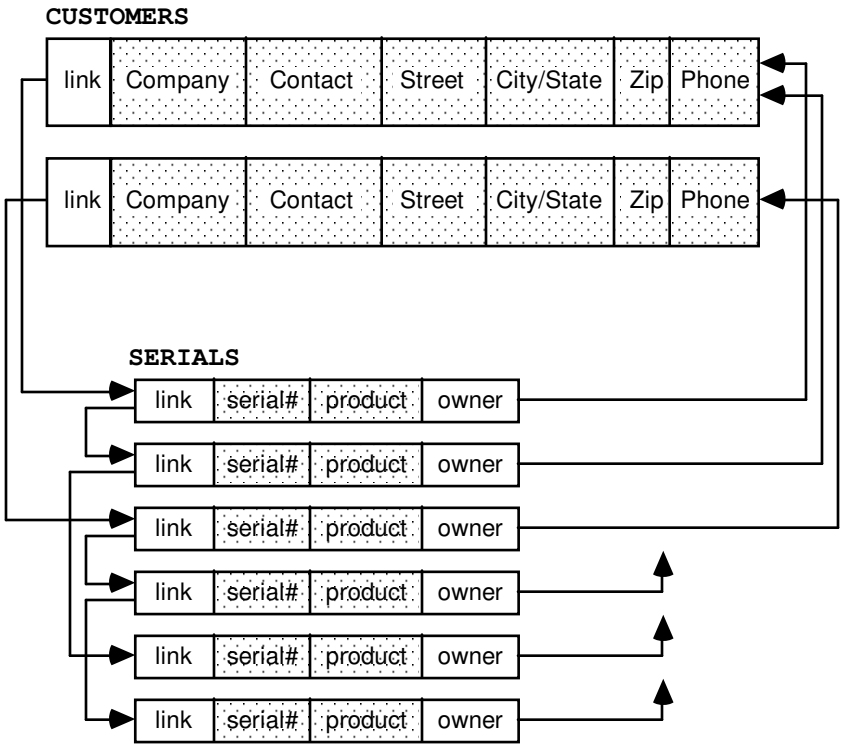


Fig. 2.11

A variable number of serial number records for products purchased by each customer. Note that each serial number record contains a pointer back to the "owner" record. This is important for maintaining file integrity.

A third example illustrates the opposite situation. Suppose we have a list of customers who have purchased our products. For each customer, we also have a list of the serial numbers of the units they received. For some customers, there are no serial numbers; for others, as many as twenty.

You can see in Fig. 2.11 that a serial number record takes much less space than a customer record. Because of this size variance, it's better to create two separate files, one called **CUSTOMERS** and the other **SERIALS**. Each main record in the **CUSTOMERS** file may chain to one or a series of records in the **SERIALS** file. A record in **CUSTOMERS** can also contain an empty link, which would be represented by a value of -1 in the **LINK** field. A -1 **LINK** also identifies the last serial number for a particular customer.

This last example raises the second consideration: whether the application must be able to handle the case of no auxiliary records, or whether the minimum number of auxiliary records attached to a main record must be one.

In the first case, when a main record is created, its link can be left alone (-1) and no auxiliary record need be **SLOT**ted. However, the routine that appends a new auxiliary record to the chain must check whether it is linking from the main record or an auxiliary record.

In the second case, when a main record is created, an auxiliary record must also be slotted, and its number saved in the main record's pointer. Furthermore, the routines for advancing through the chain will differ, as we'll see in the next section.

A third consideration is whether chaining must be last-in, last-out; last-in, first-out; or both. In the case of the **Glossary** described earlier, obviously chaining must be first-in, first-out. In such cases, the process of adding a new record to the chain involves:

1. Finding the end of the existing chain;

2. Allocating a new record;

3. Setting the link in the last record of the existing chain to point to the new record.

An example of the opposite situation is a bookkeeping database in which each customer record chains to a series of auxiliary records containing transactions. Because we are almost always more interested in recent transactions than ancient ones, we chain in a last-in, first-out manner. In this case, the process of adding a new record to the chain involves:

1. Allocating a new auxiliary record;

2. Setting the main record to point to it;

3. Placing the main record's previous link number into the link field of the new record.

If the application demands that both directions of chain-following be allowed, then each auxiliary record must contain two link fields: one to the next record in the chain, and one to the previous.

Each chained record should contain a pointer back to the record that is the head of the chain (which may or may not be in the same file as the chain). Some applications use this directly. For instance, suppose in our serial number example we keep an ordered index file using the serial number itself as the key. If records in **SERIALS** contain a pointer to the owner of the chain as shown in Fig. 2.11, then by entering a serial number the user can see which customer has received that instrument.

The most important reason for including a pointer to the owner, even if the application doesn't otherwise demand it, is for ensuring integrity of the data. If through some mischance of hardware failure a link in the main file becomes lost, the chains can be reconstructed and attached to the main records.

2.7.2 Chaining Commands

As we have seen in the previous section, the choice of chaining techniques depends on application needs and on performance tradeoffs. Rather than attempt to decide for you, the developers of polyFORTH ISD-4 provide a collection of commonly used chaining tools. You may leave them as is, or you may modify them. The table below gives the general set of commands in the chaining toolbox. Some words appear more than once; this is because several implementations may be useful, depending on how you've

answered the design questions in Section 2.7.1. The version shipped with the system is marked with an (*). The others are minor variants; code for some of the alternate versions is given elsewhere in this chapter.

Word	Stack	Action
HEAD	(-- a)	A user variable that points to the first record (head) of the current chain.
LINK	(-- a)	A pre-defined field (the first four bytes of any record) which may be used for chaining. This same field is used in ordered index records to link to the main file records.
FIRST	( )	(*) **READ**s the **HEAD** record in the chain. This version is used in applications in which there is always at least one auxiliary record and all are within the same file.
FIRST	(-- t)	Returns a flag indicating whether the main record is chained to any auxiliary records, and if it is, **READ**s the record. This version is used in applications in which the **HEAD** record may have no auxiliary records, and when auxiliary records are in a different file.
-NEXT	(-- t)	(*) Reads the next record, assuming that the chain is linked through the field called **LINK**. Returns 'true' if there is *not* a next record in the chain. Pronounced "not-next."
-NEXT	(-- r/0)	Alternate version of **-NEXT**; returns the record number of the next record in the chain, if any, 0 ('false') otherwise. Does not read the record.
-LOCATE	(n - t)	Searches the chain, starting from **HEAD**, for the nth record, returning true if the chain isn't that long. Otherwise, it returns false, having left **R#** pointing to the specified record.
CHAIN	(n)	Inserts a new record at the nth position. If *n* is larger than the length of the chain, inserts the new record at the end. Alternate versions might take no argument and chain at the beginning (last-in, first-out), end (first-in, first-out) or according to a key.
UNCHAIN	(n)	Removes the nth record from the chain.
SNATCH	(a r - r)	Given a field address and record number, fetches the record number from that field and replaces it with the record number given. It is used to update chains.

The arguments for **-LOCATE**, **CHAIN**, and **UNCHAIN** count from zero, where zero is the first record in the chain, and count sequentially down the chain. An argument of -1 is conventionally used to specify the end of the chain (since you don't necessarily know how long the chain is).

The standard versions of **FIRST** and **-NEXT** assume there is always at least one record in the chain, and it's also the **HEAD** record (i.e., it will be subject to the same processing as the others). The chain may be processed in a **BEGIN ... UNTIL** loop:

```
FIRST BEGIN ... -NEXT UNTIL ...
```

The alternate versions allow for the possibility that there are no auxiliary chains, and are optimized for a **BEGIN ... WHILE ... REPEAT** loop:

```
FIRST BEGIN  ?DUP WHILE  READ ...
   NEXT REPEAT ...
```

If you have only one set of chained records and the top of the chain is in a different file from the members, you may incorporate the selection of the file in the words **FIRST**, etc. If you have several sets, you will need to select the file externally. Still another set of variations might allow for the fact that you have more than one chain attached to your main file, and therefore not all chains start with the **LINK** in the main file record.

Moreover, there may even be multiple chains through the auxiliary records. In these cases, you would remove the references to **LINK** in these words and specify the field externally.

The intent here is to present a design concept that has worked in many applications, but which presumes that you will tailor a basic vocabulary to your specific application needs—a practice that is consistent with the overall design of Forth in general. Assuming you are adding custom versions of the chaining words for your application, don't forget to remove from the **FILES** load block the reference to the standard ones.

REFERENCES

BEGIN ... UNTIL, Section 2.4.2
BEGIN ... WHILE ... REPEAT, Section 2.4.3
FILES Load Block, Section 2.1.5

2.7.3 Application Examples

This section offers coded solutions to two application problems.

We introduced the **Glossary** program, which is included with your polyFORTH system, in Section 2.7.1. The use of this utility is more thoroughly documented in Section 2.10.

The word **(SHOW)** includes this sequence:

```
...                    ( display data from the main record)
BEGIN +L  -NEXT 0= WHILE
   10 SPACES  PHRASE B?
REPEAT ;
```

The word **+L** is similar to **CR**; see Section 2.8.4.

The word **(SHOW)** displays all information about a command. The code fragment shown above displays the list of description lines for the command. When it begins, the main record is still current.

As we saw in Section 2.7.1, the main record's link field points to the first descriptive record, if there is one, which resides in the same file. When the loop begins, **-NEXT** determines whether the main record is linked to an auxiliary record. If not, the loop ends and nothing is displayed. If so, the **WHILE** portion is executed, which displays the first line of text and repeats the loop. Now **-NEXT** indicates whether there is another auxiliary record.

