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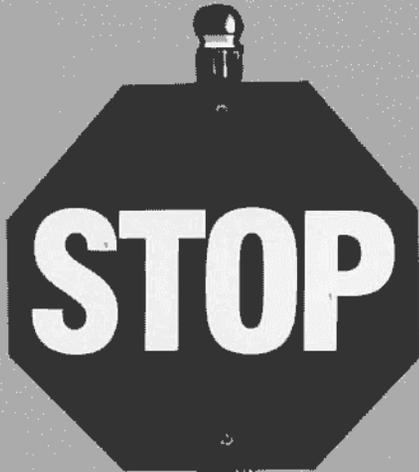
### **APPLICATIONS SOFTWARE VERSION LOG**

**02.00.00**

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### **OP. SYSTEM VERSION LOG**

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**Read Carefully**

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## Important Note to Model III Users

From time to time, Radio Shack may release new versions of TRSDOS, the TRS-80 disk operating system. Check with your local Radio Shack or the *TRS-80 Microcomputer News* for notices and instructions on these enhanced versions of TRSDOS.

If you receive a new version of TRSDOS, read the following before making any modifications to your existing software packages (applications, languages, or system utilities):

- Do not convert your Radio Shack software packages for use with the new version of TRSDOS unless you are instructed to do so.
- Before converting a Radio Shack supplied Model I software package to a Model III format, check to see if Radio Shack provides a Model III version of the package. If so, you should obtain a copy of that version.
- If you're using several different software packages, press the RESET button whenever you change software.

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8759106

# TRS-80® Pascal

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IMPORTANT NOTE FOR  
MODEL I/III TRS-80 PASCAL USERS  
(Catalog Number 26-2211)

It is important to note that when using TRS-80 Pascal with a Model I or Model III, the minimum system requirements are as follows :

- \* 48K Model I - Two disk drives
- \* 48K Model III - One disk drive for TRSDOS 1.3 users  
Two disk drives for LDOS operating system users (catalog number 26-2214)

A printer capable of printing at least 80 columns per line and connecting cable are also recommended.

When using the TRS-80 Pascal, a disk containing an operating system must be in drive 0.

TRSDOS 1.3 is supplied on both Pascal disks for the Model III. Either disk may be placed in drive 0 and used as a system disk.

The three disks containing the Model I Pascal system do not contain TRSDOS 2.3 for the Model I. TRSDOS 2.3 must be supplied by the user.

The TRS-80 Pascal system may also be used under the the LDOS operating system (floppy or hard disk versions) on the Model I or III. However, the Model III version of TRS-80 Pascal must be patched before use under LDOS. See the BEGINNERS MANUAL for information on how to patch the TRS-80 Pascal system for proper operation with LDOS on the Model III.

## NOTICE TO PROGRAMMERS

By purchase of the software product described in this manual, you have obtained a license to duplicate the supplied disk files only as necessary for personal use on your Model I/III Micro-computer.

The complete TRS-80 Pascal Development System (26-2211) includes Pascal systems for both the Model I and III. The Model III version also contains the TRSDOS operating system. None of the supplied files may be reproduced for resale.

If you intend to sell application programs developed using TRS-80 Pascal, you must follow the procedure below to avoid violation of this license and of copyright laws.

1. Use the PASCAL compiler to translate the application program to object code.
2. Use the LINKLOAD utility to link the object code with the TRS-80 Pascal runtime support and build a stand alone, executable command file (/CMD extension).
3. The executable command file may be copied and sold with no royalty payments required. However, all programs sold must document the fact that they contain TRS-80 PASCAL RUNTIME SUPPORT.

## HOW TRS-80 PASCAL WORKS

TRS-80 Pascal is a compiled language. This means that programs must first be translated to object format before they may be executed.

The first step in developing a program is to enter the program into the computer and save it to a disk file. A full screen text editor is supplied to allow you to create your programs.

The second step is to compile the program. There are two versions of the compiler which are supplied for translating your programs to object format. One version is overlaid while the other is not. The overlaid version is a little slower but will allow you to compile larger programs. The compiler generates an object format file.

The third step is to execute the program. There is a RUN utility supplied which will execute your compiled programs. This utility loads and executes object format files. Another utility, LINKLOAD, is provided which will allow you to convert object files into stand alone, executable command files (/CMD extension).

AN OVERVIEW OF THE TRS-80  
PASCAL MANUAL

There are seven fundamental sections to this manual. We suggest that you read through the Beginners guide carefully. The seven are:

1/ BEGINNERS GUIDE

- (1) Takes you through the steps of backing up the system.
- (2) Shows how to patch the system for use with LDOS or the Hard Disk Operating System.
- (3) Leads you through the steps of entering and executing a simple Pascal program.
- (4) Introductory trouble shooting guide.

2/ EDITOR MANUAL

Shows how to use the Blaise text editor in detail.

3/ SYSTEM IMPLEMENTATION MANUAL

Gives specific information on the TRS-80 implementation of Pascal. Included is more detailed information on:

- (1) Compiling and executing programs.
- (2) TRS-80 Pascal memory usage.
- (3) Using the external library of procedures and functions. (Graphics, keyboard and system call interfaces)
- (4) Using the external library of procedures and functions to perform dynamic string manipulation.
- (5) Using the Random File access routines.
- (6) Miscellaneous differences in Alcor Pascal 1.2A and TRS-80 Pascal 2.0.
- (7) Miscellaneous patches to modify TRS-80 Pascal.

4/ TUTORIAL

A step by step introduction to Pascal, aimed at people with some knowledge of a computer language.

5/ LANGUAGE REFERENCE MANUAL

A detailed guide to the TRS-80 Pascal language.

6/ ADVANCED DEVELOPMENT PACKAGE

Contains sections on the use and execution of the Native Code-generator and Optimizer programs. Explains when and why to use these utilities.

7/ MASTER CROSS REFERENCE INDEX

A cross reference index for the entire documentation package.

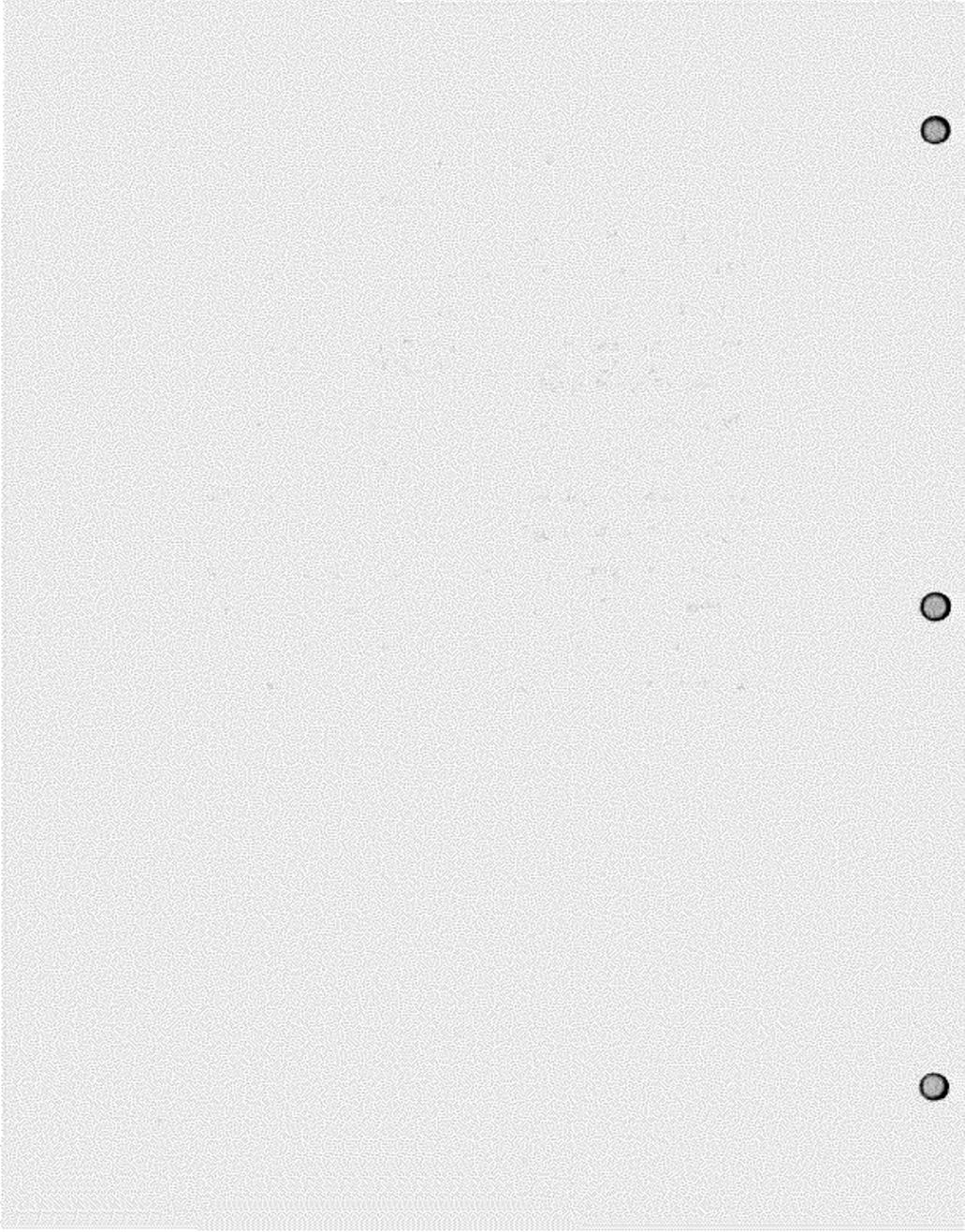
Differences in ALCOR PASCAL (1.2A) and TRS-80 PASCAL (2.0)

- A. Additional language features (see appendix of the language reference manual)
  - File buffer variables
  - GET & PUT procedures
  
- B. Library routines (see system implementation manual)
  - CALL\$ - changed (now includes the flag register)
  - SETACNM - added (easier version to use of SET\$ACNM)
  - Random file routines (now included in RUN/CMD)
  
- C. Compiler options (see appendix of the language reference manual)
  - INCLUDE
  - LIST
  - PAGESIZE
  - WIDELIST
  - RANGECHK
  - PTRCHECK
  
- D. Miscellaneous (see system implementation manual)
  - Compiler changes
    - New error message file (PASCAL/ERR)
    - 80 character source lines now accepted by compiler
    - New comment to end of line character
    - LOCATION function now works on procedures & functions
    - Compiler stack requirements
  - Linking loader changes
    - Program prompt removed
    - Lower case commands accepted
    - Build to an illegal file trapped
  - Runtime changes
    - Generating the End of File character from the keyboard.
    - Runtime error message reporting
    - Break key recognized
  - Error corrections
    - Subrange handling
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## Beginners Guide

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## MAKING A TRS-80 PASCAL BACKUP

The Model III version of TRS-80 Pascal comes with a TRSDOS 1.3 operating system on both supplied disks. Model III owners should follow these instructions to ensure safe backup copies of TRS-80 Pascal.

### Model III, 2 drive system

-----

1. Place the master "Model III version" disk labeled "Disk 1 of 2" into drive 0 and press the orange reset key on the computer.
2. TRSDOS will prompt you to enter the date and time. Enter the correct date and if desired, the correct time. The prompt for the time may be answered by simply pressing the <enter> key. The following is an example:  

```
Enter Date (MM/DD/YY)? 01/10/83 <enter>
Enter Time (HH:MM:SS)? <enter>
TRSDOS Ready
```
3. Place a new blank diskette in drive number 1 and type BACKUP <enter>.
4. You will then be prompted to specify the source and destination drive numbers and the password. Answer the prompts as follows:  

```
SOURCE Drive Number? 0 <enter>
DESTINATION Drive Number? 1 <enter>
SOURCE Disk Master Password? PASSWORD <enter>
```
5. The message \*\* Backup Complete \*\* followed by TRSDOS Ready indicates the backup process has finished. Repeat steps 3 and 4 using the master "Model III version" disk labeled "Disk 2 of 2" in drive 0 and then store the master disks in a safe place and use the backup copies.

Model III, 1 drive system  
-----

1. Place the master "Model III version" disk labeled "Disk 1 of 2" into the drive and press the orange reset key on the computer.
2. TRSDOS will prompt you to enter the date and time. Enter the correct date and if desired, the correct time. The prompt for the time may be answered by simply typing the <enter> key. The following is an example:  
  
Enter Date (MM/DD/YY)? 01/10/83 <enter>  
Enter Time (HH:MM:SS)? <enter>  
TRSDOS Ready
3. Type BACKUP <enter> and answer the prompts as follows:  
  
SOURCE Drive Number? 0 <enter>  
DESTINATION Drive Number? 0 <enter>  
SOURCE Disk Master Password? PASSWORD <enter>
4. You will then be prompted to insert the DESTINATION diskette. Replace the master disk with a new blank disk and press the <enter> key. The new disk will be formatted and then you will be prompted to insert the SOURCE Diskette. Replace the new disk with the master disk and press the <enter> key.
5. The backup process now begins. You will alternately be prompted to insert either the SOURCE or DESTINATION diskette. Insert the master disk when prompted to insert the SOURCE diskette and the new disk when prompted to insert the DESTINATION diskette. After inserting the disk, press the <enter> key. This disk swapping must be done several times after which the message  
\*\* Backup Complete \*\* followed by TRSDOS Ready will appear indicating the backup process has finished.
6. Repeat steps 3 through 5 using the master "Model III version" disk labeled "Disk 2 of 2" and then store the master disks in a safe place and use the backup copies.

The Model I version of TRS-80 Pascal does not include an operating system. Model I users must supply their own copy of TRSDOS 2.3 and then follow the instructions below to ensure safe backup copies of TRS-80 Pascal.

Model I, 2 drive system  
-----

1. Place the master "Model I version" disk labeled "Disk 1 of 3" into drive 1.
2. Place a TRSDOS 2.3 operating system disk in drive 0 and press the reset button at the top left side of the keyboard.
3. When DOS READY appears on the screen, type  
BACKUP <enter>.
4. Replace the TRSDOS 2.3 disk in drive 0 with a new blank disk and answer the prompts as follows. Specify the current date for the last prompt.  
  
SOURCE DRIVE NUMBER ? 1 <enter>  
DESTINATION DRIVE NUMBER ? 0 <enter>  
BACKUP DATE (MM/DD/YY) ? 01/10/83 <enter>
5. When the backup process is finished, the message  
BACKUP COMPLETE followed by HIT 'ENTER' TO CONTINUE  
will appear on the screen.
6. Repeat steps 2 through 5 using the master "Model I version" disk labeled "Disk 2 of 3" and again using the master "Model I version" disk labeled "Disk 3 of 3". Store the master disks in a safe place and use the backup copies.

## FILE CONFIGURATION

After working copies of the master disks have been made, you should configure development disks. Program development requires a certain amount of free disk space. The supplied files should be arranged so that you may edit, compile, and execute programs. The number of development disks required to provide a suitable arrangement of files depends on your particular computer system. Following are examples of suitable file configurations for different computer systems. You may want to keep a set of backup diskettes intact with all files, and use another set of backups for development purposes.

### TRS-80 MODEL III

-----

Both of the supplied model III disks contain the complete TRSDOS 1.3 operating systems. Most of the TRSDOS files are not necessary for Pascal program development and may be deleted to obtain more free disk space. See the PURGE command in your TRS-80 DISK SYSTEM OWNER'S MANUAL. If desired, the following TRSDOS files may be deleted using the PURGE command.

BASIC/CMD	XFERSYS/CMD	MEMTEST/CMD
CONVERT/CMD	LPC/CMD	HERZ50/BLD

The disk labeled "Disk 1 of 2" contains the following Pascal files in addition to the TRSDOS files.

PASCAL/CMD	non-overlaid compiler
RUN/CMD	utility for executing object files
ERRORS/DAT	error message file for compiler
ED/CMD	editor
HELP/HLP	help file for editor
KEY/HLP	help file for editor
CMD/HLP	help file for editor
TRSLIB/PCL	external declarations for system routines
STRINGS/PCL	external declarations for string routines
PATCHER/CMD	patch program for applying patches
DATABASE/PCL	sample Pascal program
LDOS/PAT	patch file for model III LDOS users

The disk labeled "Disk 2 of 2" contains the following Pascal files in addition to the TRSDOS files.

PASCALB/CMD	overlaid compiler
PASCAL/OV1	overlay 1
PASCAL/OV2	overlay 2
PASCAL/OV3	overlay 3
PASCAL/OV4	overlay 4
LINKLOAD/CMD	utility for linking object files
CODEGEN/CMD	utility for generating Z80 code
CODEINIT/DAT	data file for CODEGEN/CMD
OPTIMIZE/CMD	utility for making object files smaller
TRSLIB/OBJ	object code for system routines
STRINGS/OBJ	object code for string routines
RANDOM/OBJ	object code for random file routines

## Example 2 Drive Model III Configuration

---

Follow the steps below to complete the Model III two drive configuration.

- 1) Place "Disk 1 of 2" into drive 0
- 2) Place "Disk 2 of 2" into drive 1
- 3) Type COPY ERRORS/DAT:0 :1 <enter>

The two Model III disks may now be used as development disks. Either of the development disks may now be used in drive 0. Since there is not much free space left on either disk, a new formatted disk should be used in Drive 1 as a data disk to store the Pascal source, object, or command files being developed. "Disk 1 of 2" contains all the files necessary to edit, compile, and run a Pascal program. It is not necessary to use "Disk 2 of 2" until you begin developing larger programs, building /CMD command files, or using separate compilation.

## Example 1 Drive Model III Configuration

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For single drive systems, it is necessary to leave enough free space on each development disk to store the Pascal source, object, or command files being developed. You should configure at least four development disks for single drive systems.

First, make an extra backup copy of both "Disk 1 of 2" and "Disk 2 of 2". You may now free data space on each disk by deleting specific files. See your TRS-80 DISK SYSTEM OWNERS'S MANUAL (26-2111) for information on how to delete files using the PURGE command. You should delete all the TRSDOS files (see the previous page) from each of the four disks.

Take one of the "Disk 1 of 2" disks and delete the following files: the editor help files HELP/HLP, KEY/HLP, and CMD/HLP, the external declaration files STRINGS/PCL and TRSLIB/PCL, the patch program PATCHER/CMD, and the LDOS patch file LDOS/PAT. This should leave you with enough space to edit, compile, and execute the DATABASE/PCL program. You will have to delete the DATABASE/OBJ created by the compiler each time before you edit the DATABASE/PCL. Otherwise, there will not be enough space for the editor temporary file.

Take the second "Disk 1 of 2" disk and delete the following files: the DATABASE/PCL program, PATCHER/CMD, and LDOS/PAT. This disk can be used to develop new programs. There will not be much free space available. You may want to delete the editor help files and external declaration files to provide additional space.

Take one of the "Disk 2 of 2" disks and delete the following files: CODEGEN/CMD, OPTIMIZE/CMD, and CODEINIT/DAT. This disk may then be used to compile larger programs or to link together separately compiled program segments.

Take the other "Disk 2 of 2" disk and delete all the files except CODEGEN/CMD, OPTIMIZE/CMD, and CODEINIT/DAT. This disk may be used to reduce object code size or increase object code execution speed.

There are many other possible configurations. You may want to configure several more disks with fewer files to provide more disk space for development. For example, you may want a disk which just contains the editor and associated help files and another disk which just contains the compiler.

#### Example 2 drive Model I Configuration

-----

On the Model I, you may use the three disks as initially configured. You should make several copies of your TRSDOS 2.3 disk and use these disks to store the programs being developed. If desired, you may delete all the TRSDOS files to provide more free disk space. You should then do all development with your TRSDOS disk in drive 0 and one of the three Pascal disks in drive 1. The developed programs should be stored on drive 0.

As an alternative, you may configure several TRSDOS 2.3 disks and copy specific Pascal files onto each system disk. Drive 0 will then contain the operating system and Pascal files, freeing Drive 1 to store the programs being developed.

note: The above configuration also applies to LDOS. However, you cannot delete all the LDOS system files. See your LDOS manual for a description of the files which may be deleted.



## IMPORTANT

=====

IF YOU INTEND TO EXECUTE THE TRS-80 PASCAL SYSTEM WITH THE SUPPLIED TRSDOS 1.3 OPERATING SYSTEM ON THE MODEL III OR WITH YOUR TRSDOS 2.3 OR LDOS 5.1.x OPERATING SYSTEM ON THE MODEL I, YOU MAY SKIP THE FOLLOWING PAGES ON PATCHING.

### MODEL I LDOS USERS

=====

TRS-80 Pascal MUST NOT BE PATCHED for use with LDOS on the model I. LDOS on the model I is capable of reading TRSDOS 2.3 formatted diskettes. The configured diskettes may be used directly. However, if you have the Model I double density modification, you may want to copy the configured diskettes to a double density formatted diskette to provide more free space. The Pascal file RUN/CMD must be renamed to prevent conflict with the LDOS RUN command.

(eg. RENAME RUN/CMD TO PRUN/CMD)

#### Model I Hard Disk Users:

Use the BACKUP utility to copy the Pascal files from the floppy diskettes to the hard disk. The OLD parameter should be specified with the BACKUP command.

(eg. BACKUP :4 :0 (OLD) )

This command will prompt you with the name of each file on the floppy diskette in drive 4. Type Y <enter> for each file you wish to transfer to logical drive 0 of the hard disk.

### MODEL III LDOS USERS

=====

TRS-80 Pascal MUST BE PATCHED for use with LDOS on the Model III. Failure to do so will cause unpredictable results when you try to execute Pascal command files. All patching should be performed while using TRSDOS 1.3 (supplied). Follow the steps outlined on the following pages to patch the Pascal system for use with LDOS on the Model III.

NOTICE - LDOS IN THIS MANUAL REFERS TO THE FLOPPY BASED VERSIONS 5.1.x AND THE RADIO SHACK HARD DISK OPERATING SYSTEM.

THE TRS-80  
PASCAL PATCH PROGRAM

The TRS-80 Pascal system includes a program for patching disk files. This program is used to apply all current and future patches to the Pascal system. All patches to TRS-80 Pascal files should be applied with the PATCHER program since it contains extensive error checking to assure that patches have been applied correctly. The following is an outline of the patch process.

```
*****  
*                                     WARNING                                     *  
* NEVER APPLY PATCHES TO THE MASTER DISKETTES. MAKE A                          *  
* BACKUP COPY AND APPLY PATCHES TO THE COPY.                                  *  
*****
```

1. Make a backup copy of the master diskette.  
Do not apply patches to the master diskette .
2. The text of the patches should be entered into a file using the text editor if in printed form.
3. Load the diskette containing the file named PATCHER/CMD and type PATCHER <enter>. After the program has been loaded, the diskette containing PATCHER may be removed.
4. The program will prompt for the drive number to be used for the patching process. All diskettes that are to be patched must be inserted into this drive during the patch process.
5. Enter the name of the file or device to be used for the listing. The patch program will echo a patch file listing to this file and will display any error messages there. Instead of a filename, :L may be entered. This causes the listing to go to the printer.
6. Enter the name of the file containing the patches. This is known as the patch control file. The patch control file must remain on-line during the entire patching process. On two drive systems, the patch control file should be on the system diskette. (The patch control file required to modify TRS-80 Pascal for operation with LDOS on the Model III is on "Disk 1 of 2" in a file named LDOS/PAT . )

7. Change diskettes when prompted to do so. If any errors are detected, error messages will be displayed and the patches will not be applied. If a patch file requires diskettes to be changed, and they are not, error messages will be generated for those files not present on the diskette in the patch drive. They may be ignored if those files are not required to be patched.