When the last record is reached, **-NEXT** indicates this and the loop ends.

The word **?LINES** is defined as:

```
: ?LINES   1 BEGIN 1+  -NEXT UNTIL  ?PAGE ;
```

The purpose of **?LINES** is to determine whether the current command's description will fit entirely on the page, or whether it is necessary to advance the page first to keep all of its lines together. The loop counts the number of lines (the head plus an unknown number of auxiliary records, at one line each). The word **?PAGE**, introduced in Section 2.8.4, takes an argument from the stack, starting a new page if that many lines will not fit on the current page.

Here is a definition using **SNATCH**:

```
: DELETE ( r#)   ...   BEGIN READ
   LINK 0 SNATCH  DUP 0< UNTIL  DROP ;
```

The part of **DELETE** shown here removes both the main record and all auxiliary records chained to it. The code begins on the main record. The phrase **LINK 0 SNATCH** fetches the record's link field, and then replaces it with zero. This has the effect of "scratching" the record, but also provides a pointer to the next record to scratch.

The phrase **DUP 0<** tests whether the pointer indicates that the record just scratched was the last in the chain. If so, the loop ends; otherwise, it reads the next record, and so on.

You may also wish to study the definitions of **T**, **P**, and **U**, which use **–LOCATE**, **CHAIN**, and **UNCHAIN** in straightforward ways.

Our second coding example is another that we introduced earlier in this section: the customer file and associated serial numbers. Here we will present two versions of the application. The first, in Fig. 2.12, uses the versions of **FIRST**, **–NEXT**, and **–LOCATE** that are provided with your polyFORTH system.

In the first block we've defined the record structures for the two files. In the second block, we have words for entering new customers and serial numbers. The word **add** makes use of chaining.

As we saw in our earlier discussion of this application, it is legitimate for a **CUSTOMERS** record to have no serial number attached to it. In this case, the **CUSTOMERS** record will contain –1 in its **LINK** field. If auxiliary records are chained, they will reside in a separate file called **SERIALS**.

The process of adding a new serial-number record is not as simple as it would be if all records were contained in the same file. Here, add must make a decision. If there is no chaining yet, it must go to the **SERIALS** file and use **SLOT** to allocate a record.

Since this is the first record in the chain, it must also store this in the main record's **LINK** field. But if a chain has already been started, it will go to **SERIALS** and use **CHAIN** to add a new record.
The problem is that we cannot use **CHAIN** unless a chain exists already. If all records existed in the same file, then the main record would be the first record in the chain; and we could simply use **CHAIN** in all cases. We would not need a conditional. Or, even if

records existed in separate files, but a minimum of one auxiliary record was always present, we could use **CHAIN** and avoid the conditional.

The phrase **-1 CHAIN** is a cliché that means "attach a new record onto the end of the chain." The -1 serves as a number that never gets reached, and **CHAIN** is defined so that if it never reaches n it adds the new record to the end of the chain.

```
FILE Customers.dbf   FILE= Tools/File/Customers.dbf

70 500       0 BLOCK-DATA CUSTOMERS
46 500 +ORIGIN BLOCK-DATA SERIALS

( Customers and Serial Numbers)

( CUSTOMERS records:)

0  4 FILLER LINK  ( LINK to 1st serial#)
   20 BYTES COMPANY
   16 BYTES CONTACT
   30 BYTES STREET
DROP

( SERIALS records:)

0  4 FILLER LINK  ( LINK to next serial#)
   10 BYTES SERIAL#
    NUMERIC PRODUCT  ( product code)
    NUMERIC OWNER  ( link to owner CUSTOMERS record)
DROP

( Customer/serial number file)

: edit   CR  ." Company name? "  COMPANY ASK
   CR  ." Contact? "  CONTACT ASK
   CR  ." Address? "  STREET ASK ;

: new   CUSTOMERS  SLOT DUP . READ  edit ;

( Assumes a serial# chain linked thru HEAD)

: (add)   CR  ." Serial# ? "   SERIAL# ASK ;

: add   SAVE  LINK L@ DUP 0< IF  ( empty chain) DROP
         SAVE  SERIALS SLOT  RESTORE
         DUP LINK L!  SERIALS READ
      ELSE  HEAD !  SERIALS -1 CHAIN ( add at end)
  THEN (add)  RESTORE ;

: edit ( n)   SAVE SERIALS  1- -LOCATE ABORT" Can't"
   CR  Serial# B?  (add)  RESTORE ;

( Customer/serial number display)
```

```
: .company   COMPANY B?  CONTACT B?  STREET B? ;

: .companies   CUSTOMERS  RECORDS DO
     CR  I .  I READ  .company  LOOP ;


: .serials   0  SERIALS  FIRST BEGIN
  CR 1+ DUP .  Serial# B?  -NEXT UNTIL  DROP ;

: all-serials   LINK L@  0>  IF
   LINK L@  HEAD !  SAVE  .serials  RESTORE  THEN ;

: show ( n)   CUSTOMERS READ  CR .company  all-serials ;

\ Usage:
\ To enter a new customer:  new  then  add  as needed.
\ To edit an old one:  n show  then  add  or  n edit .
```

Fig. 2.12

An application example using the standard polyFORTH chaining operators.

The word **edit** may be used to change an existing serial number. From its purpose we can assume that a chain exists, and therefore it doesn't have to check the main record's **LINK** to make sure it points to a valid auxiliary record. It simply goes to the **SERIALS** file and uses **-LOCATE** to make the desired record current (aborting if the argument is not valid and **-LOCATE** terminates before reaching it). Then it displays the current contents of the field and lets the user re-enter it. Finally it restores the file pointers to the main file.

In the next block, the word **serials** displays the current company data, followed by a list of all associated serial numbers. Again, since there may be no chain at all, serial must make a decision. The test **LINK L@ 0>** returns 'true' if the link is positive (that is, not -1 or 0), indicating the first record in the chain. In this event, **serials** saves this link in the variable **HEAD**, selects the **SERIALS** file, and invokes **.serials** which uses **FIRST** and **-NEXT** to loop through all records in the chain.

To give you an idea of some of the many possibilities, we've coded the same application using different versions of the words **FIRST**, **NEXT**, and **-LOCATE**. While these definitions themselves are more complicated, they reduce the complexity of the application words that use them. These versions are sensitive to the possibility that a main record may not have any auxiliary records attached to it.

Here are the re-definitions, followed by the new versions of the affected application commands:

```
: VALID ( n - t)   0 OVER < DUP  IF
   SWAP READ  ELSE  SWAP DROP  THEN ;

: FIRST ( - t)   HEAD @ VALID ;

: NEXT ( - t)   LINK L@ VALID ;
```

```
: -LOCATE ( n - t)   FIRST IF BEGIN  DUP WHILE
      1-  NEXT 0= IF  DROP -1 EXIT  THEN
   REPEAT  ELSE DROP -1 THEN ;

: add   LINK L@ HEAD !  SAVE  SERIALS
   FIRST IF  -1 CHAIN  ELSE ( no chain)
      SLOT DUP RESTORE  LINK L!  SAVE
      SERIALS READ  THEN
   (add)  RESTORE ;

: all-serials   LINK L@ HEAD !  SAVE  0
   SERIALS  FIRST BEGIN  WHILE  CR  1+ DUP .
      SERIAL# B?  NEXT REPEAT  RESTORE  DROP ;
```

In the first block, **FIRST** returns a flag that is true if a chain exists at all. If so, the first record in the chain is made current. The word **NEXT** returns a flag that is true if another record exists in the chain. If so, that record is made current.

As you can see, both words make use of the same code, which we have factored into the definition called **VALID**.

We have also re-coded **-LOCATE** in this block. As usual, **-LOCATE** returns a "true" flag if the requested element of the chain cannot be found. In this version, it also returns a "true" flag if no chain exists.

These changes simplify our application definitions. **add** still has to make a decision, but it uses **FIRST** for the test.

Because of the way we have rewritten **FIRST**, **serials** no longer needs an **IF** statement at all. The only conditional is **WHILE**, which gets its argument the first time around from **FIRST**, and henceforth from **NEXT**. Thus, if a first record is absent, the **WHILE** phrase never gets executed. We eliminated the need for a subordinate word **.serials** completely.

REFERENCES

Data Base Design, Section 2.9

2.8 REPORT GENERATOR

The polyFORTH Report Generator is a set of words that assist you in the preparation of formatted output reports. Once you have specified the page format and column headings, and indicated the layout of a single record as a row of data, the Report Generator performs all required output formatting and also controls paging, the heading of each page and related operations.

An optional feature of the Report Generator allows subtotals and grand totals to be accumulated in a simple manner; these totals can then be printed on a separate line with a minimum of effort.

The following example will serve as a quick introduction to the Report Generator. It assumes the fields defined in the example in Section 2.1. Here is the code:

```
: .person   NAME ?B  STREET ?B  CITY ?B
   STATE ?B   ZIP ?B ;

[R                    People\Name          \Address
\City         \St.\Zip ]
   CONSTANT PEOPLE-TITLE

: all   PEOPLE-TITLE LAYOUT  +L
      PEOPLE RECORDS DO  I READ  .person
   +L  LOOP ;
```

This produces:

```
Page 1  05/12/2005
                  People
Name           Address             City          St. Zip

Andrews, Carl  1432 Morriston Ave. Parkerville   PA  17214
Boehning, Greg POB 41256           Santa Cruz    CA  95061
Chapel, Doug   75 Fleetwood Dr.    Rockville     MD  20852
Cook, Dottie   154 Sweet Rd.       Grand Prairie TX  75050
```

In the example above, the word **.person** is defined similarly to the version given in Section 2.1, except that the field reference operator **?B** is used instead of **B?**. **?B** is the Report Generator version of **B?**, and takes the same stack arguments. The difference is that it performs "tabbing" based on a table of columns created by the word **[R** (third line of example). Section 2.8.3 lists all the output operators that use this table.

The word **[R** specifies both a title (the word "People," centered) and the column headings (the row of labels above each column). It also creates the column table mentioned above, leaving this address on the stack. Note that the line is shown wrapping to the next line here, but that it must be on the same line in the source code. See Section 2.8.2 for more on **[R**.

The final word, **all** prints the tabulated report. It begins by invoking **LITERAL** so that the address passed from **[R** will become part of this definition, then calls **LAYOUT**, which consumes this address.

+L (short for "plus-line") forces an extra carriage return into the report above the first row of data. Next, **PEOPLE** guarantees that the **PEOPLE** file is current whenever we display this report. **RECORDS** supplies the appropriate arguments for **DO**. Each time through the loop, the next record is made current with **READ**, and the row is displayed with **.people**. Then, **+L** forces a new-line.

The report also contains a page banner, which includes some text at the upper-left hand corner of the page and the page number and date in the upper right. These are formatted automatically by **LAYOUT**, but are user-configurable.

REFERENCES

Controlling Paging, Section 2.8.4
Page Banner, Section 2.8.5

2.8.1 Specifying a Title/Column-Heading Pair

A single word, **[R**, lets you specify both the title and the column headings. The set-up phrase usually appears just preceding the definition of the report for which they are designed.

The format for a title/column heading pair is:

```
[R title-text \column-heading-text ]
```

The entire title/heading pair statement must not extend over multiple lines.

All characters up to the backslash, except the first blank that follows **[R**, are used for the title text.

All characters that follow the first ****, ending with the delimiter **]**, are used for the heading. The first character (blank or non-blank) that follows the first **** corresponds to the first column of the report page. The following backslashes determine where the actual column positions are located.

In addition to being saved in the dictionary, the heading text is parsed at the time the sourcce that contains the heading is loaded, to produce a table of column widths and locations of the text to be displayed. This table is used by the set of words that output the contents of fields for the Report Generator; this word set includes: **?B**, **?N**, and **?1**. Thus, each column "knows" where it should appear on the page and how wide it should be.

When displaying **BYTES** fields, it is necessary to ensure that the width of the heading text for that field matches the width of the storage field, plus a few extra spaces as desired for column separation. Any fewer spaces, or significantly more spaces, will result in a skewed output.

With numeric fields, caution should be exercised that the length of the field to be printed does not exceed the width of the column to be used. Should the actual size of a string exceed the column width, it will nonetheless be printed in full and the remaining columns will be shifted right to accommodate it.

The address of the columns table is left on the stack at load time by **[R**; this is the address that must be passed to the word **LAYOUT**. **LAYOUT** initiates the printing of a report and

specifies the type of page heading routine to be invoked. It also saves the address of the title/column heading table (in user variable **RPT**) so that each page of the report will display the same header information.

If the title/column-heading pair is to be used in several reports, the address of the table for the title/heading pair may be used as the value for a **CONSTANT**, thus giving a name to the title/heading pair:

```
[R A Report \Col1\Col2\Col3]
   CONSTANT 'SHOW'
: SHOW   'SHOW' LAYOUT  ... ;
```

Otherwise, it is more efficient to just keep this address for a **LITERAL** to compile as a literal in the definition that uses this report:

```
[R A Report \Col1\Col2\Col3]
: SHOW   LITERAL LAYOUT ;
```

This address may, of course, be **DUP**ed if more than one reference is required, provided the **DUP** appears outside any definition (and thus is executed):

```
[R A Report \Col1\Col2\Col3] DUP
: SUMMARY   LITERAL LAYOUT ... ;
: SHOW   LITERAL LAYOUT ;
```

An additional word, **[R+** provides additional functionality by parsing the word that immediately follows it and executing this word on the first line of each page. Otherwise, its behavior is identical to **[R**.

REFERENCES

+PAGE, Section 2.8.4

2.8.2 Formatting Lines

To the report generator, a line consists of a series of columns, each of which has as fixed width. These columns are used to align the data to be printed, with all data right justified in the current column.

The following words are provided by the Report Generator to display fields within the columns determined by the title/column heading pair:

Word	Stack	Action
.N	(n)	Displays the single-length integer *n* right justified in the next column, in the format used by **.** (dot).
.L	(n)	Displays the single-length integer *n* right justified in the next column, in the format used by **L.** .
.D	(d)	Displays the double-length integer *d* right justified in the next column, in the format used by **D.**
?N	(a)	Displays the contents *a* address as a single-length integer *n* right justified in the next column, in the format used by **.** (dot).
?L	(a)	Displays the contents *a* address as a single-length integer *n* right justified in the next column, in the format used by **L.** .

?D	(a)	Displays the contents *a* address as a single-length integer *n* right justified in the next column, in the format used by **D.** .
?1	(a)	Displays the contents of the specified **1BYTE** field, right justified in the next column.
?B	(n a)	Reads and displays a **BYTES** field, according to the declared length, left-justified in the next column. **PAD** is used as intermediate storage of the field.
.M/D/Y	(n)	Given a Julian date, displays it in the next report column. Since this routine invokes **(DATE)** , it will work with either calendar. Most data base applications prefer to use the mm/dd/yyyy format.
.D/M/Y	(n)	Given a Julian date, displays it in the next report column. Since this routine invokes **(DATE)** , it will work with either calendar. Some data base applications prefer to use the dd-mmm-yyyy format.
.WHEN	(n)	Given the time in seconds, displays the hh:mm:ss in the next report column.

Each of these operators advances the columns table to the next column, determines the width of the new field, and then right-justifies the output string in this column.

You may also build your own formatting words to display columns, using the words **RIGHT**, **LEFT** and **CENTER**.

RIGHT	(a n)	Displays an alphanumeric string of length *n*, beginning at address *a*, right-justified in the next column.
LEFT	(a n)	Displays an alphanumeric string of length *n*, beginning at address *a*, left-justified in the next column.
CENTER	(a n)	Displays an alphanumeric string of length *n*, beginning at address *a*, centered in the next column.

The stack arguments are identical to those of **TYPE**.

In fact, **.N**, **.L**, **.D**, **?N**, **?L**, **?D**, **?1**, and **?B** are defined using **RIGHT** and behave according to its rules:

1. If the length of the output string exceeds the width of the column, the results are unpredictable but will include loss of format control.

2. If the length of the output string equals the width of the column, the string is displayed and the column pointer is advanced.

3. If the length of the output string is less than the width of the column, the difference is output as blank spaces, so that the string will be right justified.

4. Text strings are also right justified; however the string's trailing blanks are included, making them appear left justified.

Here is an example:

```
( Accounts example)

FILE Accounts.dbf   FILE= Tools/File/Accounts.dbf

76 500 0 BLOCK-DATA ACCOUNTS

0  10 BYTES NAME   NUMERIC ACCT#   DOUBLE BALANCE
```

```
: (.$) ( d – a n)   SWAP OVER DABS
      <#  # #  46 HOLD  #S  SIGN  #> ;

: .ACCOUNT   ACCT# ?N  NAME ?B
      BALANCE D@ (.$) RIGHT ;

[R Account Balances\   Account#\Name          \Balance]
   CONSTANT ACCOUNTS-TITLE

: balances   ACCOUNTS-TITLE LAYOUT
      ACCOUNTS RECORDS DO  I READ  .ACCOUNT  LOOP ;

: enter ( n d)   ACCOUNTS  SLOT READ  BALANCE D!
      ACCT# N!  NAME PUT ;

( Example:  456 100.00 enter John Doe <RETURN> )
```

The word **BALANCES** produces:

```
Page 1  05/12/2005
Account Balances
   Account# Name           Balance
        456 John Doe        100.00
        489 Mary Smith     2970.00
        620 Ed Poore          2.59
```

Notice that the first column heading, "Account#" appears in the title/ column-heading pair three spaces after the backslash. This causes the heading on the output report to be indented three spaces (the first space after the backslash counts). On the corresponding formatted lines, the first field is formatted with **?N**, which right-justifies the string against the end of the "Account#" heading.

The middle column is formatted with **?B**; as a text string this field is effectively left-justified. To make the output more pleasing, we have forced the "Name" column heading to be flush left to match.

In the third column, the data is once again right justified under the last character of the "Balance" column heading. In this case, we wished to display the double-length field in dollars-and-cents format, requiring the use of a pictured numeric output routine (Lines 4 and 5 of the listing). On Line 6, this pictured numeric output string is displayed, but with **RIGHT** rather than **TYPE**.

If the previous column displayed was the final column on a line, **RIGHT** automatically advances to the next line and resets the column table to begin with the first column on the line.

The following words are available for special formatting requirements:

Word	Stack	Action
0COL	( )	Resets the column table pointer to point to the first column width. Exercise care with this word, since it can cause the output to be misaligned if it is not issued when the actual output print position is at the beginning of a line.
COLS	(-- n)	Advances the column pointer and returns the width of the new column.
SKIP-COL	( )	Skips one column.
SKIP-COLS	(n)	Skips *n* columns.

2.8.3 Controlling Paging

The report generator does not count each output line, since this capability tends to be too environmentally dependent. Instead, it assumes that the output can be captured and paginated appropriately. This does not, however, stop an application from doing its own page control.

When using the Report Generator, it is not necessary to explicitly invoke a "new-line" function at the beginning of each row of data. As the field-display operators cycle through the columns table, after the last column has been displayed, the next operator resets the column pointer to the beginning of the column table again and issues a "new-line."