NOTE - Once a file has been successfully patched, it may not be patched again using the same patch control file. This is because all patch control files contain information about the text that was previously in the file to be patched. Once the file has been altered, then that information is no longer valid. If you are not sure that the patches have been applied properly, make a backup of the master diskette and re-apply the patches using the patch control file.

#### Example Patch Session

The following is an example of how to patch the Pascal System for execution under LDOS on the Model III. The patching should be performed using TRSDOS 1.3. After the patching is complete, the files may be converted to LDOS format using the CONV utility of LDOS. The example assumes a two drive model III computer system with a printer connected.

- 1) Insert a disk containing TRSDOS 1.3 into drive 0.
- 2) Insert "Disk 1 of 2" into drive 1.
- 3) Type COPY LDOS/PAT:1 :0 <enter>.
- 4) Type PATCHER <enter>.

The following information will be prompted for at the terminal. Answer the prompts as shown. When prompted to load disk PASCAL1, insert "Disk 1 of 2" into drive 1. When prompted to load disk PASCAL2, insert "Disk 2 of 2" into drive 1.

```
ENTER DISK DRIVE FOR PATCHES: 1 <enter>
LISTING = :L <enter>
ALCOR SYSTEMS DISK PATCH UTILITY 1.0 (C) 1982
PATCHES = LDOS/PAT <enter>
LOAD DISK : PASCAL1 INTO DRIVE 1
PRESS <ENTER> WHEN READY <enter>
LOAD DISK : PASCAL2 INTO DRIVE 1
PRESS <ENTER> WHEN READY <enter>
STACK USED = 514 OF 4032 HEAP USED = 1574 OF 29832
TRSDOS Ready
```

Since :L was specified for the listing file, the patch listing will be printed. The following listing should be printed as shown on your printer.

ALCOR SYSTEMS DISK PATCH UTILITY 1.0 (C) 1982

```
;
;  TRS80 MODEL III FOR LDOS
;
F, RUN/CMD, PASCAL1
P,15BC,0578,0001,00,13
P,0DFF,05AC,0001,03,00
W,F4DC
;
F, PASCAL/CMD, PASCAL1
P,134C,054A,0001,00,13
P,0ED1,0554,0001,03,00
W,F562
;
F, ED/CMD, PASCAL1
P,11ED,057D,0001,00,13
P,0BD5,055E,0001,03,00
W,F525
;
F, PATCHER/CMD, PASCAL1
P,0FAL,054E,0001,00,13
P,0B16,0529,0001,03,00
W,F589
;
F, LINKLOAD/CMD, PASCAL2
P,15BC,0578,0001,00,13
P,0DFF,05AC,0001,03,00
W,F4DC
;
F, PASCALB/CMD, PASCAL2
P,0D5C,056E,0001,00,13
P,1575,051E,0001,03,00
W,F574
;
F, CODEGEN/CMD, PASCAL2
P,111A,0535,0001,00,13
P,0C9F,0583,0001,03,00
W,F548
;
F, OPTIMIZE/CMD, PASCAL2
P,111A,0535,0001,00,13
P,0C9F,0583,0001,03,00
W,F548
E
```

- 5) Insert a copy of your LDOS operating system disk into drive 0.
- 6) Delete all non-essential operating system files. (See your LDOS manual for information on configuring a minimum operating system disk. Do not delete CONV/CMD.)
- 7) Make a backup of your minimum operating system disk.
- 8) Insert a minimum LDOS operating system disk into drive 0.
- 9) Insert the patched "Disk 1 of 2" into drive 1.
- 9) Type CONV :1 :0 <enter>.
- 10) You will be prompted as to whether or not to convert each of the files from drive 1 to drive 0. Answer N <enter> for all TRSDOS files and Y <enter> for all Pascal files.
- 11) Repeat steps 8 through 10 using the other minimum configured LDOS operating system disk in drive 0 and "Disk 2 of 2" in drive 1.
- 12) Rename the file RUN/CMD on the backup of "Disk 1 of 2" to prevent conflict with the LDOS RUN command. (eg. RENAME RUN/CMD TO PRUN/CMD)

#### MODEL III HARD DISK USERS

---

The converted diskette files may be copied from the floppy diskettes to the hard disk by using the BACKUP utility. Specify the OLD parameter with the BACKUP command. Do not copy the LDOS system files to the hard disk.

(eg. BACKUP :4 :0 (OLD) )

The above command will cause a prompt for each file on the diskette in drive 4. Type Y <enter> for each file you wish to copy from the floppy diskette in drive 4 to drive 0 of the hard disk.

## USING THE EDITOR

---

Programs are entered through the use of the Blaise text editor. The disk containing the file ED/CMD must be in one of the drives before the editor may be used. Before using the editor, you should check the amount of free disk space available. The editor creates a temporary file during an edit session which is a copy of the file being edited. There must be enough free disk space to store both the temporary file and the file being edited or the editor will not be able to save the file at the end of the edit session. If there is very little disk space available, you should delete any unnecessary files to provide adequate disk space.

The editor may be used to create a new file or edit an existing file. A new file is created by simply typing ED <enter>. The editor is then loaded and the symbol \*EOB is displayed at the top left corner of the screen. An existing file may be edited by typing ED filename <enter> where filename is any valid TRSDOS file name. After the editor is loaded, it loads the first 100 lines of the specified file into a buffer and displays the first 16 lines on the screen. The \*EOB symbol will appear after the last line loaded into the buffer.

The editor uses a fixed size text buffer capable of storing approximately 13000 characters. The \*EOB symbol is used to indicate the "end of buffer". When creating a new file, the buffer starts out empty. Before text may be entered, it is necessary to insert blank lines into the buffer. Blank lines are inserted into the buffer by simultaneously pressing the SHIFT and @ keys. After inserting several blank lines, you may simply type in text. The <enter> key causes the cursor to be positioned to the beginning of the next line. The arrow keys may be used to position the cursor any place in the text. The arrow keys cause the cursor to move one character in the direction indicated by the arrow (left, right, up, or down).

There are several other editor commands which aid the edit process. Normally, when a character is typed, the character under the cursor is replaced by the typed character. However, if you first press the CLEAR key, followed by the I key, the editor will insert subsequent typed characters at the current cursor position. This provides a way of inserting characters in the middle of a line. The character under the cursor may be deleted by simultaneously pressing the SHIFT and "left arrow" keys. The line under the cursor may be deleted by simultaneously pressing the SHIFT and "right arrow" keys. Since the text buffer is large enough to hold several screens of text, there are commands provided which allow you to scroll the text through the screen display. Pressing the CLEAR key followed by the "up arrow" key causes the display to scroll toward the beginning of the buffer. Pressing the CLEAR key followed by the "down arrow" key causes the display to scroll toward the end of the buffer. Many other commands are explained in the EDITOR Manual. For now though, these commands are sufficient to allow you to edit.

The editor has a mode of operation called command mode. Command mode allows you to execute a specific set of editor commands by typing a command name. You must enter command mode in order to execute the command which causes the edit session to terminate.

Command mode is entered by typing the CLEAR key followed by the C key. When CLEAR C is typed, angle brackets <> will appear at the bottom left corner of the screen and the cursor will be placed to the right of the brackets. The editor is now waiting for you to type a command name followed by the <enter> key. There are two commands which will cause the edit session to terminate. One command is EXIT and the other is QUIT. EXIT should be used if you wish to save the edited text to a file. QUIT should be used if you wish to terminate the edit session without saving the edited text. While in command mode, the left arrow key may be used to delete the character prior to the cursor if you make a typing mistake.

If you wish to save the edited text, type EXIT <enter>. The editor then prompts you to enter a file name as follows: <EXIT>FILE: Type in any valid TRSDOS file name, including drive specifier if desired. For example, TEST/PCL:1 would save the edited text to the file TEST/PCL on drive number 1. Pascal source files should always be given the extension /PCL. If no drive is specified, the editor will place the file on the lowest numbered non-write protected drive with free space. You should always make sure that there is enough free space on the drive to hold two copies of the file being edited. As the editor is exiting, it will first display EXIT IN PROGRESS at the bottom of the screen. While this message is being displayed, the editor is writing the text to a temporary file named T011/TMP. Next the editor will display RENAME FILE at the bottom of the screen. While this message is being displayed, the editor is copying the temporary file T011/TMP to the file specified when the EXIT command was executed. Once the copying has completed with no errors, the editor deletes T011/TMP. If an error should occur, T011/TMP may be used to recover the file.

If a file was specified when the editor was initially executed, it is not necessary to specify a file name for the EXIT command. Simply type <enter> to the prompt and the text will be written to the file specified with the ED command. Of course, a drive number could have been specified with the ED command. For example, ED TEST/PCL:1 will cause the editor to load the file TEST/PCL from drive number 1. From the editor command mode, simply press <enter> when prompted with <EXIT>FILE: and the text will be saved to file TEST/PCL on drive 1. The editor also will use drive 1 for the temporary file T011/TMP.

If you wish to discard the edited text, type QUIT <enter>. The editor then prompts you as follows: <QUIT>REALLY? Type Y <enter> if you wish to terminate the edit session and return to TRSDOS. Type N <enter> if you wish to return to the edit session.

## ENTERING A SIMPLE PASCAL PROGRAM

---

Now that you know how to use the editor, a simple Pascal program may be created. From the TRSDOS Ready prompt, type ED <enter> and the editor is loaded. Since no file was specified, \*EOB will appear at the top left corner of the screen. Press SHIFT @ four times to enter four blank lines into the buffer. Then type in the following text.

```
PROGRAM TEST;
BEGIN
  WRITELN(' THIS IS MY FIRST PROGRAM. )
END.
*EOB
```

Once the text as been entered as shown above, type CLEAR C to enter command mode. Execute the exit command and answer the two prompts as shown below.

```
<> EXIT<enter>
<EXIT>FILE: TEST/PCL<enter>
```

The program will be saved to the file TEST/PCL and the editor will exit to the operating system.

Now you are ready to compile the program. At this point you should be aware of a couple of special keys which may be used when a Pascal program, including the compiler, is executing. All Pascal programs periodically scan the keyboard to see if a key is being pressed. If the "@" key" is being pressed, the program will stop execution until the <enter> key is pressed. Pressing the <enter> key resumes execution. During a compile, this feature will allow you to continually stop and resume the compile while viewing the listing being generated. If the "BREAK key" is being pressed, the program will terminate and return to the operating system. This feature provides a way of terminating a compile if an error is detected and you wish to correct it before continuing the compile.

## COMPILING THE PROGRAM

The compiler must now be used to translate the Pascal program to object format. Once in object format, the program may be executed. At the TRSDOS Ready prompt, type the following to compile the program created on the previous page.

```
PASCAL TEST <enter>
```

The Pascal compiler will load and execute. It will open the file TEST/PCL and begin reading a line at a time from the file. As each source line is read, it is translated to object format. The compiler will write the object formatted code to the file TEST/OBJ. The compiler also sends a listing to the screen as it compiles. The listing will show if there are any errors in the program being compiled. The below listing was generated by compiling the sample test program.

```
TRS80 PASCAL VER: 02.00.00 13000000 00:00:21 03/12/83 PAGE 1
```

```
-----
1 PROGRAM TEST;
2 BEGIN
3 | WRITELN(' THIS IS MY FIRST PROGRAM. )
*****                                     ^202
4 | END.
*****   ^ 20, 4, 13
          4 ERRORS DETECTED

      4 ')' EXPECTED
      13 'END' EXPECTED
      20 ',' EXPECTED
202 STRING CONSTANT CANNOT SPAN LINES
```

```
STACK USED = 1715 OF 4096   HEAP USED = 3070 OF 5832
```

As you can see, the compiler detected some errors in the program. The compiler always writes an error message line following the line where the error was detected. The error message line begins with 5 asterisks to clearly indicate that an error was detected. It also contains a pointer to the line above at the approximate location of the error. Following the pointer is an error code telling the type of error detected. At the end of the listing, all generated error codes are listed with a brief explanation of the error.

All Pascal programs, including the compiler, use a section of memory which is divided into two parts. One part is the stack and the other part is the heap. The stack is used to store most variables. The heap is used to store dynamic variables and file descriptors. When the compile is finished, the amount of stack and heap used out of the total amount available is displayed on the screen.

Because of the context in a Pascal program, a single error in the program can generate multiple error messages. Usually, the first error code will describe the real cause of the error. In this example, the first error detected is on line 3, error code 202. Error code 202 says that a string constant cannot span lines. This error was caused by the failure to include a closing quote for the string in line 3. The other 3 detected errors are a side effect of the first error. The compiler automatically creates a file named

#### PASCAL/ERR

when errors are detected in a program. Only the lines containing errors, along with the error message line, are written to this file.

The program should now be corrected before it is executed. The following will cause the editor to execute and display file TEST/PCL on the screen.

```
ED TEST/PCL <enter>
```

Move the cursor to the third line of the program and add a closing quote just prior to the right parenthesis. The third line should then look as follows.

```
WRITELN(' THIS IS MY FIRST PROGRAM. ')
```

Type CLEAR C to enter command mode and type EXIT <enter> to exit the editor. The prompt <ENTER>FILE: may be answered by simply pressing the <enter> key.

Now the program may be compiled once again by typing the following.

```
PASCAL TEST <enter>
```

The following listing will be sent to the screen as the program is compiled.

```
TRS80 PASCAL VER: 02.00.00 13000000 00:00:21 03/12/83 PAGE 1
```

```
-----  
1 | PROGRAM TEST;  
2 | BEGIN  
3 |   WRITELN(' THIS IS MY FIRST PROGRAM. ')  
4 | END.
```

```
TEST  
NO ERRORS DETECTED  
NO ERRORS DETECTED
```

```
STACK USED = 1715 OF 4096   HEAP USED = 3070 OF 5832
```

This time no errors were detected. The program is a legal Pascal program. Now that the program has been compiled with no errors, it may be executed.

## RUNNING THE PROGRAM

---

Once the program has been compiled without errors, it can be executed with the RUN command. At the TRSDOS Ready prompt, type the following to execute the sample program.

```
RUN TEST <enter>
```

The files used in a Pascal program are logical files. This means that the name of a file used in the program is not necessarily the same name as the actual physical disk file name. When a file is opened within a Pascal program, a prompt will appear on the screen. The prompt identifies the logical file name used in the program. You should then type in the actual disk file name which will be used when the program performs input or output to that logical file. This provides you with the ability to direct input and output to different files or devices each time the program is executed.

Two standard predeclared logical files in Pascal are INPUT and OUTPUT. These files are automatically opened when a program is executed. Therefore, each time you execute a program, the following prompts appear on the screen. (note: the SETACNM library procedure, explained in the System Implementation Manual, may be used to eliminate file prompts)

```
INPUT   =  
OUTPUT  =
```

The prompts occur for these two logical files whether they are used in the program or not. If you type in a file name, the program will use that file name when performing input or output. You may also simply type the <enter> key in reply to a logical file prompt. If the logical file is an input file, input will be received from the keyboard. If the logical file is an output file, output will be sent to the screen (or CRT).

The sample program uses only the logical file OUTPUT. This logical file is implicitly used by the Writeln procedure. You may simply press the <enter> key for both the INPUT and OUTPUT file prompts. The Writeln procedure will then cause the following to be printed on the screen.

```
This is my first program.
```

When a program terminates, (ie. finishes execution normally), the address of the last instruction executed is displayed on the screen. Following this is the amount of stack and heap used by the program. The stack and heap are explained in the System Implementation manual. The miscellaneous patch section of the system manual also explains how to prevent this information from being displayed.

The file names that you type to direct Pascal input and output are the same format as normal TRSDOS file names. The disk drive specification is optional as in TRSDOS. Devices may also be specified instead of a file name. For example, the name of the line printer is ":L". The name of the terminal, which is the keyboard for input and the CRT for output, is ":C". Simply typing the <enter> key is equivalent to typing ":C". There is also a dummy device. If a logical file is associated with ":D", then no actual output occurs. This is useful if you wish to discard certain outputs. For example, the listing may be discarded during a compile or you might discard some of the output generated by a program when it is executed.

The Pascal compiler always uses the extension PCL if the file name is specified when the compiler is executed. The compiler may also be executed by simply typing PASCAL without a file name. If executed in this manner, the compiler will prompt for the Pascal SOURCE file name, the file to use for the LISTING, and the file to use for the OBJECT. Either a file name or a device may be specified. If a file name is specified, the complete file name, including extension, must be used (ie. the compiler does not use default extensions).

The RUN utility uses the default extension OBJ if no extension is specified in the file name. You may also specify an extension if the object code is in a file named with an extension other than OBJ. For example, RUN TEST/COD might be used.

#### Alternate Symbol Representations

The TRS-80 Pascal compiler recognizes alternate representations of certain symbols because the TRS-80 keyboard does not generate them. Symbols with alternate representations are:

symbol	alternate
{	(*
}	*)
^	@
[	(.
]	.)

## TROUBLE SHOOTING GUIDE

### Miscellaneous Errors

1. Problem - While editing a file, the latter part of a file is found to be missing.  
Answer - Need to use the APPEND command to page the latter part of the file into the text buffer. See the editor manual.
2. Problem - Upon exiting the editor, a PHYSICAL IO error message is displayed.  
Answer - The diskette was full or not in the drive. See the editor manual for recovery of the original file from the TOLL/TMP work file.
3. Problem - During a compile, the Pascal compiler abnormally terminates with a FATAL ERROR - OUT OF HEAP, or OUT OF STACK  
Answer - The compiler does not have enough memory space due to: (a) Too large a program. (Use PASCALB version)  
(b) There are high memory drivers in place that limit the amount of memory space the compiler has, (such as the KSM driver in LDOS or a printer spooler). Remove the high memory driver or use PASCALB. See the System Manual for various ways to invoke the compiler with alternate stack parameters.
4. Problem - When executing your compiled program with the RUN command, or a command (/CMD) file built with the LINKLOAD utility, it abnormally terminates with the FATAL ERROR - OUT OF HEAP, or OUT OF STACK.  
Answer - Increase the stack specification when invoking the RUN command or increase the stack specification when building the command file with the LINKLOAD utility. See the system manual.
5. Problem - After executing the compiler using the long form where the OBJECT and LISTING files are specified by the user, the original source file suddenly contains object code.  
Answer - The source file was specified as the object file when invoking the Pascal compiler.

6. When executing under LDOS, the RUN command is invoked with a Pascal object code file as an argument, and the error message: Load file format error is displayed.  
Answer - The Pascal RUN command must be renamed to RUNP or something that does not conflict with the LDOS RUN command. You are attempting to execute Pascal object code with the LDOS RUN utility.
  
7. Problem - During an edit, you try to insert the external Pascal declarations for the TRSLIB library by specifying individual function and procedure names, and nothing is inserted by the editor.  
Answer - All of the declarations are contained in a file named TRSLIB/PCL. This file must be inserted to place the declarations into the source file.
  
8. Problem - The compiler continues to compile after the end of the entered source code is encountered and garbage text is displayed to the listing.  
Answer - The Pascal system files have not been patched for execution under LDOS on the Model III.

## COMMON ERROR MESSAGES

### (By the Compiler)

- 13 END expected - There must be an END for every BEGIN in a Pascal program.
- 52 THEN expected - IF statements require use of the reserved word THEN.
- 54 DO expected - FOR statements require use of the keyword DO.
- 104 undeclared identifier - All variables must be declared in a Pascal program.
- 119 semicolon expected - The preceding declaration or statement is not terminated by a semicolon (;).
- 127 type of actual parameter does not match formal parameter - An attempt to call a procedure or function with an argument that does not match the type of the formal parameter. In special cases, the type matching requirements may be overridden by using the type transfer operator.
- 129 type conflict of operands in an expression - An attempt to use an operator with two variables of different types.
- 154 actual parameter must be a variable - Using a constant instead of a variable when calling a procedure whose formal parameter is preceded by VAR.
- Unexpected End of File - A period does not follow the last END of the program or a comment is missing the closing comment symbol.

### (Runtime Error Messages)

The error codes discussed above are generated by the compiler due to an error in the Pascal source program. There are times when the compiler may generate a fatal error message that is not due to an error in the source program. These are called runtime errors because they are detected by the runtime that is included with all Pascal programs, including the compiler. The following are examples of runtime errors.

RUNTIME ERROR 01    OUT OF STACK  
(Caused by trying to compile or run too large a program)  
RUNTIME ERROR 02    OUT OF HEAP  
(Caused by trying to compile or run too large a program)  
RUNTIME ERROR 09  
(file not found or disk error)

Note: Explanation of COMPILER and RUNTIME error codes may be found in the appendix of the Language Reference Manual.

## COMMON PROGRAMMING MISTAKES

1. For variable types to match in expressions and not generate compiler error messages, they must be explicitly declared to be of the same type in the declaration section. For example:

```
PROGRAM TEST;
VAR A:ARRAY[1..5]OF CHAR;
    B:ARRAY[1..5]OF CHAR;
BEGIN
    A:=B;
END.
```

will generate a type conflict message by the compiler although the types appear to match. The following example will not generate an error message and is perfectly legal in Pascal.

```
PROGRAM TEST;
VAR A,B:ARRAY[1..5]OF CHAR;
BEGIN
    A:=B;
END.
```

or

```
PROGRAM TEST;
TYPE D = ARRAY[1..5]OF CHAR;
VAR A:D;
    B:D;
BEGIN
    A:=B;
END.
```

2. A procedure declaration that has non-NAMED types in the parameter list is illegal in Pascal (ie. the following is illegal).

```
PROGRAM TEST;
    PROCEDURE EXAMPLE(VAR A:ARRAY[1..5]OF CHAR); EXTERNAL;
BEGIN
END.
```

The following is legal:

```
PROGRAM TEST;
TYPE D = ARRAY[1..5]OF CHAR;
    PROCEDURE EXAMPLE(VAR A:D); EXTERNAL;
BEGIN
END.
```

3. Placing a ; (semicolon) character before the ELSE part of an IF THEN ELSE statement is illegal.



# Editor Manual

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## GETTING STARTED

### PLACEMENT OF EDITOR ON THE DISK

The editor system is composed of the main editor file labeled ED/CMD and several help files labeled with the /HLP file extension name. These files may be copied to any disk for use. The help files contain HELP messages that may be viewed while in the text editor. They are not required to be present. If they are not present on the same disk as the ED/CMD program, no help information may be obtained during the edit session.

### EDITOR WORK FILE

The text editor creates a new text file that is a copy of the file being edited. All editing changes are made to this work file.

( TOLL/TMP ) This is a protection feature to prevent any fatal hardware or software errors during the edit from destroying the edited file. After the editor successfully exits, and consistency checks have been made, the work file becomes the new copy of the edited file. The old copy is then deleted. This requires that there always be a minimal amount of disk space available on the disk where the work file exists. If during an exit, the disk on which the work file or the original file is placed runs out of disk space, the editor will flag an error message allowing an abort or appropriate actions to be taken. If an error occurs during the RENAME part of the exit command, (ie. while the work file is being copied back to the original file) then TOLL/TMP should contain the edited file. It may be used to restore the original file should the original become damaged. The work file is placed on the lowest numbered non-write protected drive unless a file name with a drive specifier was used when invoking the editor. In this case, the work file is placed on the specified drive.

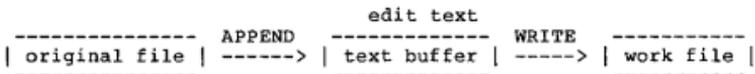
### TYPE OF FILES THAT MAY BE EDITED

New or old files may be created or edited. The size of files that may be edited is only limited by the disk space available on a disk. Files may not be split across disk boundaries. This means that the whole file must reside on a single disk. The file name syntax is the same as that allowed by TRSDOS. The text editor files are compatible with normal TRSDOS Basic files, TRS-80 Pascal source and object files, or any other ASCII formatted files that comply with TRSDOS file conventions.

## TEXT BUFFER MANAGEMENT

The editor maintains a fixed size buffer for storing text. The buffer will hold approximately 13000 characters. All editor commands except for specific file commands operate only on the text in this buffer. When editing very large files, the file must be edited a section at a time. Starting at the beginning of the file, a section is loaded into the text buffer. Before loading another section of the file into the buffer, buffer space must be made available by writing the text out to a work file. Then the next section may be loaded into the buffer. This process may be repeated until the whole file has been loaded and edited.

When editing an existing file, the editor loads the first 100 lines only. This leaves ample buffer space for adding more lines and performing the various editing functions. If the file is longer than 100 lines, the APPEND command may be used to load more text from the file into the buffer. With this command, you specify how many lines to copy from the file to the buffer. The copying begins one line past the last line previously loaded from the file. The text being copied from the file is appended to the end of the text in the buffer. If the file is very large, it is possible for the buffer to become full. If this happens, a MEMORY EXHAUSTED message is displayed. The WRITE command must then be used to write some of the text in the buffer back out to a work file. With this command, you specify how many lines to copy from the buffer to the work file. The copying begins with the first line in the buffer and continues until either the buffer is empty or the specified number of lines have been written. Once lines have been written from the buffer to the work file, they may not be edited again during the current edit session. The following diagram illustrates this process.



If the editor is exited before the entire file has been loaded into the buffer, the editor will copy the remaining lines in the original file to the work file.

The editor displays one of two symbols at the end of the text buffer. The EOB symbol signifies the end of the buffer. If editing a pre-existing file, the symbol displayed will be EOF if all text has been loaded from the original file into buffer.

REMOVAL OF DISKS FROM DRIVES  
DURING AN EDIT SESSION

The disk containing the ED/CMD file may be removed after an edit session has begun, subject to the following restrictions :

- (1) There always must be a disk with an operating system installed in the designated system drive. This disk may be swapped during the edit session as long as the new disk contains a valid operating system, and the change does not violate (2)-(4).
  - (2) Removal does not cause the disk containing the editor workfile to be removed.
  - (3) If help files are removed, then no HELP messages will be available.
  - (4) Before exiting the editor, or appending lines to the text buffer, the disk containing the original file is replaced in the drive.
- \* If the above rules are followed, you may change disks in order to use the INSERT FILE command in the editor.

## EDITOR COMMANDS

Editor commands may be accessed by two different methods. One is by entering certain pre-defined key sequences, and the other is by entering a mode that allows command names to be typed.

A key sequence command is executed by (1) simply pressing a labeled key, or (2) pressing the CLEAR key, then a labeled key, or (3) holding the shift key down while pressing a labeled key.

There are certain commands that are only accessible from command mode. They primarily are used for setting editor parameters or for performing commands that require prompted input from the user. For all following discussions, the mode which allows key sequence commands shall be referred to as the compose mode, and command name entry as the command mode.

All editing is performed on text that is loaded into a text buffer. This buffer holds new text data entered or may append text data from an existing TRSDOS file. As editing is performed, the updated buffer may be written to the file as desired.

### HOW TO START

To execute the text editor, simply type from TRSDOS Ready:

ED filename <enter>

### NEW FILES

To create a new file, leave the filename field blank. The editor will clear a new text buffer. The screen will be cleared and will display \*EOB at the top left corner. A cursor will be displayed in column one of the display. The editor automatically enters the compose mode upon startup. A blank line must be inserted into the empty text buffer before any text may be inserted. A blank line may be inserted by pressing the shift key while at the same time pressing the key labeled "@" . The blank line will always be inserted before the cursor line. After several blank lines have been inserted into the buffer, text may be typed directly into the buffer. The text is always entered into the buffer beginning at the position of the cursor. If the cursor is positioned over any text, as each new character is entered, the old character is overwritten. If text is to be inserted in the middle of an existing line, simply press the clear key followed by the I key. Any new text typed will be inserted at the cursor position causing the rest of the line to move to the right. The insert setting is canceled when any command such as a cursor movement is performed.

COMPOSE MODE

CURSOR MOVEMENT

The following denotes a key sequence.  
Shift/key =====> press shift and key simultaneously.  
Clear/key =====> press clear key, then labeled key.

The cursor may be positioned any place on the screen by pressing any of the following labeled keys while in the compose mode.

↑	Cursor up one line. If the cursor is at the top of screen, then the screen scrolls one line.
↓	Cursor down one line. If the cursor is at the bottom of the screen, then the screen scrolls one line.
→	Cursor to the right one character. If cursor is at the right edge of the screen, then no movement occurs.
←	Cursor to the left one character. If the cursor is at the left edge of the screen, then no movement occurs.
<enter>	Cursor to the beginning of the next line.
Clear/ ←	Cursor to the beginning of line.
Clear/ →	Cursor to the end of line.
Clear/ ↑	Scroll the display one page toward the beginning of file.
Clear/ ↓	Scroll the display one page toward the end of the file.
Clear/T	Tab right. If the cursor is at the right edge of the screen, then the cursor wraps around to the leftmost tab stop.
Clear/B	Tab left. If the cursor is at the left edge of the screen, then the cursor wraps around to rightmost tab stop.
Clear/H	Positon cursor to the top left of display. (Home)

#### TEXT DELETION

Shift/ →	Delete character under the cursor.
Shift/ ←	Delete the entire line under the cursor.
Clear/K	Delete text from cursor to the end of the line.

#### TEXT INSERTION

Clear/I	Enter insert character mode. This allows text to be inserted anywhere in an existing text line. Place the cursor at the desired location, press Clear/I, and type in the text.
Shift/@	Insert a blank line into the text buffer.
Clear/D	Duplicate the line above onto the cursor line. Text to the right of the cursor position is replaced by a copy of the text on the line above.

#### EDITOR PARAMETERS AND SETTINGS

Clear/A	Toggle the auto indent setting. Auto indent causes the enter key to align the cursor with the first non-blank on the next line. If the next line is blank, the cursor is placed below the first non-blank on the line above. This feature is useful when Pascal programming with indentation.
Clear/S	Sets the typewriter like tab stop at the current cursor position. The editor has preset tab stops which may be cleared in command mode using the TABS command.
Clear/Y	If a tab exists at the current cursor position then it is cleared.
Clear/?	Display the amount of unused memory available for text buffering.
Clear/C	Enter command mode.

## TEXT MODIFICATION

Clear/G	Merge the line after the cursor with the cursor line.
Clear/O	Split the cursor line into two lines at the cursor position.
Clear/F	Search forward in the text buffer for the next occurrence of the string in the find string buffer. The find string buffer is loaded with the search string in the command mode by the FIND command.
Clear/R	Search forward in the text buffer for the next occurrence of the string in the find buffer and replace with the contents of the replace buffer. The buffers are loaded with strings in the command mode by the REPLACE command.

## SPECIAL CHARACTERS

Certain characters are not present on the TRS-80 keyboard. They may be generated by the following clear key sequence.

Sequence	Character
clear 1	{
clear 2	}
clear 3	^
clear 4	{
clear 5	}
clear 6	
clear 7	-

## COMMAND MODE

If while in the compose mode a Clear/C key sequence is typed, the editor will enter command mode. A pair of angle brackets along with the cursor should appear at the bottom left corner of the display. There are 16 additional commands that are available in command mode that are not accessible in the compose mode. They are primarily used for setting editor parameters or require prompted information from the user. After a command has been executed in the command mode, the editor will automatically re-enter the compose mode and place the cursor at its new position in the text. Command name abbreviations are allowed for all commands.

When in command mode, the command line may be edited using the left arrow key. Pressing the left arrow will delete the last character on the line and move the cursor back one column. Command entry may be aborted by pressing shift/left arrow. This will return the editor to compose mode.

## COMMAND PARAMETERS

Some commands that may be accessed in command mode require user input parameters for execution. All such commands may be invoked by two different methods in the command mode. Beginners may simply type the command name and then press the enter key. If any parameters are required, the editor will prompt the user for the parameters. All parameter entries should be terminated by pressing the enter key. Advanced users may desire to enter the parameters after the command name on the same line. If all of the parameters are entered on the same line as the command name, pressing the enter key will cause the editor to immediately execute the command. If all of the parameters were not entered on the command line, the editor will prompt for the remaining unspecified inputs. The rule for entering command parameters on the command line is that any string parameter such as a file name must be enclosed or delimited by double quotes. An example would be "file name"

## COMMAND EXPLANATIONS

The sixteen additional commands available in the command mode are explained below. Where parameters are required, the command line form is included.

### APPEND numberoflines

The append command reads text from the original file and appends it to the end of the text buffer. After the append executes, a message will appear at the bottom of the display with the total number of bytes available for additional text. If the memory becomes exhausted, then text must be written to the work file by the WRITE command.

### WRITE numberoflines

A WRITE command will write to the work file the specified number of lines starting from the first line of the text buffer. As the write occurs, buffer space will be released. Once the specific lines have been written to the workfile, they may no longer be edited during the current session. They are permanently saved in the workfile.

### HELP topic

The help command will display help messages to the screen concerning the specified topic if help information is available. Supplied help topics include: HELP - General help information. CMD - Command mode information. KEY - Key definitions and compose mode information. If the subject is left blank, general help will be displayed. The help information may be viewed by using the same movement commands used in the showfile command. To exit, hit clear followed by "C".

#### SHOWFILE "filename"

The showfile command will open the desired file and display a portion of it. Several special commands may be issued while in the showfile command. They are:

```
=====
!
! Clear/^ Scroll the display up |
! one page in the file. |
! Clear/v Scroll the display down |
! one page in the file. |
! ^ Scroll the display up |
! one line in the file |
! v Scroll the display down |
! one line in the file |
! linenumbr Position absolutely to |
! line number in file. |
! + linenumbr Scroll specified number |
! - linenumbr of lines relative to current |
! cursor line. + rolls to the |
! end of buffer, - rolls to the |
! beginning of buffer. |
! Clear/C Return to editing |
=====
```

#### SHOWLINE linenumbr

The showline command is convenient for positioning absolutely to any line number in the buffer. Showline 1 is a quick way for positioning to the beginning of buffer, and Showline 9999 for positioning to the end of buffer.

#### INSFILE "filename" startline numberoflines

This command will insert a portion of any pre-existing file into the text buffer starting at the cursor location. Startline is the position in the file to be inserted where the insertion starts from. Numberoflines is the number of lines to insert. If the number of lines is greater than the last line in the file, then the insertion process stops at the last line. If the number of lines is greater than available memory in the buffer, then only the number of lines that will fit into memory will be inserted.

#### FIND "string"

The find command will search forward in the text buffer, (starting at the cursor position) for the specified string. If the string is found, cursor will be positioned at the first occurrence, at the beginning of the string. If the string is delimited by quotes, then leading or trailing blanks will be included in the search string.

#### REPLACE "old string" "new string"

Replace will search forward in the text buffer for the old string. (starting at the cursor position) If the old string is found, then the first occurrence will be replaced with the newstring, and the cursor repositioned at the beginning of the new string.

#### QUOTE "string"

The quote command is used when it is desired to insert some non-printable character into a file. It is also useful for inserting certain printable characters that are not on the TRS-80 keyboard into

the file. The quoted string is inserted at the current cursor position. Non-printable characters may be represented by a # followed by the two character hexadecimal number. (ASCII representation) For example, #5B is the left bracket. Non printable characters such as formfeed (#0C) will not be displayed by the editor. However, the find command may be used to locate such characters in the buffer.

+ numberoflines  
- numberoflines

The plus and minus commands are used to position the cursor a specified number of lines relative to the cursor line. (The blank after the + or - is required)

ROLL numberoflines

Roll will set the page size for all scrolling commands. It is set to 13 lines by default upon editor invocation.

HSCROLL column

The hscroll command will scroll the display horizontally to the left or right. This feature allows editing of files wider than the TRS-80 screen. Once a horizontal scroll is performed, the display will remain in this mode until repositioned by another horizontal scroll command. The column parameter is the new column position for the left edge of the screen. Max column for TRS-80s is 16.

TABS integer

TABS = integer,integer,integer....

TABS integer will set a tab stop every integer positions. All tabs may be cleared by setting integer to 0. The editor defaults to a tab stop every third character position. An alternate form of the command exists. Tabs may be defined as: TAB = integer,integer,integer... at the specified columns.

QUIT "answer yes/no"

Will abort an edit session. All changes to the original file are lost, and the original file is preserved.

EXIT "filename"

The exit command is used to successfully end an edit session. The exit command will write out the entire text buffer to the workfile. Any non-appended lines from the original file will also be written to the workfile. Once consistency checks have been made, file renaming or deletions will occur. If a filename was specified when entering the editor, you can respond with the enter key to the filename prompt. This will replace the old file that was edited. You can also specify the name of a new file. If the filename was left out when bidding the editor, a filename must be specified in the exit command.

#### IO ERROR DETECTION AND RECOVERY

When an error has been detected during diskette IO operations, the message: IO ERROR followed by the operating system error code will be displayed. You may type "Q" to allow the error to pass or any other key to cause a retry.

EDITOR CONTROL KEYS

KEY	alternate	FUNCTION
↑	CTL/U	Cursor up
↓	CTL/J	Cursor down
←	CTL/H	Cursor left
→	CTL/R	Cursor right
CLEAR ↑	CTL/B	Roll backward
CLEAR ↓	CTL/A	Roll forward
CLEAR ←		Cursor to BOLN
CLEAR →		Cursor to EOLN
SHFT →	CTL/P	Delete character
SHFT ←	CTL/N	Delete line
SHFT @	CTL/O	Insert line
ENTER	CTL/M	New line
CLEAR A		Toggle auto indent
CLEAR B	CTL/T	Back tab
CLEAR C		Command mode
CLEAR D	CTL/D	Duplicate line
CLEAR F	CTL/C	Find next string
CLEAR G		Merge two lines
CLEAR H	CTL/L	Home
CLEAR I	CTL/Q	Insert char mode
CLEAR K	CTL/K	Delete to EOLN
CLEAR O		Open line at cursor
CLEAR R	CTL/Z	Replace next string
CLEAR S	CTL/W	Set tab
CLEAR T		Tab
CLEAR Y		Clear tab
CLEAR ?		Display memory

COMMAND MODE

APPEND	Add text to buffer
EXIT	Exit and save file
FIND	Find string
HELP	Display help
HSCROLL	Horizontal scroll
INSFILE	Insert file
QUIT	Abort changes
QUOTE	Insert literal string
REPLACE	Replace string
ROLL	Set roll
SHOWFILE	Display a file
SHOWLINE	Position to line
TABS	Set tabs
WRITE	Write text to file
+	Move forward by lines
-	Move backward by lines

DEVICE NAMES

Name	Device
:L	Line printer
:C	Screen
:D	DUMMY

ASCII Character Set

Dec- imal	Hex	Name	Dec- imal	Hex	Name
0	00	NUL	11	0B	VT
1	01	SOH	12	0C	FF
2	02	STX	13	0D	CR
3	03	ETX	14	0E	SO
4	04	EO'T	15	0F	SI
5	05	ENQ	16	10	DLE
6	06	ACK	17	11	DC1
7	07	BEL	18	12	DC2
8	08	BS	19	13	DC3
9	09	HT	20	14	DC4
10	0A	LF	21	15	NAK

Dec- imal	Hex	Name	Dec- imal	Hex	Name
22	16	SYN	75	4B	K
23	17	ETB	76	4C	L
24	18	CAN	77	4D	M
25	19	EM	78	4E	N
26	1A	SUB	79	4F	O
27	1B	ESC	80	50	P
28	1C	FS	81	51	Q
29	1D	GS	82	52	R
30	1E	RS	83	53	S
31	1F	US	84	54	T
32	20	" "	85	55	U
33	21	!	86	56	V
34	22	" "	87	57	W
35	23	#	88	58	X
36	24	\$	89	59	Y
37	25	%	90	5A	Z
38	26	&	91	5B	[
39	27	'	92	5C	\
40	28	(	93	5D	]
41	29	)	94	5E	^
42	2A	*	95	5F	_
43	2B	+	96	60	␣
44	2C	,	97	61	a
45	2D	-	98	62	b
46	2E	.	99	63	c
47	2F	/	100	64	d
48	30	0	101	65	e
49	31	1	102	66	f
50	32	2	103	67	g
51	33	3	104	68	h
52	34	4	105	69	i
53	35	5	106	6A	j
54	36	6	107	6B	k
55	37	7	108	6C	l
56	38	8	109	6D	m
57	39	9	110	6E	n
58	3A	:	111	6F	o
59	3B	;	112	70	p
60	3C	<	113	71	q
61	3D	=	114	72	r
62	3E	>	115	73	s
63	3F	?	116	74	t
64	40	@	117	75	u
65	41	A	118	76	v
66	42	B	119	77	w
67	43	C	120	78	x
68	44	D	121	79	y
69	45	E	122	7A	z
70	46	F	123	7B	{
71	47	G	124	7C	
72	48	H	125	7D	}
73	49	I	126	7E	~
74	4A	J	127	7F	DEL



## SYSTEM IMPLEMENTATION MANUAL

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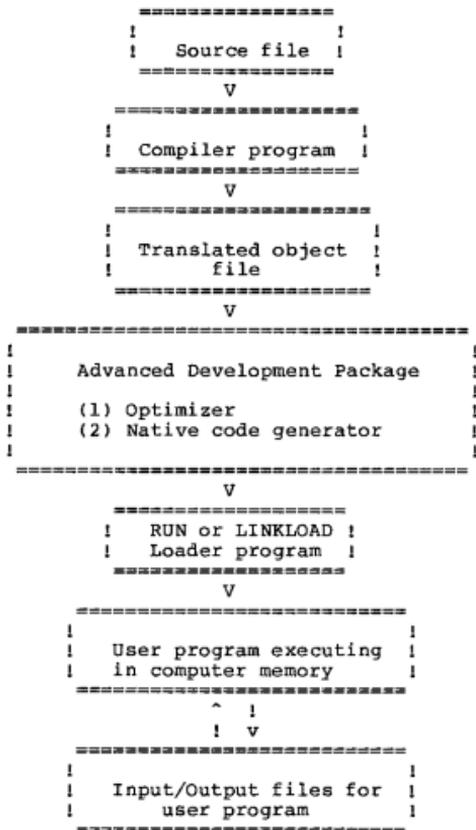


## INTRODUCTION

This manual describes the specific characteristics of TRS-80 Pascal as implemented on the TRS-80 Models I and III microcomputers. The implementation of TRS-80 Pascal on the two different models is the same except where noted. In every language system implementation, there are certain language features that vary upon computer implementation. One of the advantages of Pascal is that these variations are minor, and if a programmer minimizes the use of non-standard language extensions, source programs may be written that have a high degree of portability. Other machine dependent characteristics are such items as how to invoke the compiler and support utilities.

The process of building an executable Pascal program may be summarized by the diagram on the following page.

System overview diagram



## System Description

### PASCAL Compiler

The TRS-80 Pascal compiler is simply a program that is written in Pascal and that executes on the host computer. Its purpose is to translate Pascal source programs into an intermediate language called P-CODE. The p-code is a low level language designed specifically as a target language for the Pascal compiler and resembles the assembly language for a stack oriented computer. Once a program has been compiled, the object p-code program is stored in an intermediate file. The intermediate file may be loaded and executed by the host computer or run through the advanced development package.

### Advanced Development Package OPTIMIZE program

After the source program has been translated into object code, it may be processed by the OPTIMIZER. The purpose of the optimizer is to remove statement redundancy in the translated object code. This will effectively reduce the final size of the program by approximately 10-30 percent. The optimizer should be used when program size is important. The optimized p-code is an exceptionally compact representation of the Pascal program. This is evidenced by the fact that the Pascal compiler itself (an 8500 line Pascal program), can be run on a 48K machine without resorting to overlays.

### CODEGEN program

If program execution speed is important, the native code generator (codegen) program may be used to process the object program file. Codegen will generate native Z-80 code which may be directly executed by the processor. Execution speed is usually increased by a factor of 3 - 5 times. One of the drawbacks of code generation is that the resultant program will grow in object code size by a factor of 2 - 3 times over the p-code version. For large Pascal programs, (such as the compiler itself) the resultant program image may not fit into available memory. For small programs this may not be a factor. To combine the best of both worlds the codegen program will allow selective code generation of specific modules in a program. This allows the critical paths of a program to be translated into native Z-80 instructions, while at the same time reducing the overall program size by utilizing p-code for the rest of the program. If program size is not a factor, full code-generation may be performed.

### RUN Program

After the Pascal source program has been compiled, and/or processed by the advanced development package, it may be executed by the RUN program. This utility will directly execute the compiled object code without the use of the LINKLOAD program.

## System Description

### LINKLOAD program

After the compiler has translated the source code into p-code, the p-code file may be loaded into memory and executed. The program that performs this is the LINKLOAD utility. Its purpose is to load any number of object modules into memory. This allows separate compilation of procedures and functions. To perform separate compilation of a procedure or function, the compiler NULLBODY option must be used. For more information, see the TRS-80 Pascal Language Reference Manual. This linking loader includes an interpreter in the final load module that executes the p-code instructions when the program is run. The linking loader also has the capability of storing the memory image of the program as an executable command file. Once an image has been saved, the program can be executed simply by typing the file name at the TRSDOS command level. The linking loader and interpreter is a 9000 line program written in Z-80 assembly language.

### PASCALB ( Overlaid Pascal compiler )

The size of a Pascal program that may be compiled is dependent on the number of symbols used in the source program and not necessarily the number of lines in the program. The non-overlaid compiler should be able to compile a typical 1000 line program with all of its associated symbols. A further improvement can sometimes be made by separately compiling procedures or functions. If the program is too large for the non-overlaid compiler, the overlaid compiler may be used. The overlaid compiler has been segmented such that parts of it reside on the disk during execution, and are read into memory only as needed. The overlaid compiler will execute more slowly than the non-overlaid version, but generates identical object code. The overlaid compiler has enough space to compile a typical 4000 line Pascal program with all of its associated symbols.

## Using TRS-80 Pascal

The first step in developing a computer program is to define the problem and develop algorithms for the solution. Once the algorithms are specified, the next task is to translate them into a programming language. Pascal is a particularly good expression language for a large number of problems.

Once the program has been designed, the next step is to enter the program into the computer. This is normally accomplished with the aid of a text editor. A screen oriented text editor is supplied with the compiler. For details on how to use this editor, refer to the Editor manual. Once the program has been entered and saved, the next two steps are to compile and execute.

This section describes the procedures for performing the last two steps on the TRS-80. If you are not familiar with the Pascal language, refer to the TRS-80 Pascal Tutorial Manual for information on the language. For those familiar with Pascal, the Pascal Language Reference Manual contains compact detailed information on the features of TRS-80 Pascal.

### Compiling the program

Once the program has been entered into the computer and placed in a disk file, the next step is to compile it. The Pascal compiler translates the source program into a form that the computer can execute. For example, suppose that you have developed a program to prepare your income tax return. This source program may be stored in a file called: TAXES/PCL. The simplest method to execute this program is to type at TRSDOS Ready:

```
PASCAL TAXES <enter> to compile TAXES/PCL, creating TAXES/OBJ  
and  
RUN TAXES <enter> to execute TAXES/OBJ
```

Note: The PASCAL command appends the extension /PCL to the filename. The RUN command appends the extension /OBJ to the filename if no extension is specified.