The following words control pagination:

Word	Stack	Action
+PAGE		Starts a new page, incrementing the page count in **P#** and displaying the headings for the new page.
+L		Issues a **CR** and increments the line count in **L#**. Also resets the column pointers using **0COL**.

REFERENCES

0COL, Section 2.8.3

2.8.4 The Page Banner

At the top of each page of the report appears the "page banner" which includes:

```
Page nn  <date> <optional text>
```

where *nn* is the current page number, and **<date>** is the current system date.

If you wish to modify or eliminate the optional text, simply change the string in the definition of **'APP** variable. The definition **APP" <optional text>"** is available to make this easier.

It is possible to eliminate the page banner entirely by replacing the word **LAYOUT** with **HEADING**. Like **LAYOUT**, **HEADING** takes as an argument the address of a title/column heading table as provided by the word **[R**, and establishes this table as current. It then displays the "title" line, without attempting to center it, and on the next line displays the column headings.

HEADING	(a)	Saves the address of a title/heading table, and outputs the title and column headings.

2.8.5 How the Columns Table Works

The format of the columns table is:

Byte	Contents
address - 8	Address of the optional routine executed at the end of the header.
- 4	Address of the page heading vectored routine.
+ 0	Address of column widths table.
+ 4	Address of column headings.
+ 8	Counted string of header.
+ 8 + (h)	Counted string of columns.
+ 8 + (h) + (c)	Column widths table.
+ 8 + (h) + (c) + n	-1 marks end of column table.

A -1 entry in the table indicates the end.

A heading line can contain up to 128 characters. These lines are used to establish a table of column widths at load time in the following manner.

Starting from the backslash in the title/column-heading pair, **[R** scans forward looking for additional backslashes in a loop. Each time it encounters a backslash; it replaces it with a space and computes the difference from the starting point or previous heading (the width of the field), and compiles this into the table. This loop repeats until the **]** delimiter is encountered. At this point, the indicator for the end of the line (a column width of -1) is inserted and the scan is complete.

For example, suppose the following is the set-up string for a set of column headings (the numbers across the top are your guide to indicate column positions):

```
 0         1         2         3         4
 01234567890123456789012345678901234567890123456789
 \   Account#\Name      \Balance]
```

The backslash after the “Account#” heading occurs at relative position 12; thus the number 12 is compiled into the table as the width of the first column. The backslash after the “Name” heading occurs at relative position 22; the difference, 10, is compiled as the width of the second column. The delimiting **]** occurs at 30, and the difference of 8 is compiled as the width of the third column. Finally, a -1 is compiled to indicate the end of the table.

The finished column table, as constructed by **[R**, contains:

```
      12  10  8  -1
```

The total width of all columns equals the position number of the last non-blank character.

A line may contain as many columns as required for the output format. Due to the method of establishing columns, the minimum width of a column is one character.

2.8.6 Non-standard Report Headings

By default, the "new-page function" performs the following steps at the beginning of each page, including the first page:

1. Displays the page banner as described in Section 2.8.4;
2. Performs a **+L**;
3. Executes a word called **TITLE**. **TITLE** is defined as:

```
: TITLE   RPT @ HEADING ;
```

RPT is the user variable that points to the current title/column-heading table. **HEADING** displays the title and column-heading lines from the given table (Section 2.8.5).

However, the Report Generator lets you vector the third function above. This feature lets you execute your own definition instead of, or in addition to, **TITLE**. For instance, you might add other lines of information below the page banner.
This vectoring is possible without recompiling the **FILES** utility because the second cell of the title/column-heading table contains the address of the routine to be executed at the top of each page. When **[R** generates this table, it copies in the address of the routine **TITLE** by default. By re-setting this address to point to your own definition, you can change the output of the new-page function.

Here are some examples:

```
( Non-standard Report Headings )

APP" Acme Manufacturing Co."

VARIABLE WHICH

[R   \Col1  \Col2  \Col3]  CONSTANT SHOW-TITLE1

: .ITEM   WHICH ? ;
: ."ITEM"   ." Report on Item No. "  .ITEM ;
: 'ITEM'   ."ITEM"  TITLE ;

: SHOW1 ( n)   WHICH !
      ['] 'ITEM' SHOW-TITLE1 CELL- !
      SHOW-TITLE1 LAYOUT ;

[R+ ."ITEM" \Col1  \Col2  \Col3]  CONSTANT SHOW-TITLE2

: SHOW2 ( n)   WHICH !
      SHOW-TITLE2 LAYOUT ;
```

```
[R+ .ITEM Report on Item No. \Col1  \Col2  \Col3]  CONSTANT SHOW-
TITLE3

: SHOW3 ( n)   WHICH !
      SHOW-TITLE3 LAYOUT ;
```

This example shows a report for some particular item that is selected numerically, like this:

2500 SHOW1 Stores *2500* into **WHICH** so that you can see a report for Item 2500.

The report generator will print the item number at the top of each page, with headings:

```
Page 1  05/18/2005  Acme Manufacturing Co.
Report on Item No. 2500
Col1   Col2   Col3
```

where the top line is the standard page banner, and the text "Report on Item No.___" is formatted by user-defined code.

Here are the steps used in the above examples to vector the user-defined code into the new-page routine:

1. Create a title/column heading pair as usual (cases 1 and 2, leave the "title" blank).

2. Define words, that will be executed as the third step of the new-page routine. It includes the message "Report on Item No.," followed by the display of the chosen item number. Finally it invokes **TITLE**, which displays the title/column-heading pair.

3. Define the report-generating word (the word **SHOW1**) in the usual way, using the address of the title to set the vectored location (1 cell back).

4. Alternatively, use **[R+** to create titles that have custom execution (the words **SHOW2** and **SHOW3**).

All of these reports have the same output, and other reports may be co-resident; since each has its own title/ column-heading table, each has its own new-page execution behavior.

2.8.7 Totals and Subtotals

The Data Base Support package includes a simple utility for computing subtotals and totals of numeric fields as the report is being displayed. In general, the following steps must be followed:

1. Allot enough "working storage" for the registers. Working storage is created by invoking **n ALLOT** immediately after the word **EMPTY** at the beginning of the **FILES** load block (Section 2.6). The value of *n* is calculated by this Forth phrase:

   ```
   ( # of registers needed) 3 * 2 * CELLS  2 CELLS +  16 +
   ```

See the source comment associated with the word **REGISTER** on your system.

2. At the beginning of your report word, simultaneously define and clear as many accumulator-pairs as there are fields you wish to total, using the word **TOTALS** (see below).

3. As the fields are being displayed, accumulate the values in the subtotal registers by using either **SUM** or **FOOT**.

4. When you wish to display the subtotals (if at all), use the word **SUB**, followed by an appropriate numeric output command.

5. When you wish to display the totals, invoke **TOTAL**. This copies the totals to the subtotals registers and adds them to the grand totals. Then use **SUB** as in Step 3.

6. When you wish to display the grand totals, invoke **GRAND**. This copies the grand totals to the subtotals registers. Then use **SUB** as in Step 3.

Here are the relevant words in detail:

Word	Stack	Description
TOTALS	(n)	Defines *n* subtotal accumulators, and *n* grand-total accumulators, and sets all to zero. Each accumulator is double-length. For example, if you are totaling three fields, the phrase: **3 TOTALS** creates three subtotal accumulators and three grand-total accumulators, and sets all to zero. **TOTALS** must be used at the beginning of a report if any of the following words are used.
SUM	(d n)	Adds *d* to the subtotal accumulator for the nth relative field.
FOOT	(d - d)	Advances to the next subtotal register and adds *d* to it. If at the last register, wraps around to the first. For instance, suppose you have a **DOUBLE** field called **SALARY** that you want to both display and add to the running total. The phrase: **SALARY D@ FOOT .D** fetches the contents, adds it to the corresponding subtotal register, then displays it.
SUB	(-- d)	Advances to the next subtotal register and fetches its contents. Also adds the contents into the corresponding grand-total accumulator and clears the subtotal register. If at the last register, wraps around to the first.
TOTAL	( )	Adds the totals to the grand totals and copies the totals to the subtotal accumulators. It leaves the totals in a state such that the display of the subtotals will set the totals to 0.
GRAND	( )	Copies the grand totals to the subtotal accumulators. For example, the phrase: **SUB .D** will display the subtotal of the next field. The phrase: **GRAND SUB .D** will display the grand total of the next field.

The following example shows how subtotals and grand totals can be easily computed and displayed:

```
Page 1  05/17/2005
Wine Inventory by Store
Location          Chablis   Rose  Champagne

Northern California
Palo Alto              25     42         78
San Jose               16     32         50
```

```
Mill Valley            31      29          36
San Francisco          70      59          82
                      142     162         246

Southern California
Chatsworth             35      48          29
Woodland Hills         32      40          60
                       67      88          89
Grand Total:          209     250         335
```

Here is the code that produced this display:

```
( Totals and Subtotals)

FILE Wines.dbf   FILE= Tools/File/Wines.dbf

28 500 0 BLOCK-DATA WINES

0  16 BYTES Location   NUMERIC Chablis   NUMERIC Rose
     NUMERIC Champagne   DROP

: .amounts   Location ?B  Chablis N@ S>D FOOT .D
      Rose N@ S>D FOOT .D  Champagne N@ S>D FOOT .D ;

: .subs   SUB .D  SUB .D  SUB .D  +L ;

[R Wine Inventory by Store\Location        \Chablis\  Rose\
Champagne]

   CONSTANT WINES-TITLE

: INVENTORY   WINES-TITLE LAYOUT  3 TOTALS  +L
      ." Northern California"  +L
      WINES RECORDS DO  I READ  .amounts  I 4 = IF  +L
            SKIP-COL .subs +L  ." Southern California " +L
      THEN LOOP  +L
      SKIP-COL  .subs  ." Grand Total:     " COLS DROP
      TOTAL .subs ;

: enter ( Cablis Rose Champagne -- )   WINES  SLOT READ
      Champagne N!  Rose N!  Chablis N!  Location PUT ;

( Example:  25 42 78 enter Palo Alto <RETURN> )
```

The phrase **3 TOTALS** appears in the definition of **INVENTORY**. This creates and clears three sets of accumulators, one set for each field we wish to total.

The word **FOOT** appears in the definition of **.amounts**:

```
Chablis N@ S>D FOOT .D
```

In this case, the field is **NUMERIC** (single-length), so we fetch it with the operator **N@**. **FOOT**, however, expects a double-length number; **S>D** supplies the high-order part. **FOOT** will add the value to the first subtotal accumulator. **FOOT** also returns a copy of

the value (as a double-length number). Finally **.D** displays the value in Report Generator format.

The second invocation of **FOOT** in:

```
Rose N@ S>D FOOT .D
```

will cause the value of the **Rose** field to be added to the second accumulator, and so on.

The word **SUB** appears in the definition of **.subs**. This definition displays the contents of the three subtotal accumulators in turn. Notice that the three uses of **.D** correspond to the second, third, and fourth columns in the report generator; thus we can only invoke **.subs** when we are about to display the second column (after having output or **SKIP**ped the first column).

In **INVENTORY**, we display the standard header with **LAYOUT**, below which we display the category heading "Northern California."

Inside the loop we display the fields in the usual way, except that we check to see if the index is 4. If so, then it is time to display the subtotals for Northern California and the category heading for Southern California. Here we **SKIP** the first Report Generator column, then issue **.subs**.

After the loop has been completed and the second set of records displayed, the phrase:

```
SKIP .subs
```

displays the subtotals for Southern California, and issues a **+L**.

Finally we display the text "Grand Total." The trick here is that we also want to display the grand totals on the same line. We cannot use **SKIP**, because it outputs the necessary number of spaces to get to the next report column; after printing the text, we're half the way there already. Our solution is to pad the message with trailing blanks so that the message is 17 characters long (the width of the first field plus one); this leaves us in position to display the second column.

However, the columns table must also be advanced to point to the second column. The phrase:

```
COLS DROP
```

is the same as **SKIP** without issuing the spaces.

Finally, **TOTAL** copies the total accumulators to the subtotal registers, and **.subs** displays these.

2.9 DATA BASE DESIGN

Before building a house, it is best to have a blueprint. So too, before defining files and records, it is best to map-out the overall database needs.

In general, we can formulate two simple rules for planning your database:

1. Look at the kinds of information you have.

2. Arrange like kinds of information into files.

2.9.1 A Hospital Patient Management Data Base

Our goal in this example is to create a database for tracking patients in a large hospital. For each patient there is a set of information: items such as address, height, weight, date-of-birth, and so on. (Note that we save date-of-birth and not age. We can always compute age if that's what we need in a report, but a date-of-birth is never obsolete.)

Clearly, this information all belongs in a single record, one per patient. However, there are also a variable number of information items that may be associated with each patient. For instance, each patient may have a different number of tests, and each type of test may have a different amount of information that it produces. In short, the amount of information that we need to keep for each patient is variable in length.

At this juncture, many database designers would opt for variable-length records and fields. But variable-length records are complex and slow, as we saw in Section 2.1. With nearly the same convenience we can achieve the same results by using a fixed header plus a variable number of subordinate records.

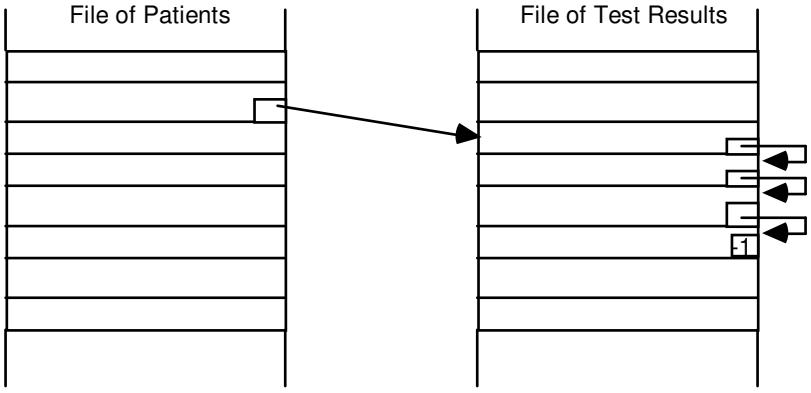


Fig. 2.13

Patient records chained to test results.

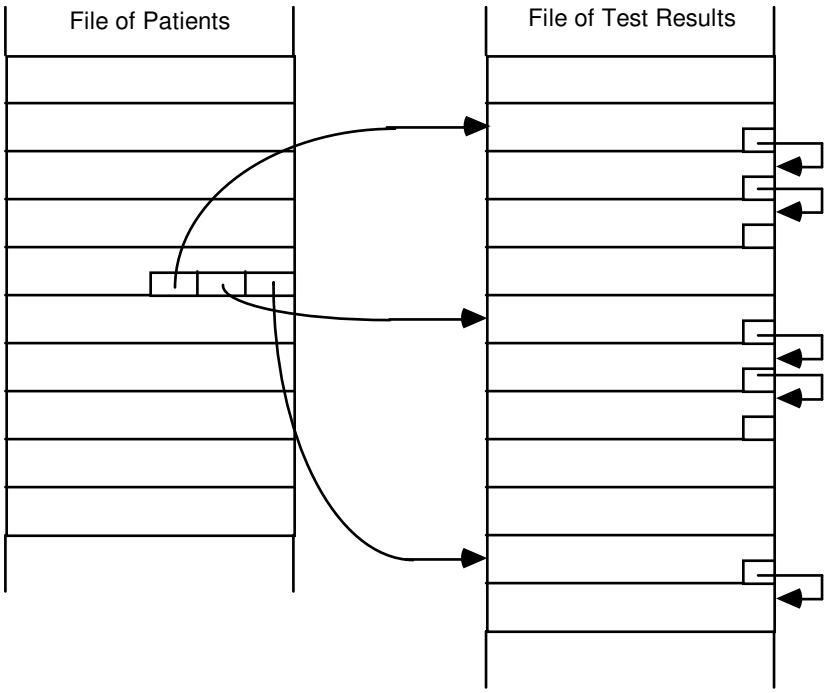


Fig. 2.14

Three "test results" chains for each patient.

This is where chains come in. Fig. 2.13 shows that a field in each **PATIENTS** record can point to the first in a series of **RESULTS** records, each of which is chained to the next. We achieve the same effect, but at much less expense.

Now suppose that we need to record particular test results for three different tests for each patient. We can accomplish this by providing three fields in each **PATIENTS** record, each pointing to a different result record or chain of records (Fig. 2.14).

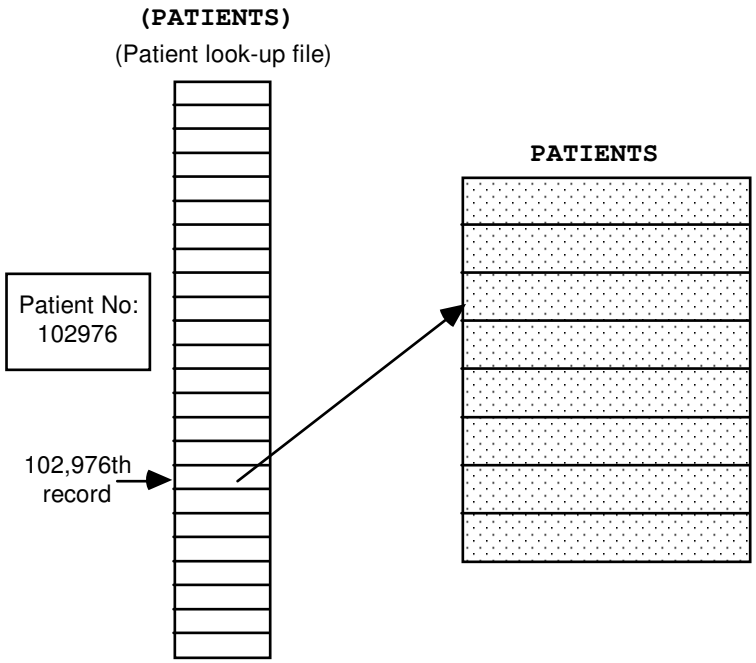


Fig. 2.15

Patient numbers directly index a record in **(PATIENTS)**, which contains a link to the main **PATIENTS** file.

Here's another intriguing problem. The application demands that a patient record can be found on the basis of a "patient number." A patient number is a very large number issued in sequence; in other words, the patient number last issued reflects the total number of patients that have ever been admitted to the hospital in its history. This number could reach 200,000 during the lifetime of our system. However, the department for which we are designing this application expects to see only 30,000 patients during the lifetime of this system. Unfortunately, maintaining an ordered index even of 30,000 records, indexed on "patient numbers," is unmanageable.

Is there any way we can translate a patient number directly into a record number for our **PATIENTS** file? Let's try this: we'll create a file of 200,000 records, each record being only two bytes long. This gives us one record per potential patient number. The two-byte field will contain a record number, pointing to the record in the **PATIENTS** file corresponding to the patient number (Fig. 2.15).