This will compile and execute your program. Let's examine the process in more detail. The first command line causes the operating system to load and execute the Pascal compiler. The compiler then translates the Pascal source code contained in the file: TAXES/PCL into code that can be run on the computer. This code is stored in a file called: TAXES/OBJ. A listing will be sent to the CRT. The listing shows the source program and will contain error messages for any errors detected. (The listing will be described in more detail in a later section.) If errors are detected, error code numbers and error messages will be contained in the listing. The errors in the source program must be corrected before the program can be executed.

Once the program has been compiled without errors, it can be executed with the "RUN" command. "RUN TAXES" causes the object code stored in the file "TAXES/OBJ" to be loaded into memory and executed.

The first thing that a Pascal program normally does is to open the files "INPUT" and "OUTPUT". When this happens, the prompts:

```
INPUT =  
OUTPUT =
```

will appear on the screen. At this time you may enter the file or device to be used when the program reads from input or writes to output. If you simply press the enter key, then input and output will be directed to the screen. When any file is opened by a Pascal program (by calls to RESET or REWRITE), a prompt will appear on the screen. To the left of the equal sign will be the name of the file being opened. You should type the name of the disk file or device to be associated with that file. Note- The INPUT,OUTPUT prompts may be eliminated by the use of the (\*\$NO INOUT\*) option. See the Pascal Language Reference Manual for compiler options.

The runtime mapping of Pascal files to physical files and devices allows a program to redirect its input and output without any changes to the source program and without recompiling the program. For example, you could test the taxes program with the output going to the screen. When you are satisfied with the results, the output can be directed to a file or line printer instead.

The file names that you type to direct Pascal input and output are in the same format as normal TRSDOS file names. The disk drive specification is optional as in TRSDOS. There is one extension. Input and output to any Pascal file can be sent to physical devices as well as to a file. The device names are simple extensions to the disk names used by TRSDOS. For example, the name of the line printer is ':L', and the name of the CRT is ':C'. There is also a dummy device. If a file is associated with ':D', then no actual output occurs. This is useful if you wish to run the program and discard some of its output.

#### THE PASCAL COMMAND

The PASCAL command causes the Pascal compiler to be loaded and executed. This command has two forms. The simplest form is:

```
PASCAL <stack> filename <enter>
```

where file name is the name of a file containing a Pascal program. The <stack> is an optional parameter that sets an upper limit on memory space that the compiler may use for stack. The default size of 4096 bytes should be suitable for most applications. After a compile is finished, the amount of stack used is displayed on the screen. If the compile terminates due to OUT OF STACK, you should specify more stack. The angle brackets <> are required if the stack is specified.

In the short form, the extension for the source file is assumed to be /PCL and the object code is sent to a file of the same name but with the extension /OBJ. Any extension typed in the command line will be ignored. A disk drive number may be specified.

## Using TRS-80 Pascal

For example, `PASCAL TAXES:1 <enter>` will cause the program "TAXES/PCL:1" to be compiled and the object to be stored on disk drive one. In this case the same disk drive will be used for both source and object. If the disk drive is omitted, TRSDOS will search all the drives for the first occurrence of TAXES/PCL and will store the object on the lowest numbered drive that is not write protected. In the short form, the listing will always be displayed on the CRT screen.

The long form of the Pascal command uses simply: `PASCAL <enter>` to invoke the compiler. In this case, the file names for the source, object and listing will be prompted for on the screen. You should type the name of the actual files to be used. Normal TRSDOS syntax applies. In this case the file names are used as specified. The source and object can be on different disk drives and the listing can be placed in a file, sent to the screen or sent to the line printer. For example, the following sequence will cause the file: "TAXES/TMP" to be compiled with the object code stored in "TAXES/OBJ" on disk drive 2 and the listing will be sent to the line printer.

```
PASCAL <stack>
SOURCE = TAXES/TMP
LISTING = :L
OBJECT = TAXES/OBJ:2
```

## THE RUN COMMAND

The RUN command is used to load and execute a previously compiled Pascal program. The object code will be loaded and the program executed. The RUN command contains the object code for the TRS-80 support routines (such as SETPOINT, CLEARSCREEN, etc). Any of these routines can be called. If any other external procedures are required, the linking loader must be used to link these external procedures to the program. The run command is invoked as:

### RUN program

Pascal programs use a stack to store local variables and to save return addresses for procedure and function calls. This stack is allocated when the program is run and the required size is determined by the number and type of variables declared and the number of and sequence of procedure calls. Methods of estimating the amount of stack required for a program are included in a later section of this manual (see Estimating Stack Size).

## Using TRS-80 Pascal

The RUN command allows the amount of stack space to be specified on the command line. In the RUN command, the size of the stack is selected by following the program name with the stack size, separated with a blank or a comma. For example, the following line would cause the program DATABASE to execute with 15K (15360 bytes) of stack space. (No angle brackets around 15K are required with RUN command.)

```
RUN DATABASE 15K
```

The stack size can be specified as a decimal or hexadecimal number. Hexadecimal numbers have a '#' as the first character. This is the same notation as is used in the Pascal language. The letter 'K' represents 1024, so 8K is equivalent to 8\*1024 or 8192. If no stack size is specified, then one half of the unused memory space is allocated for the stack, and the other half is allocated to the heap. The heap is the area of memory used by the Pascal program for dynamic memory storage as required by the procedures NEW and DISPOSE.

When execution of the program completes, the amount of stack and heap used is displayed on the screen. These numbers reflect the actual quantity of memory used during execution.

## THE PASCAL COMPILER LISTING

The Pascal compiler reads the source program from a file and produces two outputs. One of these is a file containing the object code. This code is loaded when the program is executed. The other output of the compiler is the listing. The listing contains the text of the source program with some additional information.

The listing is divided into pages. At the top of each page is a heading. The heading contains the version number of the compiler, and the page number. Each page after the first contains a form feed (control/L or #0C) character. The form feed will cause a page eject on most printers. The number of lines per page may be changed by a compiler option in the source program. (See the Language Reference Manual)

Each line of the listing is numbered beginning with line 1. The compiler may also generate hexadecimal addresses for each line of the listing. The compiler widelist option causes this extra information to be generated. The addresses represent the locations of the generated object code, relative to the start of the program. If the program contains procedures or functions, the addresses for these routines are relative to the start of the routine.

## Using TRS-80 Pascal

If errors are detected by the Pascal compiler, error messages will appear in the listing. Error message lines have a string of five asterisks ('\*\*\*\*\*') at the beginning of the line. An up arrow will appear pointing at the approximate location within the line where the error was detected. This will be followed by one or more error codes. It is possible for a single error to generate more than one error code. For example, a procedure argument which is an undefined variable also does not match the type of the parameter. In most cases the first error code identifies the cause of the error.

If any errors were detected, a summary of the meanings of the error codes that were generated is printed at the end of the listing.

### USING THE TRS-80 LINKLOAD UTILITY

This section describes the use of the Pascal linking loader. The linking loader provides powerful facilities for configuring Pascal programs. Separately compiled programs and procedures may be linked together and executed. Programs may be linked and stored as command files on disk and then later invoked from TRSDOS as commands. These command files behave in the same way as the utilities supplied with the operating system. This section assumes that the reader is familiar with the TRS-80 Pascal Language Reference manual and has some experience with Pascal on the TRS-80.

#### Invoking the Linking Loader:

The loader is executed by typing "LINKLOAD" at the TRSDOS command level. At this point the linking loader is brought into memory from disk. The first item displayed is a menu of commands followed by the command prompt:

```
L=LOAD, R=RUN, T=TRSDOS, I=INIT, S=SYMBOLS, B=BUILD CMD
>>
```

Each of these commands is described in the following 3 pages. All commands require only the single letter, although longer names will also be accepted. A command is terminated with the ENTER key. To execute a command, simply type its first letter followed by ENTER. If more information is required, additional prompts will be supplied. The list of commands can be displayed by typing "H" or "?".

### Loading Programs:

The load command is used to load programs, procedures and functions into memory. To load a program, type "L" and press the "ENTER" key. The load command will ask for a file name. Type the name of the file in standard TRSDOS notation. The file should contain object code as generated from the Pascal compiler. The object file will be opened, and the object code will be loaded into memory. Each time a program, procedure or function is loaded, its name will be displayed on the screen. This will allow you to monitor the load process, and shows the identity of the procedures being loaded.

The object code for each Pascal procedure is compiled into a separate entity. These are then linked together when they are loaded. This allows procedures to be compiled separately and then joined. Thus, a program may be compiled a piece at a time, and when changes are made, only the parts affected by the change need to be recompiled. This also allows the creation of libraries of utilities. These utilities can be loaded with any program that needs them, but they need be compiled only once.

### Symbols:

The linking loader records the name and address of each procedure in a table as it is loaded. Also in this table are the names of procedures that have been called (referenced) by another procedure, but have not yet been loaded into memory. This symbol table can be displayed to the screen with the "S" command.

The symbols command displays all currently defined or referenced symbols on the screen. One procedure name is displayed per line. After the procedure name is a character that describes the use of that procedure. A "D" indicates that the name is defined; that is, the procedure has been loaded into memory. An "R" indicates that the procedure has been referenced but not yet defined. This means that a procedure that has already been loaded makes a call to this procedure. All procedures that are called must be loaded before the program can run. A "C" indicates that the symbol is the name of a common block. Commons are used to provide statically allocated shared data. See the TRS-80 Pascal reference manual for an explanation of the use of commons.

The last item on the line is the address of the symbol. If the symbol is defined ("D") then this is the address in memory where the procedure begins. If the symbol has not been defined ("R") then this is the address of the last place it was used (called).

### Running Programs:

After a program has been loaded, it can be executed with the Run command.

The prompt from the Run command asks for the amount of stack space required by the program. As in the RUN program, one-half of the unused memory is allocated to stack, and the other half to the heap by default. If these space allocations are sufficient, then simply press the enter key. Otherwise enter a value. The size of the stack may be expressed in decimal, hexadecimal (precede the number with "#"), or in kilobytes. 8k means 8 times 1024, or 8192 bytes. Methods of estimating the required stack size are included in a later section of this manual.

The program will execute after the prompt is answered. If files are used by the program, the names of the files to be used will be determined from the keyboard. When a file is opened with RESET or REWRITE, the pascal file name will be displayed on the screen and you will be requested to type the name of the actual file to be used. The names are in standard TRSDOS notation. If you wish to use an Input or Output device instead of a file, this can be specified in a manner analogous to disk names. A device is designated by a colon followed by a letter indicating the device. For example :L is the line printer and :C is the crt and keyboard. (Prompts for filenames may be eliminated by the use of the external procedure SETACNM. Files or device names may be built in to the program with SETACNM. See the section on external procedures and functions in TRSLIB.)

### Building command files:

Once a program has been loaded, it may be saved on disk as a command file. This is done by the build (B) command. The first prompt from this command is the same as for the run command and has the same meaning. The build command then asks for a file name. This is the name of the file that will contain the generated command. The program will be saved on disk in TRSDOS loader format and may be run at a later time by typing its name to TRSDOS. The build command then returns control to TRSDOS. The program may be run by typing its name to TRSDOS.

Init:

The init command clears the symbol table and redisplay the command menu. This command may be used if the wrong program is loaded by mistake. It is equivalent to exiting to TRSDOS and then running LINKLOAD again.

TRSDOS:

The T command returns to the TRSDOS operating system.

ERROR MESSAGES

The following error messages are generated by the linking loader:

\*\*\* CANNOT OPEN FILE

This message is generated when you attempt to load and the loader is unable to find a file by the name specified. This may be caused by a misspelling, or the wrong disk being in the drive.

\*\*\* UNRESOLVED REFERENCES

When you use the run command to execute a program, or the build command to generate an image on disk, the loader checks that all of the procedures that are called within the program have been loaded. If there are procedures or functions that have been called but have not been loaded, then this message is generated. At this point, you can load the required modules and repeat the command. The symbols command can be used to list names of the procedures that are not yet defined. These will have an "R" in the listing.

\*\*\* INVALID OBJECT TAG

This message is issued when a load is performed on a file that is not in a valid object format. The most frequent cause of this error is an attempt to load the source program instead of the object.

\*\*\* SYMBOL TABLE FULL

The linking loader has room for 256 different external symbols. If more procedures than this are loaded, the symbol table will become full.

\*\*\* ILLEGAL REFERENCE

This message signifies an inconsistent structure in an object file. It is an indication that the file has been damaged. The best solution is to recompile the offending program.

## ESTIMATING STACK SIZE

Pascal programs use a stack to store local variables and to save return addresses for procedure and function calls. This stack is allocated when the program is run and the required size is determined by the number and type of variables declared and the number of and sequence of procedure calls. The stack is a dynamic structure. Space is allocated when a procedure is called and released when the procedure is exited.

The total stack size required by a program is determined from its dynamic behavior at run time. Each time a procedure is called, space is allocated for its local variables. The total stack in use is a function of the number of procedures active at the time and the number and sizes of variables used within those procedures. If two procedures are never active at the same time, then the space used by each can be shared. The total stack that must be allocated is determined from the maximum size that is in use at any given time.

The simplest method of determining stack requirements is to run the program. Specify enough stack for it to run, perhaps with an excess. When the program terminates, the maximum stack used by the program is printed on the CRT. A good rule of thumb is to allocate 20% more stack than is required for a typical execution of the program.

The size of stack required can also be determined from the source program. It is necessary to determine which procedures will be active at a given time. Then add the size of the local variables for each procedure. If too much or too little stack is allocated for the program, it may terminate unpredictably.

The sizes of simple variables are summarized below:

type	size in bytes
----	-----
CHAR	1
BOOLEAN	1
INTEGER	2
STRING	2
REAL	4
REAL (double precision)	8
FILE	32
TEXT	32

## Using TRS-80 Pascal

The size of an array is determined by multiplying the size of the array (upper bound-lower bound+1) by the size of an element. The size of a record is determined by adding the sizes of its individual fields. Packing is on byte boundaries.

The size of a set is one plus the ordinal of its largest possible member divided by 8. Enumerated types require one byte, and subranges require two bytes. (0..255 requires one byte).

To calculate the total stack size required, you should also include 64 bytes for the predeclared files INPUT and OUTPUT. Active procedures require space for their parameters as well as their local variables. Parameters passed by value require storage based on the size of the variable; parameters passed by reference require two bytes each. Each active procedure also requires 9 bytes to store dynamic return information.

### PASCAL MEMORY USAGE

The Pascal linking loader or RUN program is loaded by TRSDOS at #5200 in memory. The Pascal program that is being executed will be loaded immediately above the loader. The next segment above the program is used to contain the Pascal stack. The stack is used by Pascal to contain the local variables declared in the VAR section of each program, procedure or function. It also contains return addresses and linkage information.

The remainder of available memory is used for the heap. The heap is a section of memory that is used for allocating dynamic storage. Programs that use pointers and the procedure NEW, will use storage from the heap. The heap also contains the buffers used to read from and write to files.

The total amount of memory available to Pascal is determined from a TRSDOS system constant. On the TRS-80 model I, the location of the top of memory is stored at #4049 in system RAM. On the model III, the location is #4411. If other programs are to reside in memory along with Pascal, they should be loaded at the top of memory. The top of memory address should be changed to prevent Pascal from using the reserved locations.

Using TRS-80 Pascal  
COMPILER MEMORY CONSTRAINTS

The TRS-80 Pascal compiler requires approximately 33k of memory for code. Of this total, 27k is the compiler itself and the remainder is runtime support. The runtime support portion contains the drivers for input and output devices, an interface to the file system and the Pcode interpreter. TRSDOS occupies 4.5k of memory, which leaves 10.5k bytes of memory for data. 4.0k of this total is used for stack space by the compiler, with the result that the heap is approximately 6k bytes. This is enough space for about 250 symbols to be defined. A program that uses more than 250 symbols at a time will run out of heap space during the compile.

There are some ways of saving memory during the compile so that larger programs can be compiled. The limit on symbols is relative to the number of symbols visible at any point within the program. Symbols that are not available to the program are not retained by the compiler. The use of symbol table space can be improved by defining fewer global variables at the outer levels and making use of locals whenever possible. This is also good programming practice.

The length of symbol names is not relevant in Pascal, unlike BASIC. Use of long names has no effect on program size or compiler memory usage. Extensive use of string constants will cause the compiler to use more memory. If a string constant is used in more than one place in the program, it will take less space if it is declared as a constant.

PASCALB is the overlaid or segmented version of the compiler. This version dynamically loads portions of the Pascal compiler from disk as needed. This increases the amount of memory available for symbols and allows larger programs to be compiled. The overlaid compiler will compile programs that are four times the size that can be compiled with the non-overlaid compiler. I.E.; a typical 4000 line program will compile successfully. It also has the drawback that the compiler runs more slowly.

REAL NUMBERS

Real numbers are either single precision or double precision. The TRS-80 rom routines are used for all floating point calculations, and the precision and accuracy of calculations are the same as for Basic programs. Whether real numbers in TRS-80 Pascal are considered to be single or double precision by the compiler is set by a compiler switch setting at compile time. See the TRS-80 Pascal Reference manual, "compiler options".

	Single precision	
Accuracy		Range
6 digits		(-)1.7E-38..(-)1.7E+38
	Double precision	
Accuracy		Range
16 digits		(-)1.7E-38..(-)1.7E+38

Note: All functions are performed in single precision. Arithmetic expressions that cause a real number overflow will cause programs to not return during calculations. This is due to the fact that the ROM routines do not return to Pascal if an error is detected.

## TRS-80 Procedure and Function Library

A set of functions and procedures to access the hardware features of the TRS-80 is provided with the Pascal compiler. These procedures can be declared as external procedures within Pascal programs. The object code for these procedures and functions is provided in two forms.

If the program is executed with the RUN command, the function library is contained within the RUN program. Any of the library procedures and functions can be called and the routine will be linked to when the program is loaded. If the linking loader is used, these routines are not automatically available. This allows programs that do not need these routines to have more space available. The function library is provided in object form on disk. This file can be loaded with the load command from the linking loader. This will make all of the library routines available.

Each of the library routines is described below. A Pascal external declaration is given. This declaration should be included in any program that uses the routine.

The external declarations of the library routines are included in the file TRSLIB/PCL. Any or all of these declarations can be inserted into the source program using the insert file command in the text editor.

-----  
**PROCEDURE CLEARGRAPHICS; EXTERNAL;**

The purpose of this procedure is to clear the display when utilizing the graphics routines. Its function is similar to the clearscreen function but loads all hex 80's into the display memory, instead of hex 20's as CLEARSCREEN does.

**PROCEDURE SETPOINT(X, Y : INTEGER); EXTERNAL;**

This procedure sets a graphics point on the screen. The location of the point is specified with the x (horizontal) and y (vertical) coordinates. The value of x should be in the range:  $0 \leq x \leq 127$  The value of y should be in the range:  $0 \leq y \leq 47$

**PROCEDURE RSETPOINT(X, Y : INTEGER); EXTERNAL;**

This procedure clears a graphics point on the screen. The location of the point is specified with the x (horizontal) and y (vertical) coordinates. The value of x should be in the range:  $0 \leq x \leq 127$  The value of y should be in the range:  $0 \leq y \leq 47$

**FUNCTION TESTPOINT(X,Y:INTEGER) : BOOLEAN; EXTERNAL;**

This function tests the state of a point on the screen in graphics mode. X and Y are the horizontal and vertical coordinates of the point to be tested. The function returns TRUE if the point is on (white), and FALSE if the point is off.

## TRS-80 Procedure and Function Library

TYPE BYTE = 0..255;

FUNCTION PEEK(ADDRESS : INTEGER) : BYTE; EXTERNAL;

This function returns the contents of any memory location. It may be used to examine memory or memory mapped input devices. ADDRESS is the address being examined. An address may be passed if its value is known. The addresses of pascal variables may be obtained by calling the LOCATION function. (see Reference Manual)

PROCEDURE POKE(ADDRESS : INTEGER; VALUE : BYTE); EXTERNAL;

Poke is used to alter the contents of any location in memory. It may also be used to write to memory mapped output devices such as the printer port.

PROCEDURE GOTOXY(X, Y : INTEGER); EXTERNAL;

This procedure positions the cursor on the CRT to the specified location. If a write is performed to a file connected to the screen then the text will appear beginning at the addressed location. The procedures WRITECH and WRITESTRING (see below) also use this location. The value of x should be in the range:  $0 \leq x \leq 63$  The value of y should be in the range:  $0 \leq y \leq 15$  If GOTOXY is used in-conjunction with Pascal READ or WRITE statements, then a call to the external procedure NOBLANK at the beginning of the program is necessary. The TRS-80 ROM driver for the screen will automatically clear the next line on the display when the carriage return character is received. The can be detrimental when constructing menu displays. A call to NOBLANK will cause the next line to always be re-displayed.

PROCEDURE NOBLANK(REDISPLAY : BOOLEAN); EXTERNAL;

The TRS-80 ROM routine driver for the screen will automatically clear the next line on the display when a CR character is received. A call to NOBLANK with REDISPLAY := TRUE will cause the next line to always be preserved if REDISPLAY := false, it will be blanked. The Pascal logical files used for screen display must be RESET after the NOBLANK call for it to take effect. This includes INPUT.

PROCEDURE READCURSOR(VAR X, Y : INTEGER); EXTERNAL;

This procedure returns the current position of the cursor on the crt screen. X is the horizontal position (character) and Y is the vertical position (line).

PROCEDURE WRITECH(CH : CHAR); EXTERNAL;

This procedure writes a single character to the CRT at the current cursor location. The cursor location is advanced by one.

TYPE CHARSTRING = PACKED ARRAY[1..xx] OF CHAR; {xx is any length}

PROCEDURE WRITESTRING(VAR S : CHARSTRING; FIRST, LAST : INTEGER);  
EXTERNAL;

This procedure writes a portion of a string of characters to the screen. The text is written starting at the current cursor location. FIRST is the index of the first character to be written, LAST is the index of the last character to be written. The total number of characters displayed is: LAST-FIRST+1. If last is less than first then no characters are written.

PROCEDURE CLEARSCREEN; EXTERNAL;

A call to CLEARSCREEN causes the crt display to be cleared and the display to be set to 64 character width.

PROCEDURE INKEY(VAR CH : CHAR; VAR READY : BOOLEAN); EXTERNAL;

This procedure scans the keyboard to determine if a key is being pressed. If a key is currently pressed, then CH is the character generated by that key and READY is set to TRUE. If no key is pressed, then READY is FALSE and CH is the space character: ' '.

FUNCTION GETKEY : CHAR; EXTERNAL;

This function waits for and returns the next character from the keyboard.

FUNCTION INP(PORT : BYTE) : BYTE; EXTERNAL;

This function performs input from a Z80 IO port. The port number is passed to the function and the value read from that port is returned as the function value.

PROCEDURE OUT(PORT, VALUE : BYTE); EXTERNAL;

This procedure performs physical output to a Z80 port. It may be used in conjunction with the function INP to communicate with devices interfaced as input or output ports. The two parameters specify the port number and the value to be written to that port.

## TRS-80 Procedure and Function Library

PROCEDURE USER(ADDRESS : INTEGER; VAR DATA : INTEGER); EXTERNAL;

This procedure interfaces to assembly language routines resident in the TRS-80's memory. ADDRESS is the physical address where the routine is loaded. Any assembly language routines that are to be called from Pascal should be loaded in a portion of memory that is not used by TRSDOS or Pascal. The location of the top of memory can be set by using the TRSDOS model I debugger to alter location #4049 in RAM, or location #4411 on the model III. This location contains the highest usable location in memory. Pascal will not use any memory above this address, so assembly language routines can be loaded there.

Information is passed to the assembly language routine through the DATA parameter. When the assembly language routine is called, the HL register pair contains the value of DATA. When the routine exits, the contents of the HL register pair is returned as the new value of DATA. In cases where more than one word of information is required, the value of DATA can be the address of a variable. The address of any Pascal variable can be obtained by a call to the predefined function: LOCATION. This enables the called assembly language routine to access arrays or buffer data areas. The assembly language routine is entered with a standard Z-80 call instruction and should be exited via a return. All Z-80 registers are available for use in the assembly language subroutine.

PROCEDURE CALL\$(ADDRESS : INTEGER; VAR A,STATUS: BYTE;  
VAR BC, DE, HL, IX, IY : INTEGER); EXTERNAL;

This procedure can be used in a similar manner to USER to call assembly language subroutines. The difference is that CALL\$ permits you to set up all of the Z-80 registers from Pascal. The values passed will be in the registers when the subroutine is called. When the subroutine returns, the current contents of all registers are returned to the Pascal program via the reference parameters. Status is the Z-80 flag register. NOTE: THE FLAG REGISTER PARAMETER HAS BEEN ADDED FOR TRS-80 Pascal 02.00.00.

TYPE ALPHA = PACKED ARRAY[1..8] OF CHAR;  
PROCEDURE TIME(VAR T : ALPHA); EXTERNAL;

This procedure returns the current time of day. The time is in the form of hh:mm:ss

TYPE ALPHA = PACKED ARRAY[1..8] OF CHAR;  
PROCEDURE DATE(VAR T : ALPHA); EXTERNAL;

This procedure returns the current date as known to the operating system. The date is returned as: mm/dd/yy

TRS-80 Procedure and Function Library

FUNCTION FILE\$STATUS(VAR F : TEXT) : BYTE; EXTERNAL;

This function returns the status of a file. The file can be of any type, but the external declaration must specify a type that matches the type of file being tested. The byte returned is the error code for the latest IO (input or output) error. If no errors have occurred, then zero is returned. This function is used in conjunction with IO\$ERROR and allows a program to detect and recover from its own IO errors.

PROCEDURE IO\$ERROR(NEWSTATE : BOOLEAN;  
VAR OLDSTATE : BOOLEAN); EXTERNAL;

This procedure sets the state of the IO error recovery flag within the pascal runtime system. This flag is used to determine whether a program detects its own IO errors. If the flag is set to true, then default error processing is performed. In case of an error on a file or device, a message is displayed on the CRT and the program halts.

If the IO error flag is set to false, then all IO errors are ignored by the system, and it is up to the program to check for and recover from IO errors. IO errors can be detected by calling the function FILE\$STATUS.

NEWSTATE is a boolean value that sets the new state of the IO error recovery flag. OLDSTATE is used to return the previous value of the flag. This allows a program to change the state temporarily and then restore it.

PROCEDURE HP\$ERROR(NEWSTATE : BOOLEAN;  
VAR OLDSTATE : BOOLEAN); EXTERNAL;

This procedure sets the state of the heap error recovery flag within the pascal runtime system. When this flag is set to true, then a call to the procedure NEW will cause the program to terminate with an error message if no more space is available. Setting this flag to false causes the procedure NEW to return NIL if no space is available. The calling program should check for NIL on each call to NEW when this flag is set to false. This allows a program to use maximum memory from the heap without danger of an abnormal termination when space is exhausted.

NOTE- Both NEWSTATE and OLDSTATE must be initialized before calling IO\$ERROR or HP\$ERROR.

PROCEDURE \$MEMORY(VAR STACK, HEAP : INTEGER); EXTERNAL;

This procedure allows a program to determine the amount of memory currently available. The parameter STACK returns the current number of stack bytes available and the parameter HEAP returns the amount of heap available.

TRS-80 Procedure and Function Library

```
TYPE FILENM = PACKED ARRAY[1..XX] OF CHAR;
      ALPHA = PACKED ARRAY[1..8] OF CHAR;
      (Where XX is any length long enough for the file name)
```

```
PROCEDURE SET$ACNM(VAR F : TEXT; VAR file name : FILENM;
      NAMELENGTH : INTEGER; VAR FILEID : ALPHA); EXTERNAL;
```

SET\$ACNM is used to set the name of the physical file or device to be associated with a Pascal file. It allows a program to compute file names internally. For example, a database program may know the name of the file containing the database. This procedure allows the program to specify the file name rather than requesting it from the keyboard.

The parameter F can be a file of any type. The external declaration of SET\$ACNM that is included in the source program must specify a type for F that matches the actual file type to be used.

File name is a string containing the text of the file name. This string must be compatible with the operating system syntax for file names. The physical devices: lineprinter (:L), crt (:C) and dummy (:D) may also be used. NAMELENGTH is an integer that specifies the length of the file name.

FILEID is an 8 character string that is used to identify the Pascal name for the file, such as INPUT or OUTPUT.

If SET\$ACNM is called prior to a RESET or REWRITE on a file, then Pascal will not prompt the CRT for the file name. All subsequent RESET or REWRITES will not cause a prompt unless a CLOSE(file name) is performed on the file. The file name association will remain as previously defined by SET\$ACNM.

(Example program segment)

```
TYPE FILENAME = PACKED ARRAY [1..15]OF CHAR;
      ALPHA    = PACKED ARRAY [1..8]OF CHAR;
VAR  FNAME :FILENAME;
      FILEID:ALPHA;
      F      :TEXT;
PROCEDURE SET$ACNM(VAR F:TEXT; VAR FNAME:FILENAME; LEN:INTEGER;
      VAR FILEID:ALPHA); EXTERNAL;
```

```
BEGIN
  (* THIS ASSIGNMENT STATEMENT REQUIRES THE NAME TO BE LEFT *)
  (* JUSTIFIED, AND BLANK PADDED TO THE CORRECT ARRAY LENGTH *)
  FNAME:='DATA/TXT:0      ';
  FILEID:='F              ';
  SET$ACNM(F,FNAME,10,FILEID);
  RESET(F);
  READ(F,CH);
  (* AND ETC..... *)
```

```
PROCEDURE SETACNM(VAR logical : filetype;
                 physical : STRING); EXTERNAL;
```

The library procedure SETACNM serves the same purpose as SET\$ACNM but is simpler to use. The procedure takes only two parameters, the Pascal logical file variable, and the physical file or device name to associate with it. Filetype is any legal Pascal file type. The physical name parameter is a dynamic string. The SETACNM procedure disposes this string before exiting to recover the space.

If multiple file types are used in a program, the type transfer operator (::) may be used to allow SETACNM to be called with different file types. The external declaration of SETACNM may specify one of the file types used. The type transfer operator must then be used with the other file types to avoid a type mismatch error during the compile. Each of the other files must be type transferred to the same type as the one used in the declaration. The following example illustrates the use of SETACNM.

```
(* $NO INOUT *) {eliminate the prompt for INPUT & OUTPUT}
PROGRAM sample;

VAR printer : TEXT;
    out      : FILE OF INTEGER;

PROCEDURE SETACNM(VAR f : TEXT; name : STRING); EXTERNAL;

BEGIN
    {main body of program sample}
    {map logical file "printer" to the line printer}
    SETACNM(printer, BLDSTR(':L'));
    {no prompt will occur when REWRITE(printer) is executed}
    REWRITE(printer);
    {map logical file "out" to disk file "OUT/DAT"}
    SETACNM(out::TEXT, BLDSTR('OUT/DAT'));
    {no prompt will occur when REWRITE(out) is executed}
    REWRITE(out);
    ...
    ...
END.           {end of program sample}
```

## STRING FUNCTION LIBRARY

-----

The following functions are provided for handling dynamic string manipulations. (See the appendix of the Language Reference Manual for information about dynamic strings.)

FUNCTION LEN(S : STRING) : INTEGER;

This function returns the length of a string.

FUNCTION LEFT\$(S : STRING; POSITION : INTEGER) : STRING;

This function returns the left portion of the string ending at the specified position within the string.

FUNCTION RIGHT\$(S : STRING; POSITION : INTEGER) : STRING;

This function returns the right portion of the string starting at the specified position within the string.

FUNCTION MID\$(S : STRING; POSITION, LENGTH : INTEGER) : STRING;

This function returns the portion of the string starting at the specified position and including the number of characters specified by length.

FUNCTION STR\$(LENGTH : INTEGER; CH : CHAR) : STRING;

This function returns a string of the specified length which is filled with the specified character.

FUNCTION ENCODEI(N : INTEGER) : STRING;

This function returns a string which is the character representation of the specified integer.

FUNCTION ENCODER(R : REAL) : STRING;

This function returns a string which is the character representation of the specified real for single precision.

FUNCTION ENCODED(R : REAL) : STRING;

Same as ENCODER, but for double precision reals.

FUNCTION DECODEI(S : STRING) : INTEGER;

This function returns an integer number which is the binary representation of the specified string.

FUNCTION DECODER(S : STRING) : REAL;

This function returns a real number which is the binary representation of the specified string for single precision.

FUNCTION DECODED(S : STRING) : REAL;

Same as DECODER, but for double precision reals.

FUNCTION CHARACTER(S : STRING; POSITION : INTEGER) : CHAR;  
This function returns the character at the specified position in the string.

TYPE COMPAREVALUE = (LESS, EQUAL, GREATER);  
FUNCTION CMPSTR(S1, S2 : STRING) : COMPAREVALUE;  
This function compares the two specified strings and returns an enumerated value based on the comparison. The returned value is LESS if S1<S2, EQUAL if S1=S2, and GREATER if S1>S2.

FUNCTION CONC(S1, S2 : STRING) : STRING;  
This function returns a string which is the result of the concatenation of the two specified strings.

FUNCTION CPYSTR(S : STRING) : STRING;  
This function returns a copy of the specified string. The typical use for this function is in the assignment of one string variable to another. This prevents both string variables from referencing the same string. EG. STRING1:=CPYSTR(STRING2); will cause STRING1 to refer to a different copy of STRING2. STRING1:=STRING2; causes STRING1 to refer to the same copy of STRING2 and any changes in the value of STRING1 would cause STRING2 to change also.

FUNCTION DELETE(S : STRING; POSITION, LENGTH : INTEGER) : STRING;  
This function returns the string which results after deleting a specified number of characters beginning at the specified position in the string.

FUNCTION FIND(SUBSTRING, S : STRING) : INTEGER;  
This function returns an integer number which points to the start of the specified substring within the specified string. If the string does not contain the substring then the returned value is 0.

FUNCTION INSERT(SUBSTRING, S : STRING; POSITION : INTEGER) : STRING;  
This function returns a string which is the result of inserting the specified substring into the specified string at the specified position.

FUNCTION REPLACE(OLDSTRING, NEWSTRING, S : STRING) : STRING;  
This function returns the string which results after replacing the old substring with a new substring within string S.

## RANDOM ACCESS FILES

Random Access files refers to a file access method where any record may be READ or WRITTEN to in any order. As most Pascal programmers know, Pascal does not define the Random file type.

The following Pascal procedures and functions will allow random access to files on the TRS-80. The following Pascal routines are supplied in object code format on the release disk (RANDOM/OBJ). When using random access files, these routines should be declared as external in the main program. Then simply link to the supplied object file of random access routines with the linking loader to satisfy any external references.

The object code for random files is built in to the RUN command.

The following declarations should be included in the source program if you use the random file routines.

### RANDOM FILE ROUTINES

```
PROCEDURE OPENRAND(VAR F:FILETYPE; RECORDLEN:INTEGER;  PATHNAME:STRING;  
VAR STATUS:INTEGER); EXTERNAL;
```

The purpose of this routine is to open a random file. The F variable is of any file type. Random file types are fixed in length and should be declared as a FILE OF DATATYPE. A text file is not a particularly useful DATATYPE. The filetype may be any structure such as an ARRAY, RECORD, etc... RECORDLEN must be the size required for the datatype. The SIZE(J) function may be used to determine the RECORDLEN. PATHNAME is the physical filename on disk. You must prompt the user if it is to be changed at runtime. STATUS is a code returned by Pascal or the operating system. The status code returns the status of an operation on a random file.

```
PROCEDURE READRAND(VAR F:FILETYPE; RECORDNUM:INTEGER;  
VAR DAT:DATATYPE; VAR STATUS:INTEGER); EXTERNAL;
```

This routine is used to read data from a random file. The RECORDNUM is the record number to be read. DAT is the buffer for the data and must be declared as the same type as the components of FILETYPE. (eg. if FILETYPE = FILE OF INTEGER; DATATYPE = INTEGER; )

```
PROCEDURE WRITERAND(VAR F:FILETYPE; RECORDNUM:INTEGER;  
VAR DAT:DATATYPE; VAR STATUS:INTEGER); EXTERNAL;
```

This routine is used to write data to a random file. The RECORDNUM is the record number to be written. DAT is the buffer for the data and is declared to be of the same type as the components of FILETYPE.

```
PROCEDURE CLOSERAND(VAR F:FILETYPE); EXTERNAL;
```

Random files are not automatically closed. This procedure must be used before the program terminates to close all random files that have been opened. Failure to close a random file may result in loss of the file.

As with random files on any operating system, there are some peculiarities about random files. For example:

- (1) If you WRITE record number 1 and WRITE record number 100, and then read any record from 2 to 99, the returned buffer will contain trash. The data will be whatever was previously on the diskette, probably the contents of an old file. This is because the operating system does not keep that much context. It is up to the user to keep track of unwritten records so they are not READ.
- (2) Random file record sizes may be from 1 to 256 bytes only. All blocking is taken care of by the system.
- (3) The standard functions EOLN, EOF have no meaning for random files. The status codes as returned by the above routines (the parameter STATUS) perform those functions where applicable.

- (4) The procedure OPENRAND is used to open a file for reading and writing. Opening an empty file and reading is perfectly legal.
- (5) Random file record numbers are defined from 0..32767.
- (6) As with normal files, if a file is declared LOCALLY within a procedure and opened, (not passed in as a parameter) once the procedure is exited, Pascal will automatically close the file using the standard CLOSE file routine for non-random files and position the EOF mark in the directory at the last record read or written. This may not be the correct position as desired by the programmer. An explicit call to CLOSERAND should be used to close the random file and position the EOF. This will always correctly place the EOF mark.
- (7) You may declare a file to be:

```
(*WHERE XX IS ANY RECORD LENGTH FROM 1 TO 256*)
TYPE LINE = ARRAY(.1..XX.) OF CHAR;
VAR F:FILE OF LINE;
```

Once the file has been opened, you may access it by using the READRAND and WRITERAND external procedures even if the file was not created by Pascal. There is only one procedure for opening random files (no reset and rewrite). You may read or write to a random file.

The random file routines return a STATUS of 0 if no error occurred during the random file operation. Below is a list of the error codes returned.

Random File Error Codes  
Returned via STATUS parameter

(Generated by the operating system:  
See TRSDOS error messages in your Disk Operating  
System Manual for a complete list of TRSDOS errors)

15 - DISK WRITE PROTECTED  
26 - DIRECTORY SPACE FULL  
27 - DISK FULL  
28 - END OF FILE  
29 - RECORD NOT FOUND (PAST EOF)

(Generated by the random file routines)

128 - PATH NAME IS NULL OR TOO LONG  
129 - RECORD LENGTH IS NOT BETWEEN 1 AND 256  
130 - FILE IS ALREADY OPEN  
131 - FILE IS NOT OPEN

If multiple random file types are used in a program, the type transfer operator (::) may be used to allow the random file routines to be called with different file and data types. The declarations may specify one of the file and data types used in the program. Any other files used must then utilize the type transfer operator when calling one of the random file routines. The other file and data types must be type transferred to the same types used in the declarations to avoid a type mismatch error during the compile. The following example illustrates the use of the random file routines. The status may be checked after each random file operation to determine if an error occurred. The returned status will be 0 if no error is detected during an operation.

```

PROGRAM sample;
TYPE file1 = FILE OF CHAR;
    file2 = FILE OF INTEGER;
VAR f1 : file1;
    f2 : file2;
    value1, ch : CHAR;
    value2, status, number : INTEGER;
PROCEDURE OPENRAND(VAR f : file1; length : INTEGER;
    name : STRING; VAR status : INTEGER); EXTERNAL;
PROCEDURE CLOSERAND(VAR f : file1); EXTERNAL;
PROCEDURE READRAND(VAR f : file1; number : INTEGER;
    VAR data : CHAR; VAR status : INTEGER); EXTERNAL;
PROCEDURE WRITERAND(VAR f : file1; number : INTEGER;
    VAR data : CHAR; VAR status : INTEGER); EXTERNAL;
PROCEDURE checkstatus(status : INTEGER);
BEGIN
    IF status<>0 THEN
        WRITELN('* I/O ERROR: code number = ',status:3,' *')
    END;
BEGIN
    {open file "F1/DAT"}
    OPENRAND(f1,SIZE(CHAR),BLDSTR('F1/DAT'),status);
    {open file "F2/DAT"}
    OPENRAND(f2::file1,SIZE(INTEGER),BLDSTR('F2/DAT'),status);
    FOR number := 0 TO 255 DO
        BEGIN
            {write the ascii character set to F1/DAT}
            ch := CHR(number);
            WRITERAND(f1,number,ch,status);
            {write the ordinal values of the character set to F2/DAT}
            WRITERAND(f2::file1,number,number::CHAR,status);
        END;
    FOR number := 0 TO 255 DO
        BEGIN
            {read the ascii character set from F1/DAT}
            READRAND(f1,number,value1,status);
            {read the ordinal values of the character set from F2/DAT}
            READRAND(f2::file1,number,value2::CHAR,status);
        END;
        checkstatus(status);      {check error status}
        CLOSERAND(f1);           {close F1/DAT}
        CLOSERAND(f2::file1)    {close F2/DAT}
    END.

```

MISCELLANEOUS

COMPILER

The compiler outputs the lines of a program which contain errors to a file named PASCAL/ERR. If this file does not already exist, then the compiler creates it the first time an error is detected during a compile. For each line containing an error, the line number, the line itself, and the error number(s) are sent to this file. This makes it possible to discard the compiler listing (map to :D) and still be able to determine what errors were detected during a compile.

The compiler reads in the first 80 characters of each line of a Pascal program. Previous versions read only the first 72 characters of a line.

The compiler uses the \ (backslash) character to signify that the remainder of a line is to be treated as a comment.

```
a := 1;           \this is a comment
```

The compiler now allows you to use the LOCATION function on procedures and functions. This is useful when interfacing to assembly language routines from Pascal. You may use the LOCATION function rather than fixed addresses inside the Pascal program. Then if the location of an assembly language routine must be changed, it does not require a recompilation of the Pascal program which uses it.

The minimum stack required by PASCAL/CMD is currently 3900 bytes. If you specify less than this amount, 3900 will be used. PASCAL/CMD requires this much stack even though the stack used message at the end of a compile may indicate that less was needed. PASCALB/CMD has no such minimum.

## LINKING LOADER

-----

The prompt PROGRAM = has been removed from the <B> command of the linking loader. This prompt requested the name of the currently loaded program when building a command file. The program name prompt has often been confused with the file name prompt. Since the program name is not essential, it has been removed to avoid confusion.

The linking loader now accepts lower case for commands, file names, or devices. Lower case is translated to upper case.

The linking loader now displays an error message when there is an attempt to build a command file to the screen or to a full or write protected disk.

## RUNTIME

-----

The runtime now recognizes the ` (backquote) character as EOF (end of file) when receiving input from the keyboard. On the model I and III, this character is generated by <shift><@> (hex 60).

The runtime now displays English error messages for the most commonly occurring runtime errors. It also identifies the error as being a runtime error. This is especially helpful when using the compiler. The compiler has its own runtime which can detect runtime errors and terminate a compile. Runtime errors such as out of stack or out of heap previously caused the error numbers 01 and 02 respectively to be displayed. These numbers may be confused with the compiler detected error numbers 1 and 2 which are totally independent error messages. Now when the compiler runtime detects an out of stack condition, it displays the fact that a runtime error occurred and that the error was OUT OF STACK.

The runtime periodically checks to see if the break key is pressed. If so, then the executing program terminates. This applies to all supplied /CMD files except ED/CMD, and also applies to all /CMD files which you create using the linking loader. It should be noted that when you break out of an executing program, no files are closed. Any files which are open for writing may be lost. The break key will not terminate a program while the program is waiting for input. It must be actively executing for the break key to have an effect.

#### ERROR CORRECTIONS

-----

##### SUBRANGES

-----

The problem of reading a value into a subrange variable with a non-zero lower bound has been corrected.

##### REAL FORMATTING

-----

Real formatting has been corrected so that it now conforms to the ISO standard for Pascal. The following now applies when outputting real values.

1. If no field specifiers are present, the format defaults to exponential format with a field width of 12 for single precision and 20 for double precision.
2. If only the first field specifier is present, the format is exponential with the specified width. A minimum width of 8 is used, even if a smaller width is specified.

3. If both field specifiers are present, the format is fixed with the first field specifying the total number of characters to output and the second specifying the number of characters to the right of the decimal point. If the first field specifier is not sufficient to accommodate the number being output, the width is expanded to a size sufficient to display the number.

Examples:

```
WRITE(25.0)          --> 2.50000E+01
WRITE(-0.1:12)      --> -1.00000E-01
WRITE(3.2:12:2)     -->          3.20
```

4. The maximum number of characters output in either fixed or exponential format is 32.

## MISCELLANEOUS PATCHES

The following patches may be applied using the PATCHER utility to alter the execution characteristics of the TRS-80 Pascal system. They should be entered into a text file using the Blaise text editor. Then they are used as patch control files for the PATCHER utility. For complete instructions on the use of the PATCHER utility see the first section in the Beginners Guide.

### Blaise Editor Patch

The following patch will change the definition of the command key from the CLEAR key on the TRS-80 keyboard to the / (slash) key. When using LDOS with the KSM filter, the CLEAR key gets mapped to a SHIFT CLEAR which may be inconvenient.

```
MODEL I or MODEL III
; The clear key will now be generated by the / key.'
; The / key is generated by a // sequence.
F, ED/CMD, PASCAL
P,459A,05AC,0001,1F,2F
P,45B2,058B,0001,1F,2F
W,F4C9
E
```

### LINKLOAD Patch

When a user program terminates normally, a stack and heap used message is displayed to the terminal. This message may be suppressed by applying the following patch to the linking loader. All command (/CMD) files built with the patched LINKLOAD utility will not display these messages upon normal termination. This is useful when producing application programs for resale.

```
MODEL I
F, LINKLOAD/CMD, PASCAL2
P,2ACC,085A,0003,2A,C3,49,2D,40,40
W,F7A6
E
```

```
MODEL III
F, LINKLOAD/CMD, PASCAL2
P,2ADC,0852,0003,2A,C3,11,2D,44,40
W,F7AE
E
```

### LINKLOAD and RUN Patch

The following patch will disable the BREAK key from being able to terminate a program.

```
Model I or Model III
F,RUN/CMD,PASCAL1
P,0010,050E,0001,00,E9
W,FAF2
F,LINKLOAD/CMD,PASCAL2
P,0010,050E,0001,00,E9
W,FAF2
E
```



## TUTORIAL

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## Preface

This section is intended to be a tutorial for Pascal programming. It was specifically designed as a learning aid for TRS-80 Pascal, and is an intermediate level tutorial guide. It is assumed that the reader has had some programming experience. This tutorial is an excellent teaching aid for most other Pascals because TRS-80 Pascal is an implementation of standard Pascal. Any extensions to the language are covered in the TRS-80 Pascal Reference Manual. In this book the standard Pascal referred to is defined by Pascal USER MANUAL AND REPORT(2nd edition) by Kathleen Jensen and Nikalus Wirth (Springer-Verlag, 1975). People with some exposure to BASIC or other programming languages should have no trouble understanding the explanations or example programs. It may be helpful to refer to the TRS-80 Pascal reference manual, for additional details and answers. This tutorial was designed to be as clear and precise as possible for the newcomer to Pascal. It avoids all tricky and confusing explanations, and in many cases includes program segments as examples. This greatly reduces the clutter that often gets in the way of learning computer languages.