This elegant scheme requires 400 blocks for the look-up file, and yet gives immediate access to a patient record, with only one intermediate disk access. No searching is needed. Furthermore, when new patients are added, **SLOT** is not needed in the look-up file.

In general, direct access is much faster than searching, and should be used whenever appropriate.

2.9.2 An Integrated Business System

Our goal in this example is to create a package that will track income (sales and accounts receivable) and expenses (purchase orders, accounts payable, and payroll), and from these inputs will produce general ledgers, income statements and balance sheets.

Although many commercial business packages treat these functions as separate programs, our goal is to integrate them into a single system. By doing so, we will make the system simpler to use and reduce the opportunity for error. For instance, when a sales order is entered, the order should be forwarded to the accounts receivable component, and the sale automatically posted to the general ledger without further manual entry.

How shall we organize our database? Let's begin by identifying the entities and operations that are part of our business, and the reports that we wish to obtain:

```
Entities: Operations:       Reports:
customers sales:             general ledger:
vendors     order entry        income statement
employees   accounts receivable   balance sheet
            payments received
          purchases:
            purchase orders
            accounts payable
            checks written
          payroll:
```

Looking first at the left column, clearly we will need to store information about the entities in a file structure. The question to ask is, "What do we need to know about these entities?" It turns out that for each of our three types of entity, the answer is remarkably similar. In each case we need to know:

```
name
address (street, city, state, zip)
phone number
```

This observation suggestions the possibility of using shared code, an opportunity for program simplification. At the very least, this means we can use the same field definition names (**NAME**, **STREET**, etc.) for three different files.

In fact, though, we never have more than several hundred people and companies that we do business with in any year. As a result, we can mix all people and companies in single file, called **PEOPLE**, and add an extra field called **KIND** to indicate whether the entity is a customer, vendor, or employee.

This reduces the number of files for "entities" from three to one, and simplifies the program accordingly.

Because we will need to search and order this file on an alphabetical basis, we must also create an index file, called **(PEOPLE)**. This index will contain simply a link field—to

point to the corresponding record in **PEOPLE**—and a "nickname" field, which contains the name in a form that we want it alphabetized by.

We can establish the following rules for entry of the "nickname" field:
for human beings: last name, first name, initial
for companies (**customers or vendors**): company name
(sometimes somewhat abbreviated)

As for the additional fields that employees need, we find it simplest to create an additional file called **AUXILIARY**. Each employee record contains a pointer to a record in **AUXILIARY**.

Now let's turn to the operations. Each operation results in a transaction that must be saved. These transactions will become records in a file of *events*. What do we need to know about these events? In the case of a sale, we have:

customer
date of sale
amount
check number

In the case of a purchase order, we have:

vendor
date of order
amount
purchase order number

In the case of payroll, we have:

employee
date of paycheck
amount
check number
commissions (for commissioned salespeople)
tax contributions, etc.

Once again, it appears that many fields exist in common. With the exception of the extra information needed for payroll, we can summarize the above requirements as:

WHO
WHEN
AMOUNT
NO.

We decide to keep all events in a single file. We will call this file **DETAIL**. Besides the fields described above, we will add a field called **KIND** to indicate whether the event is a sale, an order, etc.

When we organize our data needs in this way, we see that entities and events can be organized together for simplicity. With this understanding, it will be easier to integrate the entire system.

Let's look at the **WHO** field. What should it contain? Perhaps the name of the person or company.

On the other hand, we know there will be many more **DETAIL** records than anything else, so we want to make each record as small as possible. Were we to keep a name field in the **DETAIL** file, it would take up considerable space and require that we look up the name in an index in order to get the address or other information on the name.

Instead, we will keep the record number of the related person or company in the **WHO** field. This occupies only two bytes, and requires no searches.

Now let's study some of the operations we'll want to perform. Suppose it is the end of the month and time to write checks. This is easy. We simply look through the **DETAIL** file looking for accounts payable entries that are due now. From the record in **DETAIL** we can follow the pointer into **PEOPLE** to get the name and address of the payee.

Let's take another example. We want to be able to determine the current balance owed by a particular customer or to a vendor. But we have not included a "Balance" field in the **PEOPLE** records. All we have to do is let each **PEOPLE** record point to the most recent transaction, then let each transaction record point to the next-most-recent transaction, etc. Here we are using chains.

```
ACME Widgets, Inc.      Page 1  31 OCT 1986

          So. Bay Office Supply Account Status
 # Job  Ref   Due  DR#  CR# Amount  PaidBalance
3344  108629 NOV 5220 2100 189.24  0.00189.24
334347 62629 NOV 1210 2100  10.74  0.00  10.74
3205  227010 OCT 2100 1030 779.74779.74  0.00
277361 93030 SEP 1210 2100  59.04 59.04  0.00
```

Fig. 2.16

Portion of a report showing a vendor account. The first column shows the number by which each detail item is referenced; it is actually the number of the record in the **DETAIL** file. The report title is a 'custom' one, showing the subject account. Custom report titles are described in Section 2.8.7.

Chaining is appropriate in cases such as this, in which there is no way to predict how many elements there will be, and it makes it easy to generate reports of activity for a vendor such as the one in Fig. 2.16.

There are at least three ways that chaining can be done:

1. Chaining from most recently entered transaction to least recent.
2. Chaining from least recent transaction to most recent.
3. Chaining by something other than order of entry, such as date field, etc.

In this case, we prefer to list transactions starting with the most recent events. This makes possible reports such as shown in Fig. 2.16. As we saw in Section 2.7, the

polyFORTH Data Base Support package includes a block of chain manipulation words that you can customize for your particular application.

So far we have a **PEOPLE** file and a **DETAIL** file. Now let us look at our desired reports. The general ledger is produced monthly, organized by account. Under each account are itemized all transactions, both credits and debits involving that account during the month. In the balance sheet (Fig. 2.17), we show year-to-date summaries for each account.

```
ACME Widgets, Inc.       Page 1  31 OCT 1986
                      Balance Sheet
CURRENT ASSETS
   CASH
   Continental Bank           24,165
   Amalgamated Bank          104,965
   Short Term Investments    248,000
   Petty Cash                  5,000 382,130
```

Fig. 2.17

Portion of a Balance Sheet report.

The traditional data base approach to General Ledger might involve running, once each day, some program that looks through the latest events and posts them to another file containing the general ledger data. To produce the general ledger at month's end, this approach would require sorting the transactions file by accounts.

But daily posting not only requires creating another file, it also involves an extra step for the bookkeeper. And sorting would take longer because it requires handling each record several times. As we've mentioned, the polyFORTH Data Base Support package offers many techniques that reduce the need to sort.

Still, each transaction record must indicate the account it affects. When we produce the general ledger and income statements, we will need to display accounts by name, *e.g.* "Advertising." It doesn't make sense to place an account name in each transaction record. Following our dictum, "Arrange like kinds of information into files," we create a new file called **ACCOUNTS**, containing the name of each account. Now our transaction records can simply use a record number to point to an account record.

Actually, each transaction affects two accounts, one as a debit and one as a credit. So, each transaction really needs two pointers. We will call one **DR#** (debit record number) and the other **CR#** (credit record number). As each transaction is made, we know what accounts are involved. For example, when we enter an invoice, the amount will be credited as a sale and debited as an account receivable.

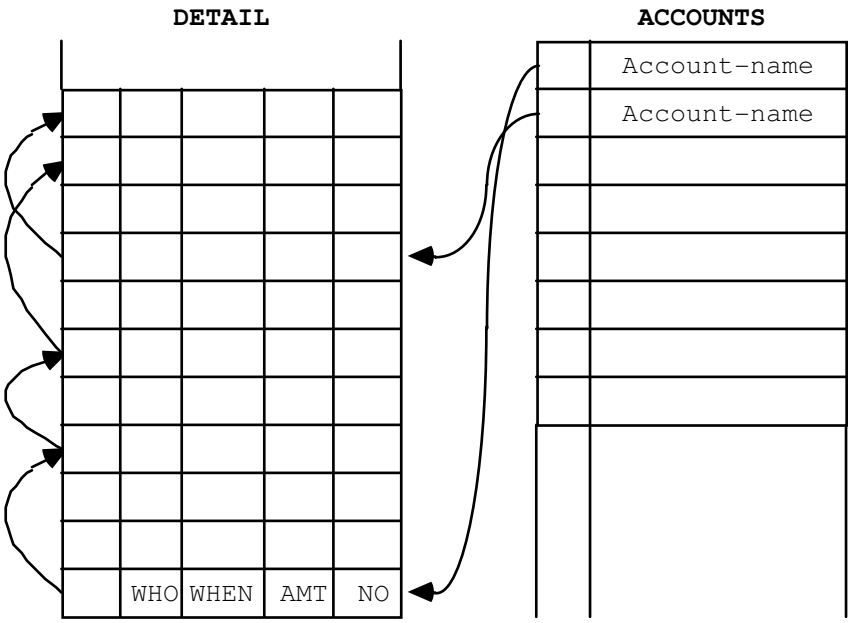


Fig. 2.18

Chains can be used to link transactions affecting each general ledger account.

Since each transaction points to a pair of account records, when displaying a transaction we can also display the account names.

What about a general ledger file? Upon further analysis, we realize that numbers don't need to be transferred to another file, when they are in one file already. It will be easier to run a program once a month that computes the account balances.

To run the general ledger, we need to start with each account, and then look at the transactions that affected that account to produce an account summary. We could loop through the **ACCOUNTS** file, and for each account record, step through each transaction that affected the current account during the month. This approach could also use chains. Each **ACCOUNTS** record would point to the most recent transaction affecting it, and each transaction would point to the previous transaction affecting the same account (Fig. 2.18).