The first chapter examines the major advantages of Pascal as a general programming language. You may skip this section and begin reading chapter two if you wish. However, there are many important aspects about Pascal that are explained in chapter one. This tutorial will provide a logical and structured approach to learning . After all, that's what Pascal is all about.

## INTRODUCTION

Pascal was created by Professor Nicklaus Wirth at the Swiss Technical Institute in Zurich Switzerland. It was first announced in 1965 when the most popular programming languages in use by the computer industry were Fortran and Cobol. In teaching environments, like Universities, Algol was a popular language for introducing students to computer programming. Wirth felt that languages like Fortran and Cobol were too loosely structured to promote good programming habits to students. Algol, although more structured, had significant drawbacks. Wirth decided to depart from normal teaching practice and designed a new language patterned after Algol, to be his new teaching language.

Pascal inherits the structured control statements of Algol and adds powerful data structuring capability. The language was designed to promote good programming practices and encourage clarity and modularity in programs. Since the first implementation of Pascal on the CDC-6600 computer system in 1971, Pascal has proven to be one of the most popular programming languages in existence.

Pascal has the distinction of being created for the purpose of making the development of computer programs a structured and logical process. Pascal contains the best features of most high level programming languages. Many college instructors at major universities today use Pascal or Pascal like languages to teach structured programming classes. Structured programming classes emphasize the use of guidelines and rules for developing computer programs. Some of the goals of structured programming are to encourage modularity and functionality, promote good documentation and to generate programs that have smooth flows of logic from the beginning to end. Programs are usually developed in Pascal or an English like Pascal and then hand translated to any available computer language such as Basic, for execution.

Although the implementation language may not be highly structured, the final program will be more clear and readable. Indeed, that is exactly what most Pascal programmers do when they need to use other languages. However, this is no replacement for implementing the program in Pascal, as there are no translations for the rich and powerful data structures and many other features that exist in Pascal.

Data types and structures are two important features of the language. They comprise one of the largest differences between languages such as Pascal and BASIC. Most BASIC programmers are familiar with the data types integer and real. A data type is simply the kind of information that may be stored in a variable. Pascal includes nine predefined types: char, integer, real, set, file,array,record, boolean and text plus an infinite variety more, as you may invent data types at will.

Data structure is another name for a variable type such as the array. Pascal allows you to build new data structures as desired. The use of record data structures can be very powerful when building or maintaining data bases. With one simple output statement, an entire data structure may be written to a file.

Variables are assigned storage only as needed during program execution, thus reducing demands on memory. They also may have names with as many characters in them as desired provided that the first 8 characters form a unique name. Long names don't require any more storage space than short ones.

Extra spaces,tabs, and carriage control may be placed freely in a source program, except in the middle of identifiers and character strings. An identifier is defined to be a program, variable, constant, type, procedure or function name. Comments may be inserted anywhere spaces are allowed and are delimited by (\* \*) or { }. These features don't affect the speed or the size of the final program, and greatly improve readability.

The concept of local variables is important. Variables declared in this manner will have restricted access by other parts of the program. This can prevent accidental changes in their values.

If there are a series of statements that need to be executed by different sections of the program, they may be placed in a procedure or function declaration. A procedure or function is just a collection of program statements that may be called to perform their task at various times during the program. Repetitive programming may be prevented by creating libraries of commonly used procedures or functions. Parameters may be passed to these subroutines by "value or reference".

When a parameter is passed by reference, the actual parameter is passed to the procedure, and if the procedure alters its value, the parameter's value is changed in the rest of the program. When a parameter is passed by reference, the argument must be a variable.

When a parameter is passed by value, what is passed is a copy of the argument. If the procedure alters the parameter's value, the value in the rest of the program is not changed. When a parameter is passed by value, its argument may be a variable or any legal arithmetic expression. Parameters passed by value can prevent accidental changes in a value by procedures.

A careful use of procedures and functions will make the program more readable and will eliminate branching statements that are difficult to follow.

The logical operators AND, OR, and NOT along with the relational operators: greater than ">", less than "<", equal "=", not equal "<>", greater than or equal ">=", less than or equal "<=" are available in Pascal. Statements like: IF(count < 10) and (not FAILURE) then "do the following", make control statements very clear.

There are six statements in Pascal used for the flow of control. Loop control is performed by the FOR, REPEAT and WHILE statements. Conditions are tested with the IF and CASE statements. Branching is accomplished by the GOTO statement.

Program execution speed may be of particular importance in certain applications. TRS-80 Pascal programs execute between 10 and 50 times faster than most interpreted Basics on the same computers. In fact, they are significantly faster than many other Pascal implementations.

As a general programming language, Pascal has the following advantages.

- (1) The powerful ability to build new data types and structures as desired.
- (2) The control statements while, repeat, for, if, case and goto.
- (3) The logical operators AND, OR, NOT.
- (4) The relational operators: equal to, less than, greater than, less than or equal to, greater than or equal, not equal to.
- (5) Recursive procedures and functions with parameter lists.
- (6) The ability to insert blanks and comments in the source program easily, and long variable names, with no space or time penalty.
- (7) User controlled dynamic memory management.
- (8) Efficient memory management of variables, functions and procedures.
- (9) Arrays of one or more dimensions.
- (10) Record data structures.
- (11) Sets and set operations.
- (12) Subrange and enumerated data types.
- (13) Named constants.
- (14) Read and write statements plus formatted write statements.
- (15) Built in functions and procedures.

TRS-80 Pascal has the added advantage of being a full implementation of standard Pascal, thus program portability is greatly enhanced. These features, and the fact that programs generated by TRS-80 Pascal execute much faster than programs generated by most BASIC or other Pascal systems, make TRS-80 Pascal a logical choice as a general high level programming language.

## STARTING CONCEPTS

At the simplest level of structure of a Pascal program are the program, begin, and end statements. They may be thought of as the outer shell that must be around all programs. The actual program is placed between these begin and end statements. Example:

## Listing 1.1

```
PROGRAM test;  
BEGIN  
END.
```

This is a completely legal Pascal program although it actually does nothing. We can modify it by adding a writeln statement to it.

## Listing 1.2

```
PROGRAM test;  
BEGIN  
  WRITELN(OUTPUT, '* Pascal is a very structured language. ');  
  WRITELN(OUTPUT, '* It promotes good programming habits. ');  
END.
```

The program will write to the file associated with OUTPUT the following message.

```
* Pascal is a very structured language.  
* It promotes good programming habits.
```

The two `writeln` statements comprise the only action in the program. The `OUTPUT` in the `writeln` tells the computer to write the message to the file associated with the logical name `OUTPUT`. How this association is accomplished is a computer dependent process, and is explained in the System Implementation Manual. The string in single quotes is a text string that may be composed of printable characters. Notice two things about this program. First, the text string may not be broken up across line boundaries, however blanks may be used freely elsewhere to make the program more readable. Secondly, a semi-colon is required after each `writeln` statement. In fact, semi-colons are required after most Pascal program statements. For now, a good rule of thumb is to always include a semicolon after legal Pascal statements. The program name is `test`, but may be any identifier where the starting character is a letter. The "." must always occur after the last `END` statement in the program.

Another output statement similar to the `writeln` statement is the `write` statement. In the first sample program the two messages were written to different lines on the file. The `writeln` statement caused the file position pointer to reposition to the beginning of the next line after each message was written. The file position pointer is another name for the cursor when the file I/O is directed to the terminal. The `write` statement, does not reposition the cursor after the message has been written. Instead, the cursor remains at the end of the last message, and the next text will appear on the same line. The cursor represents the point on a line where text will appear from the next `write` statement.

## Listing 2.1

```
PROGRAM test;
BEGIN
  (* the purpose of this program is to give an example *)
  (* of how to use the WRITE and WRITELN procedures *)
  WRITE(OUTPUT, ' * Now is the time');
  WRITE(OUTPUT, ' for all good programmers');
  WRITE(OUTPUT, ' to learn');
  WRITELN(OUTPUT, ' Pascal. ');
  (* The next statement starts on a new line *)
  WRITELN(OUTPUT, ' * You will become a Pascal magician. ');
END.
```

The following message will be written to output.

- \* Now is the time for all good programmers to learn Pascal.
- \* You will become a Pascal magician.

If you noticed, the text enclosed between the (\* \*) did not affect the program execution. They are simply comments by the programmer to help clarify the logic in the program. Comments may be especially helpful later when you have forgotten how the program functions. They may be inserted anywhere except in the middle of identifiers or text strings. An identifier is just another name for a program, variable, constant, procedure or function name. Procedures and functions will be explained later.

#### Tutorial Quiz 2.0

- (1) The first statement of a Pascal program must be the \_\_\_\_\_ statement.
- (2) The \_\_\_\_\_ statement will not move the cursor to beginning of the next line.
- (3) The \_\_\_\_\_ statement will move the cursor to the beginning of the next line.
- (4) Most Pascal statements are followed by a \_\_\_\_\_.
- (5) The \_\_\_\_\_ statement must be the last statement of a program.
- (6) Quoted \_\_\_\_\_ may not be broken up across line boundaries.

#### Answers:

- (1) program
- (2) write
- (3) writeln
- (4) semicolon
- (5) end
- (6) strings

## DATA CONCEPTS

## Variables

Variables in Pascal serve the same purpose as they do in most other programming languages. They serve as storage areas for the information that the programmer may wish to manipulate. These storage areas are referred to by names that are chosen by the programmer. Each variable name must start with a letter. It may be composed of any combination of letters and digits, although in many Pascal implementations, the first eight characters must form a unique name within the program.

## Reserved words

There are certain words in Pascal that have special meanings. These words are called reserved words, and variables may not have these names. For a complete list see the TRS-80 Pascal Language Reference Manual.

## Variable types

Variables must have associated with them a specific type. The type is the kind of information that is going to be stored in that variable. For example, the variable "taxnumber" may represent a business tax number. This taxnumber might take on the numerical value of 1 to 100 at any time in the program. This would be an example of the type, integer.

## Declaring variables

All variables must have their specific type declared in a special section of Pascal programs called the var section. There are five predefined variable types in Pascal that we will concern ourselves with at this time. They are integer, real, char, text and boolean. The var section of a program consists of the word VAR followed by any number of variable declarations. A variable declaration has the form of variable name: variable type; . A colon separates the variable name from the variable type, and a semicolon must follow each variable declaration.

## Integer variables

The type integer may be used to represent whole numbers. The minimum and maximum size allowed by Pascal is computer dependent, but on many micro computers they range from -32768 to +32767 . The following is a program example of a variable declared as an integer. Notice that a colon is required to separate the variable name taxnumber, from the variable type, integer.

## Listing 3.1

```
PROGRAM test;
VAR
taxnumber:INTEGER;
BEGIN
END.
```

## Real variables

The type real may be used where a variable must store numbers that may have fractional or decimal values. The numbers 2.98 , 3.047 , 0.0009 , 0.009 and 37.0998 are all examples of real numbers. Real numbers must start with a digit and may contain a decimal point. If a decimal point is present, a digit must follow the decimal point. The numbers .009, 10. are illegal real numbers, as there is no digit before and after the decimal point. The size and precision of real numbers are computer dependent . Real variables may represent the dollar selling price of some product by a store, or an entry into your checkbook. They are declared as follows:

## Listing 3.2

```
PROGRAM test;
VAR
  taxnumbr:INTEGER;
  cost      :REAL;
BEGIN
END.
```

Note that the indentation of the declaration section does not affect the execution of the program.

### Char variables

If a variable is declared as a char type, then it may represent a single character such as the character 'A'. In Pascal, the characters may be composed of letters, digits and other special symbols. If a digit is to be referred to as a character instead of a number, it is enclosed in single quotes like the character string was in program listing 2.1. The only difference is that a char variable may only represent one character at a time.

### Text variables

Variables declared to be of the type text are used to direct output or input information to files on disks, or to other devices. Text is predefined to be a special file of char.

### Boolean variables

A variable declared as the type boolean may only have two values. They are true and false. This kind of variable is primarily used in flow control statements. Boolean variables are typically used in the WHILE, IF or REPEAT control statements. These statements will be covered in later chapters.

### Const section

Often, specific variables will have fixed values during program execution. In this case you may declare these values as constants. In Pascal, they are declared in the CONST section. The const declaration section is placed between the program and the first begin statement of the program. Constants may have names like variables do. In fact their names should reflect their nature. Constants may be integers, real numbers or a text string. A text string constant is any character string enclosed between single quotes. A string constant generally may be used anywhere a packed array[1..n]of char variable may be used. This variable type will be explained later.

- (1) \_\_\_\_\_ serve as storage areas for information that the programmer may wish to manipulate.
- (2) Variable types are declared in the \_\_\_\_\_ section of the program.
- (3) Five predefined type of variables in Pascal are \_\_\_\_\_ , \_\_\_\_\_ , \_\_\_\_\_ , \_\_\_\_\_ , \_\_\_\_\_ .
- (4) The syntax of a variable declaration is :  
var        variable name : \_\_\_\_\_ ;
- (5) Variables declared as the type \_\_\_\_\_ may take on the value of letters, digits and other special symbols.
- (6) A variable declared to be of the type \_\_\_\_\_ is used to direct I/O to files.
- (7) A value that is fixed in the program and will not change may be declared as a constant in the \_\_\_\_\_ section of the program.

**Answers:**

- (1) Variables (2) type (3) char, integer, boolean, real, text  
(4) type (5) char (6) text (7) const

## ADVANCED I/O

Procedures `rewrite`, `writeln`.

Can you guess what this program will do if you run it ?

Listing 4.1

```
PROGRAM alpha;
CONST
  pi      = 3.141597;
  maxtax  = 2000;
  tstring = ' I am a  Pascal Wizard';
VAR
  out     :TEXT;
  max     :REAL;
  number:INTEGER;
BEGIN
  REWRITE(out);
  WRITELN(OUTPUT,'Program starting execution.');
```

```
  WRITELN(' The value pi = ',pi);
  WRITELN(' The value maxtax = ',maxtax);
  WRITELN(tstring);
  WRITELN(out,'This program tests file I/O');
  WRITELN(OUTPUT,'Program finished.');
```

```
END.
```

From example 2.1 you already know that the first and last `writeln` statement will cause the program to direct the messages to the file associated with `output`. The following message will be written to `output`.

```
Program starting execution.
The value pi = 3.14159
The value maxtax =      2000
I am a Pascal wizard
Program finished.
```

The message, "This program tests file I/O", will be written to the file associated with `out`.

Examine the first `writeln` statement. In the specific case where the first argument for the `writeln` statement is output, the user is not required to declare output in the `var` section as with other files. Notice also that there is no output argument in the second, third and fourth `writeln` statements. In Pascal, it is not required to have output as an argument. Output is a default argument. I.e; the statements `writeln(output, ' help');` and `writeln(' help');` are equivalent in Pascal. In Pascal the `write` and `writeln` statements may have multiple arguments. The first argument always directs the I/O operation to a specific file except for the case previously explained. In listing 2.1 the two arguments were output and a text string. Constants and variables may also be arguments. The values of the variables and constants will be written in the same order as they appear in the argument list.

#### Rewrite statement

The purpose of the `rewrite(logical filename)` statement is to open a file on some hardware device, and ready it for writing. Note that the previous contents of any file used in a `rewrite` statement will be lost. The specifics of how to associate the logical filename in parentheses with a physical filename is implementation dependent and is explained in the TRS-80 Pascal System Implementation Manual. Standard Pascal does not require the file output to have a `rewrite` performed on it before it is written to. Output is the only file in Pascal that does not require a `rewrite` before it is written to. It is predeclared to be a textfile by Pascal.

#### Reset statement

The purpose of the `reset` statement is to ready a file for reading to a program. A `reset(logical filename)` statement will open the physical file associated with the logical filename and read the first line. In TRS-80 Pascal, the first line is not read until required by an EOF or EOLN function call. These functions will be explained later. All files that are to be used for reading must be reset, except Input. Input is a predeclared textfile within Pascal.

#### Read, readln statements

The `read` statement is similar to the `write` statement, except that its purpose is to read information into the program instead of to write information. The `read` statement will read a value into a variable from a file and will leave the cursor at the last character read.

Specific reads on the same file will cause a series of inputs to occur from the same line. When a read is performed on an integer or real quantity in a text file, the read will start scanning the line until any non-blank character is found. The next contiguous non-blank characters will be interpreted by the read as the input value. If another read is performed on the same file, the read procedure will scan forward and repeat the process, until the end of line is reached. If the end of line is reached before any integer is found, the scan will continue at the beginning of the next line.

The readln statement performs the same function as the read statement, except that the cursor will always be positioned to the beginning of the next line after all inputs to the read statement are satisfied, even if the end of line has not been reached. The readln statement is not required to have arguments. The effect of such a readln is to position the cursor to the beginning of the next line without reading any values. The arguments allowed for the read statement are variables. As with OUTPUT in the write statement, INPUT is predeclared to be a text file. If a read statement does not have a file argument, it is assumed to be the predeclared file INPUT.

Try running the following program. It will give you a little more experience performing program I/O.

#### Listing 4.2

```
PROGRAM testIO;
(* Purpose- the purpose of this program is to      *)
(* demonstrate I/O to a text file using integer and *)
(* real input variables.                            *)
VAR
  taxnumbr,emnumber   :INTEGER;
  tax                 :REAL;
  ID                  :PACKED ARRAY[1..72]OF CHAR;
BEGIN
  WRITELN(OUTPUT,'* Enter your federal tax number: ');
  READLN(INPUT,taxnumbr);
  WRITELN(OUTPUT,'* Enter your dollar tax total: ');
  READLN(INPUT,tax);
  WRITELN
    (OUTPUT,' * Enter your employee number,a space,');
  WRITELN(OUTPUT,' followed by your business ID number:');
  READ(INPUT,emnumber);
  READLN(INPUT,ID);
  WRITELN(OUTPUT,' Tax number      = ',taxnumbr);
  WRITELN(OUTPUT,' Dollar tax total = ',tax);
  WRITELN(OUTPUT,' Employee number = ',emnumber);
  WRITELN(OUTPUT,' Business I.D.   = ',ID);
END.
```

The following I/O will occur at the terminal if the filename associated with input and output is the local terminal.

```
* Enter your federal tax number:
32000                                <user input>
* Enter your tax total:
2345.98                             <user input>
* Enter your employee number, a space,
followed by your business ID number:
23455 4669                          <user input>
Tax number                           = 32000
Dollar tax total                      = 2345.98
Employee number                      = 23455
Business I.D.                       = 4669
```

#### Tutorial Quiz 4.0

- (1) The predefined file variables \_\_\_\_\_ and \_\_\_\_\_ are not required to be declared in the var section as the type text.
- (2) The first argument in a \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ statement directs I/O to a file or device.
- (3) The purpose of the \_\_\_\_\_ statement is to open a file and ready it for writing.
- (4) The purpose of the \_\_\_\_\_ statement is to open a file and ready it for reading.
- (5) After a \_\_\_\_\_, the previous contents of the file are lost.
- (6) A \_\_\_\_\_ or \_\_\_\_\_ statement will cause the cursor to move to the next line after execution.

#### Answers:

- (1) input, output (2) read, readln, write, writeln
- (3) rewrite (4) reset (5) rewrite (6) readln, writeln

## STATEMENTS

## Assignment statements

From previous examples, you know how to read a value into a variable and how to write it. Now you will learn how to alter its value within the program. The statement that does this is the assignment statement. It allows you to set a variable's value equal to an expression. An expression may be a variable name or a series of arithmetic or boolean operations. A simple assignment statement takes the form of `variablename1 := variablename2; .` The `:=` operator causes the variable on the left hand side to become equal to the value of the variable on the right hand side.

## Listing 5.1

```

Program MAGIC;
VAR
  intrate,principle,aint,calc:REAL;
BEGIN
  WRITELN(' ***** Interest rate problem *****');
  WRITELN(' Enter annual interest rate:');
  READLN(intrate);
  WRITELN(' Enter the principle amount of loan:');
  READLN(principle);
  calc:= intrate * principle;
  aint:=calc;
  WRITELN(' Your annual interest payment = ',aint);
END.

```

## Arithmetic operators

In the program listing 5.1 you may have noticed the statement `"calc:= intrate * principle"`. The `" * "` is the multiply operator in Pascal. There are seven arithmetic operators in Pascal with precedence as follows :

OPERATOR PRECEDENCE TABLE 5.1

Symbol	Precedence	Description
-	(1) Highest	Unary operator. Negates a single argument.
*	(2)	Multiplies two arguments
/	(2)	Divides two real arguments
div	(2)	Divides two integer arguments
mod	(2)	Divides two integer arguments and keeps the remainder as the result.
+	(3) Lowest	Adds two arguments
-	(3) Lowest	Subtracts two arguments

### Operator precedence

If an arithmetic expression is composed using different operators without any parentheses, the order of evaluation is based on the above table, where operations with the highest precedence are performed first. Any operations at the same level are performed in left to right order.

### Parentheses

In Pascal, this natural order of precedence may be altered by enclosing a portion of the expression in parentheses. The parentheses has the highest precedence of all operators. Parentheses may be nested to alter the evaluation sequence as desired. In this case, operations buried deepest within are evaluated first.

The following program will illustrate the use of the arithmetic operators and parentheses.

## Listing 5.2

```
PROGRAM math;
CONST
  fudge    = 100;
  lossacre = 0.50;
VAR
  acsoy,acgreen  :INTEGER;
  prsoy,prgreen  :REAL;
  profit,overcost :REAL;
BEGIN
  Writeln(OUTPUT, ' **** Farmers profit analysis program **** ');
  Writeln(OUTPUT, '* Please enter the following information:');
  Writeln(OUTPUT, '* Acres planted in soy beans = ');
  Readln(INPUT,acsoy);
  Writeln(OUTPUT, '* Profit per acre of soybeans = ');
  Readln(INPUT,prsoy);
  Writeln(OUTPUT, '* Acres planted in green beans = ');
  Readln(INPUT,acgreen);
  Writeln(OUTPUT, '* Profit per acre of green beans = ');
  Readln(INPUT,prgreen);
  Writeln(OUTPUT, ' $$$ COMPUTATION IN PROGRESS $$$ ');
  profit:= acsoy * prsoy + acgreen * prgreen
    - (fudge / (acsoy+acgreen) * lossacre);
  Writeln(OUTPUT, ' Your computed profit is ');
  Writeln(OUTPUT,profit);
END.
```

The profit calculation uses parentheses to alter the normal operator precedence. If the normal precedence is followed, the calculation will yield the wrong result.

The order of evaluation without parentheses would be:

- (1) acsoy and prsoy multiplied.
- (2) acgreen and prgreen multiplied.
- (3) fudge / acsoy
- (4) acgreen \* lossacre
- (5) result1 + to result2
- (6) result5 - result3
- (7) result4 + result 6

The desired result is obtained by including the parentheses as in the example. The apparent order of evaluation would be:

```
profit := acsoy * prsoy + acgreen * prgreen
        -(fudge / (acsoy+acgreen) * lossacre) ;
```

- (1) acsoy added to acgreen
- (2) fudge / result1
- (3) result2 \* lossacre
- (4) acsoy \* prsoy
- (5) acgreen \* prgreen
- (6) result4 + result5
- (7) result6 - result3

If two numbers are operated on, the normal result will have a type that is dependent on the argument types. The variable types required to store the results of specific operations are summarized in the following table.

*	multiply	real * integer = real result. integer * real = real result. real * real = real result. integer * integer = integer result.
/	real divide	real / real = real result. real/integer = real result. integer/real = real result. integer/integer = real result

div	integer divide	integer div integer = integer result. integer arguments only.
mod		integer mod integer = integer (integer div integer= remainder)
+	add	integer + integer = integer result.
		integer + real = real result.
		real + integer = real result.
		real + real = real result.
-	subtract	integer - integer = integer result.
		integer - real = real result.
		real - integer = real result.
		real - real = real result.

#### Compound statements

If a series of program statements are surrounded by a begin and end statement, then the enclosed statements are considered a compound statement. Compound statements are normally used as arguments to control structures such as the WHILE and IF. A compound statement may occur by itself anywhere in a Pascal program, however, its meaning would be the same as if the begin and end were not present. The important thing to remember about Pascal is that anywhere a single statement may be used, a compound statement may be used.

- (1) \_\_\_\_ is the symbol for the assignment operator.
- (2) If a series of statements are surrounded by a begin and end , it is called a \_\_\_\_\_ statement.
- (3) Operator precedence refers to the order in which an \_\_\_\_\_ is evaluated.
- (4) The natural order of expression evaluation may be altered by using \_\_\_\_\_ .
- (5) The \_\_\_\_\_ with the highest precedence will be evaluated first.
- (6) Operators that have the same level of precedence will be evaluated in \_\_\_\_\_ to \_\_\_\_\_ order.
- (7) After executing the following Pascal statement, variable x will have the value \_\_\_\_\_.

```
PROGRAM QUIZ;  
VAR  
    x:integer  
BEGIN  
    x:=4 + 5 * 2;  
END.
```

Answers:

- (1) := (2) compound (3) expression (4) parentheses
- (5) operator (6) left, right (7) 14

## FLOW CONTROL

## FOR statements

If you wish to execute a series of statements a predetermined number of times, you should use the FOR statement. The for statement will cause a single or compound statement to execute a specific number of times. Examine the following example .

## Listing 6.1

```

PROGRAM math;
CONST
  fudge      = 100;
  lossacre  = 0.50;
  prsoy     = 195.98;
  prgreen   = 200.56;
VAR
  acsoy,acgreen,nofields,select,fieldnumber:INTEGER;
  profit,overcost: REAL;
BEGIN
  WRITELN(OUTPUT,'* Farmers planting analysis program * ');
  WRITELN(OUTPUT,'* How many fields do you have ?');
  READLN(INPUT,nofields);
  FOR fieldnumber := 1 to nofields DO
    BEGIN
      WRITELN(OUTPUT,'* For field number ',fieldnumber);
      WRITELN(OUTPUT,'* Acres planted in soy beans = ');
      READLN(INPUT,acsoy);
      WRITELN(OUTPUT,'Acres planted in green beans = ');
      READLN(INPUT,acgreen);
      profit:= acsoy * prsoy + acgreen * prgreen
              - (fudge / (acsoy+acgreen) * lossacre);
      WRITE(OUTPUT,'* Your computed profit for field number ',
            ,fieldnumber,' is ');
      WRITELN(OUTPUT,profit);
    END;
  END.

```

The loop control variable is "fieldnumber" . This variable is declared as an integer. When the loop starts its execution, "fieldnumber" takes on the value of one for the first pass through the loop. Successive loop iterations cause this value to be incremented by one until its value is greater than "nofields" . At this point, the loop will stop and control will be passed to the next statement in the program. The lower and upper bounds on the loop control variable do not have to be variables or constants, but may be arithmetic expressions. The expression is evaluated one time, at the beginning of the loop. The upper bound must be greater than or equal to the lower bound for the loop to execute at least once.

A variation on the for loop just described causes the loop control variable to be decremented by one instead of incremented by one. The syntax for this is the same as above except that the "to" in the for statement is replaced with "downto" . The initial upper bound on the loop control variable must be larger than or equal to the lower bound for the loop to execute at least once.

#### Case statement

The case statement is used as a selection control statement. It is used when you need to execute one statement from a list of statements. Notice the following program. In front of every statement in the list, is a case selector constant. This selector value must be of the same type as the case selector variable, and may be composed of a list of values for each statement it precedes. The "end" must follow the last statement in the list in order to terminate a case statement. We will be concerned with selector variable of type integer at this time.

## Listing 6.2

```

PROGRAM moonphase;
CONST
  dayphcorr = 10;
  lencycle = 28.3;
VAR
  daynumber,intphase           :INTEGER;
  startphase,phase,month,day,year :INTEGER;
  realphase,phasecorrection    :REAL;
BEGIN
  WRITE(OUTPUT,' *** Lunar Phase calculation program');
  WRITELN(OUTPUT,' ***');
  WRITELN(OUTPUT,' Enter the month/day/year:');
  READLN(INPUT,month,day,year);
  startphase := ((year-78) * 365) + dayphcorr ;
  CASE month of
    1: daynumber:=1;
    2: daynumber:=32;
    3: daynumber:=60;
    4: daynumber:=91;
    5: daynumber:=121;
    6: daynumber:=152;
    7: daynumber:=182;
    8: daynumber:=213;
    9: daynumber:=243;
    10: daynumber:=274;
    11: daynumber:=304;
    12: daynumber:=334;
  END; (*case*)
  startphase := startphase + daynumber + day;
  realphase := startphase / lencycle;
  intphase := TRUNC(realphase);
  realphase:=realphase-intphase;
  phase:=realphase * lencycle;
  CASE phase OF
    1,2,3,4,5,6,7           : WRITELN(OUTPUT,
      'The moon is in its first quarter.');
```

8,9,10,11,12,13,14	: WRITELN(OUTPUT,	'The moon is in its second quarter.');
15,16,17,18,19,20,21	: WRITELN(OUTPUT,	'The moon is in its third quarter.');
22,23,24,25,26,27,28	: WRITELN(OUTPUT,	'The moon is in its fourth quarter.');

```

  END; (*case*)
END. (*PROGRAM*)

```

The purpose of the program in listing 6.2 is to compute the phase of the moon. Several examples of case statements are used with differing case selector lists. The calculations are based on a known starting phase of the moon at some past day, and year. The initial startphase calculation yields the number of days since this known starting date as a function of the number of years, corrected for the starting phase of the moon. The remainder of the calculations simply adjust this value to yield the whole number of days since the known starting phase, then divide the resultant number of days by the lunar cycle length in days. This program does not consider the effect of leap years. Notice that mixed mode expressions consisting of real and integer arithmetic are used throughout the calculations. A careful study of the previous type result tables will verify their validity. Notice that the value of realphase is used as an argument for the TRUNC function. This is a predefined function available in Pascal that will truncate a real number and store the result in an integer.

#### Tutorial Quiz 6.0

- (1) The \_\_\_ statement is used to make a single or compound statement execute a specific number of times.
- (2) In successive loop iterations in a \_\_\_\_\_ loop, the loop control variable is either incremented by one or decremented by one.
- (3) The \_\_\_\_\_ statement is used to select a statement to execute from a list of statements.
- (4) The "downto" and "to" are elements of the \_\_\_\_\_ statement.
- (5) An \_\_\_ must follow the case statement.

#### Answers:

- (1) for (2) for (3) case (4) for (5) end

## DECISION TESTING

Often, it is necessary to make tests to determine the flow of control in a program. The case statement is a simple example. However, it may become necessary to perform more complex tests than the case statement was intended for. Pascal has a powerful set of logical and relational operators that make such testing easy. Most logically complex programs use relational testing for advanced control. The logical and relational operators are as follows :

## Logical operators

- and - Will evaluate two boolean expressions, then perform a logical "and" on them, returning either a boolean "true" or "false".
- or - Will evaluate two boolean expressions, then perform a logical "or" on them, returning either a boolean "true" or "false".
- not - Will change a boolean value to the opposite value.

## Relational operators

It is often necessary to compare several variables for equality in an expression to determine the flow of control. This may be accomplished by relational testing. There are six relational operators in Pascal, all with equal precedence. Their precedence may be altered just like the arithmetic operators by the use of parentheses. If the relational test fails, a Boolean False is returned by the expression. If the test succeeds, then a true is returned. The operators are as follows.

=	Equal to	<>	Not equal to
>	Greater than	<	Less than
>=	Greater than or equal to	<=	Less than or equal to

There are two constructs in Pascal that often use relational testing for loop control. They are the while and repeat statements. Almost all goto and other branching constructs may be replaced with these statements. Unlike the goto statement, these statements force simple and clear design of loops, often eliminating the unclear conditions for exiting. Usually, if it is not possible to formulate a loop construct using the while, repeat and if statements, instead of a goto, it is because the loop itself has not been properly defined. I.e; the programmer does not have the specifics clear in his mind.

#### If statement

A typical use of a relational test is illustrated in the if statement. In the following example let the variables "Monday" and "October" be of the type boolean with their values both being true.

#### Listing 7.1

```
PROGRAM testIF;
VAR
  Monday,October:BOOLEAN;
BEGIN
  Monday:=true;
  October:=true;
  IF October AND Monday THEN
    Writeln(OUTPUT,'Its October and Monday')
    (*notice no semicolon after the previous statement*)
  ELSE Writeln(OUTPUT,'Date unknown.');
```

This program will print the message, "Its October and Monday" since October is true, and Monday is true. This example illustrates the use of the "if then else" statement in Pascal. If the expression is evaluated to be true, the first action will be taken. If it is false, the statement following the else will execute. The statements may be simple or compound. Notice that a semicolon may not precede the else in the IF statement.

Notice the following example where "income" has been declared as the type integer and "president" is of type boolean.

```
IF (income > 32000) AND NOT(president) THEN
  BEGIN
    WRITELN(OUTPUT,'You are being audited by the IRS.');
```

```
    WRITELN(OUTPUT,'Please justify your deductions.');
```

```
  END;
```

The value of the expression will be true if the integer value of "income" is greater than 32000 and the boolean value of "president" is false. When the value of "president" is false, the not operator will reverse its value to true. This type of expression is one of the strengths of Pascal. With a little experience, you will find it easy to write expressions. This greatly improves the readability of logically complex programs. Arguments for relational operators must be of the same type. In the example, "income" must be declared as an integer type for the statement to be valid in Pascal. For now, we will concern ourselves with integer and boolean comparisons.

#### While statement

The while forces a statement to execute while some condition is satisfied. The condition is the value of a boolean variable or the boolean result of some expression. Some computation inside the loop should change one of the variables used in the test to cause the relational test to fail, terminating the loop. The while statement will perform the test at the beginning of every loop. The while loop might never execute any of the enclosed statements as the initial test occurs before the loop is entered. In the next example, cnt, cost and unitprice are declared as type integer, and underbudget is of type boolean. Notice the following example syntax.

```
cnt:=0;
underbudget:=true;
WHILE (cnt < 20) AND (underbudget) DO
  BEGIN
    cnt:= cnt + 1;
    cost := cnt * unitprice ;
    IF (cost > 200 ) THEN underbudget :=false;
  END;
```

The previous example will execute as a conditional loop instead of a predetermined number of times as in the for loop. When "cnt" gets incremented to twenty one, or cost exceeds 200, the loop will terminate. Note that the "cost > 200" test could have been put in the while expression just as easily.

#### Repeat statement

Another statement similar to the while is the repeat. A statement or series of statements will be repeated until an expression becomes true. The difference between the while and repeat may not be obvious. The difference is that the repeat statement will always execute at least once because the relational test occurs at the end of the loop. The use of repeat sometimes causes problems for new programmers, as there may be cases where you do not want the loop to execute at all, however it will always execute at least once. An example of repeat is as follows:

```
cnt:=0;
underbudget:=true;
REPEAT
  cnt:=cnt + 1;
  cost := cnt * unitprice;
  inventory:=inventory +1;
  IF (cost > 200) then underbudget:=false;
UNTIL(cnt >= 20) OR NOT(underbudget);
```

Notice that the test was changed to use the OR operator instead of the and operator. This is simply due to the different context of the two statements. There is no begin or end required. The statement(s) to be executed are simply placed between the repeat and until. What happens to this loop if the initial value of "unitprice" is greater than 200 ? The loop will terminate on the first iteration, but alters the value of "inventory". This might not be the desired result and could cause an illegal entry into the inventory. In this situation, the while statement would be the proper choice of a looping construct, as it would detect this before "inventory" is changed.

#### Tutorial Quiz 7.0

- (1) The logical operators in Pascal are: and, \_\_\_\_, \_\_\_\_ .
- (2) The and operator will return a value of \_\_\_\_, if the value of the both expressions it is evaluating is true.
- (3) The or operator will return a value of \_\_\_\_, if one of the expressions it is evaluating is true.
- (4) The not operator will reverse the value of a \_\_\_\_\_ variable or expression.
- (5) The IF statement will execute the else portion of the statement, if the value of the expression is \_\_\_\_\_.
- (6) The while statement will execute as long as the boolean result of the expression is \_\_\_\_\_.
- (7) The repeat will execute all statements between the repeat and until as long as the expression is \_\_\_\_\_ .

#### Answers:

- (1) or, not (2) true (3) true (4) boolean (5) false  
(6) true (7) false

## PROCEDURES AND FUNCTIONS

## Procedures

In the introduction, one of the claimed strengths of Pascal was that it promotes modularity. Modularity is another name for organizing a program into sections, each of which performs a specific function, instead of one large block of continuous statements. One of the reasons that Pascal programs may have a high degree of modularity is that the language was designed with procedures and functions in mind. In a few languages, they are not even supported, and in others, passing parameters can become a major chore. This is not the case in Pascal, as several different methods are available to pass data to subroutines that need it. Furthermore, there are rules about how procedures may call other procedures and access their internally defined variables. These scoping rules, as they are called, may seem a little restrictive, but they provide valuable protection. This partitioning of the problem eventually decreases program size and improves readability to the programmer or anyone who must maintain it. A simple way to decide whether a procedure or function should be used is to examine the problem and to decide if there are a series of statements that need to be executed several times, and in different parts of the program. The identified program segments should be placed in a procedure or function.

## Procedure structure

Procedures may be thought of as complete sub-programs that have data passed to them as needed. In many descriptions written about Pascal, they are often called one of the basic blocks, and in this manual, a block will be considered to be a program, procedure or function. The structure of a procedure is the same as for the original program with a few exceptions. The data that is passed to a procedure block is passed through a parameter list. The parameter list is placed after the procedure name. Examine the following program.

```

Listing 8.1
PROGRAM INSTRUCTIONAL;
VAR
    number :INTEGER;
    posnumber:INTEGER;
    legal :BOOLEAN;
PROCEDURE readn ( VAR number: INTEGER; VAR legal: BOOLEAN );
(* The purpose of this routine is to read *)
(* a positive number from a file in a *)
(* character format and convert it to an integer*)
(* format. *)
VAR
    loopcontrol,forcntr,inc:INTEGER;
    string :ARRAY [1..72]OF CHAR;
BEGIN
    FOR loopcontrol :=1 to 72 DO string[loopcontrol]:= ' ';
    loopcontrol :=0;
    WHILE NOT EOLN(INPUT) DO
        BEGIN
            loopcontrol := loopcontrol + 1;
            READ(string[loopcontrol]);
            IF(string[loopcontrol]=' ')THEN
                (* Remove all leading blanks from array *)
                loopcontrol:=loopcontrol - 1;
            END;
            number:=0;
            inc:=1;
            FOR forcntr :=loopcontrol DOWNTO 1 DO
                BEGIN
                    number:=number+((ord(string[forcntr])-ord('0'))*inc);
                    inc:=inc*10
                END;
            IF (number < 0) THEN
                BEGIN
                    legal := false;
                    WRITELN('* Error - Illegal entry. Try again. ');
                END
            ELSE legal:= true;
        END;
    END;
    (*procedure readn*)

BEGIN
    legal:=false;
    WHILE NOT legal DO
        BEGIN
            WRITELN('Enter any positive number:');
            READN(posnumber,legal);
        END;
    END.

```

The purpose of the program 8.1 is to read a positive integer in from the file input and to check for illegal entries. This declared procedure represents a typical use for a procedure, since it might be called several times, from different places in the program. Notice the `coln(input)`. `Eoln` is a boolean function that will return a true value when an "end of a line" of the file specified in the parentheses is reached. As soon as the cursor is moved from this position by another `readln`, it's value becomes false again. Notice also the function call to `ORD`. `ORD` is a Pascal function that returns the internal integer representation of a character.

Since there is only one copy of this procedure in memory no matter how many calls there are, a considerable amount of memory space can be saved. In fact, a procedure's variables do not occupy storage space until the procedure is actually called.

The procedure declaration comes after the `const` and `var` section, and before the first begin statement of the block in which it resides. Remember, a block may be a main program, procedure or function.

### Local variables

Local variables are declared in a particular procedure, function or program. For example, the variable `forcntr` declared in procedure `readn`, is local to `readn` and is accessible from `readn` only. However, notice the variable `number` declared in the main program block. Inside the procedure `readn`, the variable `number` may be used without declaring it, since it appears in the calling program. This means that if `readn` is called by the main program and `readn` alters `number`, then upon return to the main program, `number` will have the altered value. This side effect can be avoided by declaring `number` again in the procedure block. Then all references to `number` will refer to a different variable. The use of global variables should always be kept to a minimum, so as to minimize any accidental changes in their values.

### Procedure parameters

An alternate method of changing global variables within a procedure is to pass them as parameters in a parameter list. This allows different variables to be passed at different times and makes the use of the global variable more visible in the program. The parameter list is placed in the procedure declaration after the keyword `procedure`. In the parameter list, a variable may be passed by two different methods. These two methods are referred to as passing by reference, or passing by value.

When a parameter is passed by reference, the actual argument is passed to the procedure, and if the procedure alters its value, the argument's value is changed in the rest of the program. When a parameter is passed by reference, the argument must be a variable.

When a parameter is passed by value, what is passed is a copy of the argument. If the procedure alters the parameter's value, the value in the rest of the program is not changed. When a parameter is passed by value, the argument may be a variable or any legal arithmetic expression. Parameters passed by value will prevent unwanted changes in a variable value by the called procedure. Notice the following example parameter list.

```
PROCEDURE test ( date: INTEGER; VAR profit:REAL; cost:REAL);
```

The variables "cost" and "date" will be passed by value. The variable "profit" will be passed by reference. Every time a variable is to be passed by reference, the keyword "var" must precede it, otherwise it will automatically be passed by value.

It is sometimes hard for new programmers to understand the difference between letting variables be global when accessing them in a procedure, versus passing them by reference. There is a major difference, in that different variables may be passed to a procedure. The only stipulation is that the variables must match the parameter list. If they are declared as globals and altered by a procedure, then all values to be passed to the procedure must be transferred to these global variables. A second major difference is that in large programs, it is often difficult to determine what routines are changing specific variables. Sometimes accidental changes may occur in global variables. These changes are often referred to as side effects.

By adhering to the convention of passing the variables to a procedure, it is easier to determine how procedures alter external variables and to minimize unwanted side effects. Certainly, global variables do have use in Pascal programs, but many new Pascal programmers have a tendency to over use them.

### Calling procedures

Procedures are called simply by referencing their name followed by an argument list enclosed in parentheses. The list should be composed of variables of the same type and order as declared in the procedure declaration section.

## Functions

Another block in Pascal similar to the procedure is the function. Its internal structure is the same as the procedure with const, var and type sections optional. The purpose of a function is similar to a procedure. A procedure may stand alone as a statement, as the call to "readn" illustrates in program 8.1 . A function may not stand alone. It must be used in an expression, and may be used anywhere a variable can be used. Consider the following program.

Listing 8.4

```
PROGRAM functiontest;
VAR
    num:INTEGER;

FUNCTION ABS( number: INTEGER ) : INTEGER;
BEGIN
    IF (number < 0) THEN ABS := - number
    ELSE ABS := number;
END;

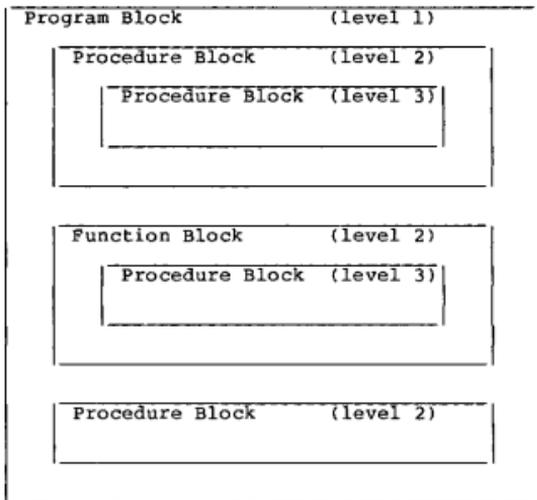
BEGIN
    num:= -30;
    num := ABS (num);
    WRITELN(' the absolute value of num = ',num);
END.
```

The result returned by the abs function is of the type integer. The result must be used in an expression or assignment statement. It is not valid to simply say abs (num) . The mechanism used to transfer the functions calculated value back to the calling program is the use of an assignment statement to assign the value to an identifier that has the same name as the function name. This particular function is already predefined in Pascal, and serves the same purpose as the example.

## Advanced program structure

Pascal is a block structured language. This means that a program is constructed in a block like manner. At a minimum, a program consists of one block. More blocks are created through the use of procedures and/or functions by placing them inside this outermost "program block". The term for this process is called nesting. The rule for nesting is that a block may lie entirely within another block, but blocks do not overlap in any other way. A level of nesting can be assigned to each block of a program. This provides an appropriate tool for describing scope rules which are discussed later. The block structured organization of a program can be represented pictorially by the following diagram.

Diagram 8.1



A program then consists of at least one block, the program block, and optionally it contains procedure and/or function blocks which are nested within.

Local variables are those variables declared within the var section of a particular procedure. Locals can be accessed from the body of the procedure in which they are declared and from those procedures declared within it. If a variable is used within a procedure and is not declared local to it, then a global variable is used. Global variables are those variables declared in an outer enclosing block.

Listing 8.2

```
PROGRAM globals;
VAR
  i : INTEGER;
  b : BOOLEAN;

PROCEDURE inner;
VAR
  b : INTEGER;
BEGIN
  b := i + 25;
  i := i + 1;
END;

BEGIN
  i := 0;
  writeln(i);
END.
```

In the above program, the *i* in the procedure refers to the variable *i* in the main program. Since the program "global" is an enclosing block to the procedure "inner", the variables declared within the program are accessible to the procedure. In the case of the variable "b", the var section of the procedure redeclares *b* to be an integer. When *b* is referred to in the procedure inner, the local variable is used. The declaration of *b* as a local variable "masks" the global definition of *b*.

#### Scope rules

The rules of accessibility of variables, types and constants are referred to as scope. The scope of an identifier is the procedure in which it is declared, and all procedures declared within that procedure. All identifiers including types, constants, variables and procedure declarations have scope.

If an identifier is redeclared within its scope, the outer definition becomes inaccessible within the scope of the inner definition. In the example above, the declaration of `b` as an integer within the inner procedure causes all references to `b` in that procedure to refer to the local variable. The outer definition of `b` as a boolean cannot be seen.