However, chaining is somewhat complicated, and better avoided whenever possible. Rather than chaining from **ACCOUNTS** to **DETAIL**, we can simply loop through our **DETAIL** file for this month. Each **DETAIL** record points to a pair of **ACCOUNTS** records. For each transaction, we can *add* the amount to an accumulator for a credit account, and *subtract* the amount from an accumulator for a debit account. In this way, we can tally *all* our account totals by looping through the **DETAIL** file only once.

But where do we keep these accumulators? Since we need one and only one for every account, it makes sense to add a field called **BALANCES** to our **ACCOUNTS** records.

Is this idea really better than following chains? By following chains from **ACCOUNTS** to **DETAIL**, we would have to handle each transaction record twice: once while following

a credit-account chain, and once for a debit-account chain. By keeping balances, we can loop through our transactions only once.

By using a one-pass posting algorithm with no chaining, we improve performance a great deal by avoiding sorting, and by about a factor of two by not using chains.

Our **ACCOUNTS** file can use some embellishments. In addition to the two fields it already has:

```
Account No.
Balance
```

we can add **HISTORY**, which is an array of balances for the past 12 months.

In addition, the **ACCOUNTS** file needs an index, which we will call **(ACCOUNTS)**. At first it would appear that we could use the account numbers themselves to sort the accounts when preparing the balancing statement. In fact, however, accountants prefer to sub classify accounts into groups for their own reasons. For instance, taxes are an expense account, but they are usually listed at the end of the list of expense accounts. For this reason, the **(ACCOUNTS)** file is numbered according to the order in which we want accounts to appear on the balance sheet.

Our next step is to write words that reflect the kinds of high-level actions the bookkeepers want to record. Let's start with the operation of placing an order. How must this order affect our database? What do we need to know?

Clearly we are going to create a new **DETAIL** record. This record will include a **WHO** field to indicate the company from which we are ordering. Since we have our vendors in the **PEOPLE** ordered index file, we need supply only the name of the company. The program can then look up the company, find the record number and place it in the **WHO** field of the new transaction record. The program must also link this new transaction into the chain for that vendor.

We also need to supply the amount of the purchase, and our purchase-order number. The program itself can place the current system date into the **WHEN** field, and by default, place the date 30 days hence into the **DUE** field. Since this is an order, the program must place the code for a purchase in the **KIND** field.

So what should our "program" for entering an order look like to the bookkeeper? We know the bookkeeper must supply:

1. The amount.
2. The purchase-order number.
3. The name of the vendor.

The simplest, most Forth-like solution is to call the word **BOUGHT**, precede it with the two numeric data items and follow it with the string data. This gives us the syntax:

```
200.00 5134 BOUGHT ACME
```

We can now take a similar approach with a program to record a sale:

```
3998.00 7409 SOLD CROFT
```

The word **SOLD** is preceded by amount and their purchase-order number, and followed by the name of the customer.

We can record the receipt of a check with the word **FROM**:

```
amount check# line# FROM Conway
```

In the above, **line#** is a number that identifies the sale for which this is a payment received. The bookkeeper finds this number on a report of outstanding balances (see Fig. 2.16). While this is simple for the bookkeeper, it is also simple for the program because **line#** just happens to be the record number of the **DETAIL** record showing the sale.

The same syntax can be used for writing a check:

```
amount check# line# TO ROSS
```

Thus, each "program" is simply a Forth word. This approach allows our application to use the Forth interpreter. The problem of how the bookkeeper selects a given operation is effectively eliminated.

To appreciate the significance of this, consider the typical alternative. Most business applications are menu-based. From the main menu, the bookkeeper might select Accounts Payable. Then, from the Accounts Payable menu the bookkeeper might choose Purchase. From there, an entry form might appear, wherein the bookkeeper can select or enter the customer, and then fill in the data.

While popular, this menu-based approach can be more laborious for the user. To avoid the switching application modes, the bookkeeper may separate all the purchases from the sales, etc., and do each group one at a time. This requires more paper shuffling.

Our approach, with no hierarchy, lets the user enter various transactions in any order, leading to a more pleasant, efficient working environment. A "help screen" can display the syntax of the commands on request during the learning curve.

In retrospect, we seem to have designed the database very efficiently. The file with the most records, **DETAIL**, also has the smallest records. Each record in **DETAIL** is only 16 bytes long, and contains no text at all. (This means that 64 such records will fit in a block.)

2.9.3 A Facility Management System

In this example we will see how to organize and simplify a massive data problem by studying the data and looking for a natural hierarchy.

The example involves the problem of controlling digital and analog input/ output with a distributed computer system, where there are several thousand I/O points in dozens of buildings and other locations at a large industrial plant.

Digital “points” include switches, buttons, pressure-sensitive floor plates, pulses to unlock doors, and so on. Analog points include thermocouples, meters on control panels, heating levels, lighting levels, and so on. Our task is to install a distributed computer system to control all these points.

We begin by studying the points as the architects and engineers designated them. The ID for an individual point has the form:

ABC-123-1234

Experience has taught us that numbers such as this are usually encoded, and that usually the coding scheme presents a goldmine of information on how to organize the system. Upon further investigation we discover these relationships:

ABC - 123 - 1234

a facility a control panel a point number on a control panel in a facility.

This information provides the key for our establishing a hierarchical database, a necessary strategy when dealing with thousands of anything. Another example in which coded numbers can reveal hierarchy is with inventory or parts numbers.

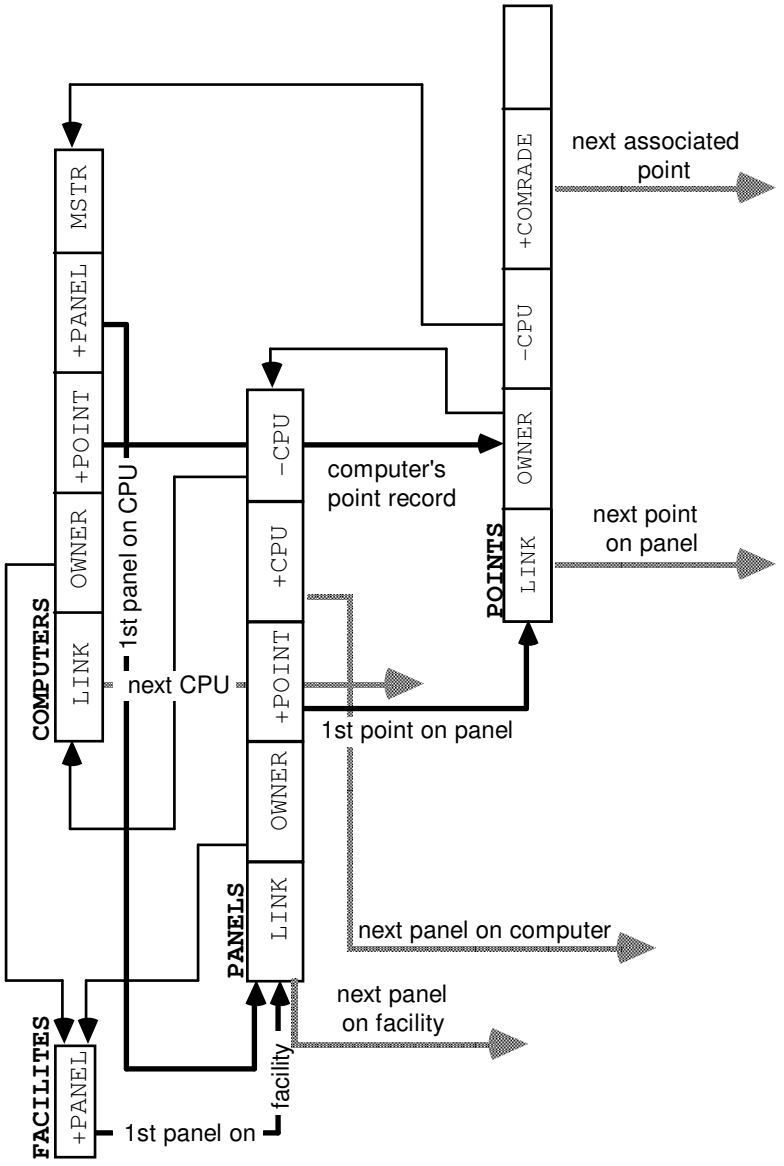


Fig. 2.16

Diagram of the database for the Facility Management example.

One of the things we must do is allow the control of individual points from the central computer. The operator can enter a point ID and indicate some action. So one of our problems is to associate a point ID with a physical hardware location. One approach would be to have a points index containing the ID of each point in the system. The nature of the coding scheme makes it a candidate for an ordered index, but with over 20,000 records even a binary search is more cumbersome than we can afford. The logical hierarchy will help deal with the volume, and thus the performance. It will also improve the information content; for example, in reports we can make use of the implicit meaning of the data.

The first part of the code is a “facility:” A physical building or location on the plant, like the parking garage, the fire station, etc. A “panel” may be a manually attended console; a

switchbox in a closet, or it may be imaginary, as in the case of points attacked directly to the computer.

A single panel may control many points. And a computer may control many points in many buildings (for instance, the fire station computer needs fire alarms in all buildings). But what is the relationship between computers, facilities, panels and points?

Further digging uncovers fact that a panel is attached to only one computer. This means that each computer can be responsible for its own private database of panels. Each panel can be chained to any number of points. The master computer can have a file of facilities. Each facility can be chained to any number of panels.

We can now identify four files:

FACILITIES
COMPUTERS
PANELS
POINTS

We have solved the problem of chaining from computers down to points. Now let's consider the reverse problem. Inputs generate "events." An event has to be dealt with quickly; for instance, the event may be an alarm. If a fire alarm is triggered, a computer will need to display information about the point, such as which building it is in. In other words, we must have linkage from point to panel to building.

The first step of this linkage is the association between an electrical event within the computer and the corresponding point in the **POINTS** file. For instance, the pressing of a button might cause execution of an interrupt routine. This routine must be able to determine which point caused the interrupt.

At first it may seem logical to keep a table that associates hardware addresses with point names. But this would require an extra search. It is more direct to create a table that associates points' hardware addresses with record numbers within the **POINTS** file. Another benefit is that the point record number only requires two bytes, so the table is small.

With this scheme, an electrical event is associated with a record in **POINTS**, which in turn contains the information we need to know about the point, including its code name. Because the code name contains meaningful information, we can now determine which building the point is in.

We can now rest assured that we have found a good solution to the problem, since we have achieved good performance while at the same time reducing complexity. This sort of win/win situation provides the positive feedback that tells us we're on the right track as we iterate through our design.

2.9.4 A Filing Scheme for Image Processing Applications

Our final example illustrates the flexibility the Data Base Support package provides—including the freedom to *not* use some of its features when the application dictates otherwise!

Conceptually, a filed image has two elements, a header and the pixel data. The header indicates what the image is, when it was recorded, who made the image, the dimensions of the image (in pixels), and so on.

There are a variety of ways to index into images. But the real problem is managing the pixel data. Image processing is a prime example of an application in which speed is critical, because there is simply so much pixel data to handle. An array of 512x512 points contains 262,144 pixels, which at 8 bytes per pixel occupies 256 blocks. Just reading this many blocks will take some time.

Now imagine trying to access these pixels one at a time using **`1@`** (or **`N@`**). This approach involves the invocation of **`BLOCK`** plus the record and field accessing computations for each and every pixel. This will be unacceptably slow.

An approach that has proven effective is an interesting hybrid of the Data Base Support package tools, plus ordinary direct disk-access techniques. In this approach, we use the Data Base Support commands for header information, but we keep the pixel data elsewhere on the disk. In other words, we reserve three regions on the disk: a file for headers, another for an index to our headers, and a region of blocks that are *not* files for pixel data. Within the header, a field points to the *block number* where the pixel data begins for that image. Another field indicates how many blocks are used.

We also recommend keeping the data in the form used by the image-processing device (usually binary integers). You may want to process an image using floating point (although in the absence of a hardware floating point processor the fixed-point routines supplied with polyFORTH will be much faster). But a 64-bit floating point number is eight bytes long, which means an image will require eight times as many blocks and take eight times as long to read and write off the disk. It is faster to float the numbers after fetching them.

Some users believe that saving pixel data in floating point form retains better resolution. In fact, however, the typical A/D converter on a Vidicon camera (for instance) does not possess many bits of resolution. In industrial vision applications, these devices rarely provide more than one byte of precision. The extra bits that floating point provides simply represent noise.

On the other hand, some applications do utilize greater precision, but store a much smaller number of pixels. In astronomy, for example, an image size may be only 64x64. But the image might be recorded with a highly sensitive detector over a four-hour period with atmospheric correction. Thus, each pixel has already been integrated and may contain as 16 bits or more of information.

2.10 GLOSSARY UTILITY

The **Glossary** is a Forth utility that allows maintenance of a file that contains descriptions of Forth words. This provides a convenient way to document polyFORTH programs. It is also an excellent example of the use of all data base management features.

Each word defined in the glossary has the following information associated with it:

1. The block in which the word is defined.
2. The glossary vocabulary.
3. Stack usage.
4. One or more lines of text that describe the word and its use.

The **Glossary** utility provides commands to maintain this file and to print reports that include either selected glossary vocabularies or the complete file of words.

2.10.1 File Structure

The **Glossary** uses one or more glossary files that are specified by the user. Each glossary file is physically composed of two separate files; a data file and an index file. Index file support in the polyFORTH system is required to implement the glossary.

You must pre-allocate the two polyFORTH files required for a glossary. The data file is composed of 64-byte records, several of which may be chained together to provide multiple lines of text, 64 characters per line. It is named **GLOSSARY**.

The index file used for the glossary is compiled of 28-byte records, with a 24-byte key length comprised of the word-name (12 bytes) and a vocabulary-name (12 bytes). One index record is required for each glossary entry. The name of the index file is **(GLOSSARY)**. It is an ordered index, ordered by word-name and vocabulary; this has the effect of maintaining the glossary in alphabetic order.

Here is a sample definition for a glossary file that contains 450 entries.

```
( BYTES  RECORDS    ORG                NAME)
    28      432       0    BLOCK-DATA (GLOSSARY)
    64     2300  +ORIGIN   BLOCK-DATA  GLOSSARY
```

2.10.2 Loading Instructions

The **Glossary** is loaded with the following command:

```
include Tools/File/Glossary.fth
```

The procedure for entering a word into a **Glossary** consists of making the block number and glossary vocabulary current, entering the stack usage and the word-name,

and then entering associated text. You can change block number, stack usage, and text lines easily. The following sections are interdependent; reading through them at one sitting will provide a helpful overview.

2.10.3 Source Block Identification

When you begin to document your application, you will usually specify a source block to be documented and then enter all the words that are defined in that block.
To specify a source block, use the following phrase:

```
blk# SOURCE 2 nC!
```

Until changed by re-use of the phrase above, this current block number will automatically be stored with each succeeding word entry.

REFERENCES

Entry Changes, Section 2.10.8

2.10.4 Glossary Vocabulary Identification

Along with each word, the system stores the name of the entry's application vocabulary. This usually means the name of the portion of the application in which the word is used, such as the name of its load block. These vocabularies are not necessarily the same as program vocabularies. Glossary vocabularies exist only for logical grouping of words and to enable the same word to be variously defined several times in different blocks.

Before you begin entering words for a new glossary vocabulary, make it the current vocabulary by typing:

```
VOCAB vocabulary-name
```

Note that the name cannot be longer than ten characters. Until changed, this name is kept in memory and copied into each succeeding data record entered.

In order to search for a previously entered word, you must make its vocabulary the current one.

The glossary vocabulary name serves as a secondary key for searches. This means that the same word may be entered in numerous vocabularies, with each entry unique.
The vocabulary is also set by the report command **/VOCABULARY**.

REFERENCES

/VOCABULARY, Section 2.10.7
Finding Previously Entered Words, Section 2.10.8

2.10.5 Glossary Entries

Words are entered into the glossary through the **ENTER** command. This command sets the basic entry into the file. It has the following format:

ENTER word-name (*e.g.,* **ENTER NAME**)

The program will prompt you for brief (16-character) descriptions of stack entries before and after execution. Any valid Forth word name may be used; the maximum length recognized by the **Glossary** is twelve characters. If a longer word name is entered, its length will be truncated to twelve characters.

Following **ENTER**, the new word is made the current word, with which will be stored the current block number, current glossary vocabulary name, and up to four lines of associated text. Immediate subsequent use of **AT**, **STACKS**, **T**, **U**, or **P** will affect this entry.

REFERENCES

Entry Changes, Section 2.10.8
T and **P**, Section 2.10.6

2.10.6 Text Specification

The **Glossary** provides commands that allow up to four lines of text to be associated with each entry and also allow modification of previously entered text.

The following command is used to enter a line of text that is associated with a definition:

U new text line

The command U inserts "new text line" under the current text line (which begins at 0 after a new entry). The new text line may be composed of one to 64 characters, including embedded blanks.

Following the use of **ENTER** or **FIND**, the current text line is initialized to zero. Use of **U** not only inserts a new text line, it also increments the current line number. Thus subsequent usage of **U** adds additional text lines.

The command **P** is used to modify existing text. You do this by displaying the line to be changed and then using **P** to replace the old text with new text. Remember that you can only work on the current word in the current vocabulary. You display the appropriate line of text (lines are numbered starting from zero) by typing:

line# T (*e.g.,* **3 T** to display the fourth line)

After a line of text has been displayed, you can modify it by using the following command:

P replacement-text-line

The command **X** is used to delete a text line previously selected by the **T** command. Thus, to delete Line 2 you would type:

```
2 T
X
```

REFERENCES

ENTER, Section 2.10.5
FIND, Section 2.10.8

2.10.7 Definition Display

To display the current entry, type:

```
F
```

To print all definitions in all the vocabularies in the glossary, in ASCII alphabetical sequence, use the word **SUMMARY**. The same information as for **FIND** is printed for each word entered in the glossary. The printed report is paged and numbered.

The command:

```
/VOCABULARY
```

will print definitions as for **SUMMARY** but only in the glossary vocabulary whose name is specified.

REFERENCES

Glossary Vocabularies, Section 2.10.4
Making an Entry Current, Section 2.10.8

2.10.8 Changes

Changes always affect the current word. Words are made current in two ways.

1. A word just entered is the current word.
2. A previously entered word in the current vocabulary may be made current by using the command:

```
FIND word-name
```

This displays the requested word, with its vocabulary name, block number, stack usage, and text description.

Following the use of **ENTER** or **FIND**, the current line number is initialized to zero.
The current word's stack entries may be changed by typing:

```
STACKS
```

The current word's source-block# may be changed by typing:

```
new-blk# AT
```

You may not change vocabulary and word names except by deleting and re-entering the entry, since these two items form the index keys.

To redisplay the complete entry for the current word, type:

```
F
```

REFERENCES

Changing Description Lines, Section 2.10.6
Making a Vocabulary Current, Section 2.10.4

2.10.9 Text and Definition Deletion

The following command is used to remove all text lines associated with the current definition and then to delete the current definition from the glossary:

```
DELETE word-name
```