Pascal requires that all identifiers be declared before they are used. If the declaration of an identifier has not yet been encountered in the text of a program, then the identifier is considered undefined. A procedure can be called from the body of the block declaring it, from the procedures declared within it and from the procedures declared within the same block. However, if procedure `A` is declared before procedure `B` in the same block, then procedure `B` can call `A`, but procedure `A` cannot call `B`. This is due to the fact that the declaration of `B` has not been encountered in the source text when the body of procedure `A` is being compiled.

The above visibility restriction can be avoided with the use of forward declarations. In a forward declaration, the body of the procedure is replaced with the word `FORWARD`. The actual body is then supplied later. If all procedures within a block are declared forward, then any one of them can call any other.

## Listing 8.3

```
PROGRAM Outer;
VAR
  i : INTEGER;
FUNCTION Distance(x1, x2 : INTEGER):INTEGER;FORWARD;
FUNCTION Abs(tvalue : INTEGER) : INTEGER; FORWARD;

FUNCTION Distance(*(x1, x2 : INTEGER) : INTEGER *);
BEGIN
  distance := abs(x2 - x1);
END;

FUNCTION Abs(*(tvalue : INTEGER) : INTEGER *);
BEGIN
  if tvalue < 0 then abs := -tvalue
  else abs := tvalue;
END;

BEGIN
  WRITE('DISTANCE = ',Distance(8,2));
END.
```

If a procedure is declared forward, its parameter list is supplied by the forward declaration. The body appears later in the text. The body is introduced by the procedure name followed by a semicolon. The parameter list is not repeated. Notice that in the example, the parameter list is commented out by putting (\* \*) around it. It is good practice to include the parameter list of a forward procedure in a comment. This makes the body of the procedure easier to read.

#### Tutorial Quiz 8.0

- (1) \_\_\_\_\_ and \_\_\_\_\_ promote modularity and functionality in programs.
- (2) Data is passed to procedures and functions through a \_\_\_\_\_ list.
- (3) Blocks may be \_\_\_\_\_ within other blocks.
- (4) Nesting affects the \_\_\_\_\_ of blocks.
- (5) A block nested within an outer block may access the outer blocks \_\_\_\_\_ .
- (6) Parameters may be passed by value or \_\_\_\_\_ .
- (7) When a variable is passed by \_\_\_\_\_ , a copy of the variable is passed.
- (8) When a variable is passed by reference the keyword \_\_\_\_\_ must precede it in the parameter list.

#### Answers:

- (1) Procedures, functions (2) parameter (3) nested
- (4) level (5) identifiers (6) reference (7) value
- (8) var

## ADVANCED DATA TYPES

## Array data type

Another cousin to the data types already explained is the array. Sometimes a large number of variables of a particular type are needed. If for example you required seventy two variables of the type char to represent a user's input character string from a file, you could declare them as previously explained. The disadvantage is obvious, as the effort would be time consuming. Furthermore, accessing the individual variables would be confusing, as each would have a different name.

There is a simple answer to this problem and it is the data type array. You may declare a variable as :

```
variablename : array [1..n] of type;
or
variablename : array (.1..n.) of type;
```

Note - In TRS-80 Pascal, (. may be substituted for [, and .) for ]

where type is any previously defined data type and n is the number of variables desired. For now we will concern ourselves with integer dimensions. Integer dimensions may be any positive or negative numbers such that the range of dimensions do not cause a storage overflow. This is a machine dependent constraint that varies among implementations. Thus we may declare :

```
VAR   line : array [1..72] of char;
      varname:char;
```

To access a component of this array you would use a subscript denoting the numerical element. An example assignment might be varname := line[4]; . Varname would be set to the value of the fourth element in the array line.

Any array may be declared with the word PACKED as a prefix. The packed attribute tells the compiler to store the data elements as efficiently as possible. In Standard Pascal, you may not pass elements of packed structures by reference to procedures or functions, and packed elements may not be used as arguments in READ statements. In TRS-80 Pascal, there are no such restrictions.

## Arrays

## listing 9.1

```
PROGRAM onedimarray;
VAR
  string1: PACKED ARRAY [1..72] OF CHAR;
BEGIN
  WRITELN('Enter command string');
  READLN(INPUT,string1);
  WRITELN(OUTPUT,string1);
  WRITELN('Program complete');
END.
```

If the I/O is directed to the terminal, the program will display the prompt: "Enter command string". At this point the user may type up to seventy two characters of input, terminated with the return key. The input characters will be input to the array "string1" left justified. If the input character string is less than seventy two characters in length, the remaining storage positions in the array will contain blanks. At this point the input message will be echoed to the terminal. In TRS-80 Pascal, an entire single dimension packed or nonpacked array of char may be input/output by a single read/write.

Arrays in Pascal may have multiple dimensions. Suppose that you had a number of input character strings as in the previous example, and it was desired to store every character string. A simple answer would be to declare the array line : array [1..5,1..72] of char; . This declaration is a Pascal short form for the declaration of array[1..5] of array[1..72]of char; .

If the data structure is a two dimensional array of char, then the read command will not input the entire array automatically, but instead requires that each individual sub-array be read in with a separate read statement.

Remembering that any single dimension array may be input by a single READ statement, leads to the following example array input sequence. Examine the following program.

## listing 9.2

```
PROGRAM arrayIO;
VAR
  I      : INTEGER;
  string1 : ARRAY [1..5,1..72] OF CHAR;
BEGIN
  FOR I:= 1 TO 5 DO
    BEGIN
      Writeln(OUTPUT,'Enter command line ',I);
      Readln(INPUT,string1[I] );
    END;
  END.
```

This program will prompt the user for five different command lines. In each case, the individual sub arrays are loaded into the array by the program.

Since individual array elements are of the type char, any operations that can be performed on a simple variable, of type char, may be performed on an array element. Remember also that arrays may be of any type such as boolean, integer or any user defined data types, including arrays. Arrays may have upper and lower bounds declared as constants in the declaration, and in fact, the name of most simple data types may be substituted for the bounds. The number of array elements in this case is determined by the number of elements in the data type.

## User defined data types

The data types explained so far have been pre-defined. In Pascal, you may define new data types at will. These defined types have names chosen by the programmer and are declared in the TYPE section. Once declared, they may be used where predefined type names are allowed. This is a very powerful feature. Take for example the case where a programmer is manipulating an integer variable in Basic that may take on one of four values, 1..4. The numbers may represent the colors red, green, blue and orange. When the value is 1 : a message is written to the terminal saying that the color red is being processed, 2 : That the color green is being processed and so on. This is typically known as decoding information from a variable's value. Needless to say, when Basic programs get very long, it is difficult to determine their flow because of this decoding and encoding of information. A simpler way would be to declare a variable that could take on the value of red, green, blue and orange. Then tests could be performed to see if the value of the variable is red, etc. Program logic would be much clearer and easier to follow. In fact, this is exactly what the following program does.

## listing 9.3

```
PROGRAM usertypes;
TYPE difcolor = (red, green, blue, orange);
VAR
  color: difcolor;
BEGIN
  color := red;
  REPEAT
    CASE color of
      red   : Writeln(OUTPUT, ' The color is red');
      green : Writeln(OUTPUT, ' The color is green');
      blue  : Writeln(OUTPUT, ' The color is blue');
      orange : Writeln(OUTPUT, ' The color is orange');
    END;
    color := succ(color);
  UNTIL( color = orange );
END.
```

## Enumerated user defined types

Program 9.3 illustrates an enumerated user defined type, "difcolor". An enumerated type is where a list of possible variable values are given in the type declaration. The predefined function, "succ" is available in Pascal, and is a convenient way of incrementing a user defined variable type to the next possible value. In a simple program using an integer variable, this could be accomplished by adding one to the variable, but this would not make sense with a user defined type. User defined enumerated data types may not have their values written out. Program 9.3 gives an example of how that may be accomplished.

## Subrange types

A variable may assume a value that is in a sub- interval of some other simple type. In this case, it may be declared to be a subrange type. For example, integer may represent all whole numbers between -32,768 and 32,767. In the type section, a subrange user defined type might be declared to be `byte = 0..255`; I.E.; any variable of the type `byte` may take on the value from 0 to 255. The same operations may be performed on a subrange type that are applicable to the original type. Also a subrange type may be the subrange of any user defined simple type.

## listing 9.4

```
Program subrange;
TYPE
    baddate           = 1900..1903;
    uppercaseletters = 'A'..'Z';
    lowercaseletters = 'a'..'z';
    digits           = '0'..'9';
    xaxis            = -100..100;
VAR
    testyear          : baddate;
    upperletter       : uppercaseletters;
    lowerletter       : lowercaseletters;
    digit             : digits;
BEGIN
END.
```

All of the above examples are valid subrange declarations. Named subrange types are very helpful when a programmer wants to clearly identify the data differences between specific variables to increase readability. Also, the storage required for a subrange variable is proportional to the interval it spans. This may be important when building large data structures to be implemented on microcomputers.

## RECORD data types

So far, the only structured data type examined has been the array. The array is an excellent mechanism for storing large amounts of data of the same TYPE. For example, the series of text strings input from the terminal were efficiently stored using arrays of CHAR, and any individual character was easily accessible. However, it is often desired to keep variables of different data types grouped together. Take for example, a list of a business's customers along with vital information about each customer. Suppose that you desired to keep the following information about every customer:

Name
Customer category
Mailing address
Telephone number
Dollars spent in store
On catalog circulation list

This might represent a situation where the business would like to keep a data base updated. In languages like Basic, the only way to maintain this information would be multiple arrays containing encoded information. This is not the case in Pascal, as you may build a RECORD which can store all of the above information in a clear and concise format. Furthermore, you may declare an array to be of this user defined type.

## Record data types

In Pascal, a RECORD is a predefined data structure which is composed of component variables. These component fields may be variables of any Pascal predefined, or user defined data types. The purpose of a record is to group variable information into logical entities, such that any particular component field may be operated on, or the entire record may be referenced as a whole. The following is an example of how the previous business record is declared in Pascal.

## Listing 9.5

```
PROGRAM database;
TYPE
  custmrcategory = (business,individual);
  custmrecord = RECORD
    custmrtype : custmrcategory;
    address    : PACKED ARRAY[1..72] OF CHAR;
    telephone  : PACKED ARRAY[1..15] OF CHAR;
    expenditures : REAL;
    cataloglist : BOOLEAN;
  END;
VAR
  custmr      : custmrecord;
  custmrlist : ARRAY[1..100] OF custmrecord;
  index      : INTEGER;
  ans       : CHAR;
PROCEDURE custmrinp( VAR custmr:custmrecord);
VAR custyp : CHAR;
BEGIN
  WRITELN('* Enter customer type: (business/individual)');
  READLN(custyp);
  IF (custyp='I') THEN
    custmr.custmrtype:=individual
  ELSE custmr.custmrtype:=business;
  WRITELN('* Enter address:');
  READLN(custmr.address);
  WRITELN('* Enter telephone number:');
  READLN(custmr.telephone);
  WRITELN('* Enter expenditure in dollars:');
  READLN(custmr.expenditures);
  WRITELN('* Want on catalog circulation list: (true/false)');
  READLN(custmr.cataloglist);
END;
BEGIN
  index:=0;
  ans:='N';
  WRITELN('** BUSINESS XYZ CUSTOMER RECORD PROGRAM **');
  WHILE (ans <> 'S') DO
    BEGIN
      index:=index+1;
      custmrinp(custmrlist[index]);
      WRITELN('* MORE CUSTOMERS (STOP/CONTINUE)');
      READLN(ans);
    END;
  END.
```

The outer shell that must enclose record type declarations is of the form:

```
type name = RECORD
    END;
```

The component field declarations reside between the RECORD and END; . The field declarations are defined in the same way as the VAR section of the program. In program 9.5, the user defined record name is `custmrecord`. The component field declarations: `custmrtype`, `address`, `telephone`, `expenditures`, and `cataloglist` are defined exactly the same way as the program variables are in the VAR section. All the field components belong to the data type `custmrecord`. Since `custmrecord` is treated like any other user defined type, we may now declare a variable to be of type `custmrecord` in the program VAR section.

The difference between a record and other simple user defined data types is that there are component fields in a record that are really variables themselves. In example 9.5, the variable `custmr` is of a record type. When referring to `custmr` in expressions, to reference the entire record, you simply use the variable name, `custmr`. To access the component field, `expenditures`, you would prefix `expenditures` with the record variable name, `custmr`, separated with a `'.'` character. Example:

```
custmr.expenditures:= 99.95;
```

If another record named `excustomer` had been declared, the following would be a valid statement.

```
excustomer:=custmr;
```

In this case, all component fields in `excustmr` would be set to the component fields in `custmr`. Variables of type `record`, and their associated component fields, obey the same rules for use as all other typed variables.

The purpose of program 9.5 is to perform record I/O utilizing the predeclared text files input and output. Notice the read and write statements utilize record component fields as arguments. Read and write behave as though the component fields were variables declared in the VAR section. As with other variables, I/O may not be performed to a text file through a component field that is of a user defined enumerated type.

## WITH statements

The use of records may often cause segments of the program that reference them to become long and tedious, because every time a component field is referenced, the record variable name must precede it. Accessing component fields may be simplified by using the WITH statement. Examine the following procedure, which could be included in program 9.5 .

## Listing 9.6

```
PROCEDURE custmrouput(VAR custmr:custmrrecord);  
  
BEGIN  
  WRITELN('** CUSTOMER OUTPUT RECORD FOR BUSINESS XYY **');  
  WITH custmr DO  
    BEGIN  
      IF(custmrtype=business)then  
        WRITELN ('Customer type      : Business')  
      ELSE WRITELN('Customer type      : Individual');  
      WRITELN   ('Address           : ',address);  
      WRITELN   ('Telephone          : ',telephone);  
      WRITELN   ('Expenditures       : ',expenditures);  
      WRITE     ('Circulation list : ');  
      IF (cataloglist)THEN WRITELN('Yes')  
      ELSE WRITELN('No');  
    END;  
END;
```

The action of the WITH statement is to eliminate the normally required record variable name prefix when accessing component fields of that record. The scope of the WITH is one statement, which in this case is a compound statement.

---

**File of TYPE**

INPUT and OUTPUT are examples of TEXT files in Pascal. These FILE types have been used for all of the program examples so far. A TEXT file is TRS-80 Pascal predeclared to be a special file of char, with rules for performing I/O using INTEGER, REAL and BOOLEAN variables. In TRS-80 Pascal, there are extensions to allow for performing I/O using ARRAY variables in text files.

A FILE OF <any known type> may be declared in Pascal. Files of types other than text are primarily used for storing data which will be retrieved at some other time. For example, a FILE OF customerecord could be defined in the type section. (customerecord as defined in listing 9.5) A variable of type customerecord could be written to this file. The important thing to remember is that an entire record may be written (or read), by one I/O statement. Component fields of this record may not be read or written individually to a file of records. When I/O is performed with a FILE OF <any type except text>, no ASCII encoding or decoding of information takes place. Instead, the binary representation is used. This is not particularly useful when the I/O is directed to a terminal, but is effective for storing large amounts of information on disk media. The predeclared procedures WRITELN and READLN are not valid when performing I/O with a file of any type except TEXT, although read and write perform normally. The program in the appendix of this manual utilizes a FILE OF custmrecord for storing information in a data base. This is a typical use for a FILE OF TYPE.

- (1) If a large number of variables of the same TYPE need to be declared, the \_\_\_\_\_ may be the correct data structure to use.
- (2) Arrays in Pascal may have more than \_\_\_\_\_ dimension.
- (3) New user defined \_\_\_\_\_ may be declared in Pascal programs.
- (4) An \_\_\_\_\_ TYPE is defined by a list of identifiers given to be the different values allowable for a variable.
- (5) A \_\_\_\_\_ TYPE is any user defined TYPE that is a sub-interval of another simple TYPE.
- (6) A \_\_\_\_\_ TYPE is used to logically group together data of different types.

**Answers:**

- (1) array (2) one (3) types (4) enumeration  
(5) subrange (6) record

## DYNAMIC DATA TYPE

All of the variable types discussed so far have been "static" in nature. This means that the size of data structures such as the array have to be defined before the program is compiled or executed. In program 9.5, the size of the array customer list has an upper bound of 100 entries. If more than 100 storage locations are needed to store the customer records, the array declaration has to be changed in the source program, and the source recompiled. In most popular micro-minicomputer Pascal implementations today, there are limits to the number of storage locations that may be declared in a program. This limitation is usually proportional to the size of the program in conjunction with the type and number of variable declarations. It is usually impractical due to these memory restrictions to declare arrays and other data structures to be larger than required. The static nature of variable declarations often create problems in some programming applications. Suppose for example, that in program 9.5 it was desired to keep a list of sales transactions for each customer attached to each customer record. This could be accomplished by declaring a component field of each customer record as being an array of transaction records. Then at any time you could access the sales transaction of every customer. This would require that the number of sales transactions per customer be limited to a preset number by the array declaration. It might be feasible to limit the number of customers to 100, but the number of transactions per customer might vary. There is a mechanism in Pascal to allow for dynamic variable allocation at program execution time. It is possible to request a new storage location for a variable by calling the Pascal pre-defined procedure NEW.

## Procedure NEW

By calling the procedure NEW, it is possible to get a pointer to a memory storage location that is the proper size for the argument variable. It is important to remember that the same limitations on the amount of memory available still apply, however dynamic allocation of memory allows for better utilization of space. The variable used as an argument for the NEW procedure call must have been declared in the VAR section. It must be declared as a TYPE that is a pointer to the actual data type. An example of a pointer data type declared in the TYPE section is as follows:

## Listing 10.1

```
TYPE
    trxptr = ^trxrec;

trxrec = RECORD
    nexttrx: trxptr;
    invoicenum : INTEGER;
    date : ARRAY [1..10] OF CHAR;
    transprice : REAL;
    partnumberlist : ARRAY [1..10] OF CHAR;
END;

VAR
    trx : trxptr;
```

In the example program segment, the variable `trx` is of type `trxptr`. In the type section, `trxptr` is defined to be a pointer to " `trxrec` ". The character " `^` " denotes a pointer in Pascal. Therefore, the variable `trx` is a pointer to a storage location in memory of the size required to store the RECORD `trxrec`. This storage location may be requested anytime during program execution as opposed to program startup. Pointer types to large data structures may be declared in a program with minimum memory space penalty until the procedure `NEW` is called during program execution. Notice at the "`^trxrec`" point in the type declaration, `trxrec` has not been defined. In Pascal, declaring a pointer to an as yet undefined type is valid.

The following program segment illustrates a few simple methods of using pointer variable types.

## Listing 10.2

```
PROGRAM dynamic;

(* TYPE declaration section from listing 10.1 *)

VAR
  trx      : trxptr;
  nexttrx  : trxptr;
BEGIN
  NEW(trx);
  trx^.invoicenumber:=2345;
  trx^.transprice  :=99.95;
  nexttrx:=trx;
  WRITELN('* Transaction invoicenumber : ',
          trx^.invoicenumber);
  WRITELN('* Transaction price      : ',
          trx.transprice);
  DISPOSE(trx);
END.
```

If the pointer itself is being referenced, just the variable name is used. In the example, the pointer variable `nexttrx` is set to the value of `trx`. When referring to the contents of the storage location, an `^` follows the variable name. `trx^.transprice` refers to the value of the component field stored at that location. These basics of pointer data type manipulation are used to build "linked lists". A linked list is a chained list of dynamic storage areas.

Notice the procedure call to `DISPOSE`. The purpose of `DISPOSE` is to release the storage area acquired in the `NEW` call. After the `DISPOSE`, the data stored at the dynamic memory location is effectively lost. This is an important feature of Pascal. Careful use of `NEW` and `DISPOSE` can result in programs that dynamically grow and contract in memory size as needed, and efficiently manage the computer resources.

## LINKED LIST

A linked list is a programming technique that chains together a series of variables. A thorough discussion of linked list processing would entail several chapters, and is really a topic for a data structures book. It will be covered briefly here because it is integral to discussions about dynamic memory management.



The variable `headnode` is a pointer variable declared in the `VAR` section of the program. At some point in the program, a `NEW` procedure call could be made with `headnode` as its argument. `headnode` would now be a pointer to the start of the list. Notice the word `NIL` at the end of the list. `NIL` is a reserved word in Pascal. This simply sets the pointer to an initialized value that may be tested for in looping statements. A word of caution when using pointers in Pascal. If a pointer variable has been declared, but not set to any value, there is no guarantee of its value. It will not necessarily be set to `NIL`. Most Pascal implementations do not perform a runtime check for uninitialized values. Use of uninitialized pointers can lead to the program writing over itself in memory with execution becoming unpredictable. These kinds of programming errors will not show up at compile time, and can be extremely hard to find during program execution. The following segment illustrates how list 10.3 could be built.

## Listing 10.4

```

PROGRAM linkedlist(input,output);
TYPE
  trxptr = ^trxrec;
  textline = PACKED ARRAY [1..10] OF CHAR;
  trxrec = RECORD
    nexttrx: trxptr;
    invoicenum : INTEGER;
    date       : textline;
    transprice : REAL;
    partnumberlist : textline;
  END;
VAR
  headnode,transnode:trxptr;
  I : INTEGER;
PROCEDURE readtrx(VAR trx:trxrec);
(* The purpose of this routine is to prompt the user for *)
(* the purchaser's trx record *)
BEGIN
  WITH trx DO
    BEGIN
      Writeln('ENTER INVOICE NUMBER:');
      Readln(invoicenum);
      Writeln('ENTER DATE:');
      Readln(date);
      Writeln('ENTER TOTAL PURCHASE PRICE:');
      Readln(transprice);
      Writeln('ENTER PARTNUMBER(S) SEPARATED BY COMMAS:');
      Readln(partnumberlist);
    END;
  END;
END; (*readtrx*)

```

## Listing 10.5 (continuation 10.4)

```

PROCEDURE writetrx(VAR trx:trxrec);
(* The purpose of this routine is to write the purchaser *)
(* trx entry *)
VAR I:INTEGER;
BEGIN
  WITH trx DO
    BEGIN
      FOR I:= 1 TO 35 DO WRITE('*');
      WRITELN;
      WRITELN('INVOICE NUMBER      : ',invoicenum);
      WRITELN('DATE                : ',date);
      WRITELN('TOTAL PURCHASE PRICE : ',transprice:10);
      WRITELN('PART NUMBER LIST   : ',partnumberlist);
      FOR I:=1 TO 35 DO WRITE('*');
      WRITELN;
      WRITELN;
      END;
    END;
  END; (*PROCEDURE writetrx*)

PROCEDURE listrxs( temptr : trxptr );
(* the purpose of this procedure is to traverse the linked*)
(* list attached to the argument pointer, writing the *)
(* values of the trx records *)
VAR
  loctrx : trxrec;
BEGIN
  (* traverse trx linked list, writing txrs *)
  WHILE (temptr <> NIL) DO
    BEGIN
      (* load the contents of localtrx with the *)
      (* contents of temptr *)
      loctrx:=temptr^;
      writetrx(loctrx);
      (* set temptr to the next node in the linked list *)
      temptr := temptr^.nexttrx;
    END;
  END; (*listtransactions*)

```

Listing 10.6 (continuation 10.5)

```
BEGIN      (* begin main program linkedlist *)
(* initialize pointer that will always reflect the *)
(* beginning of the list.                          *)
(* this will set the end of the list to NIL during the first *)
(* pass through the FOR loop                        *)
headnode := NIL;
(* read 3 trxs and link each new one to the beginning *)
(* of the list                                     *)
FOR I := 1 to 3 DO
  BEGIN
    NEW(transnode);
    (* insert the newnode in front of the old headnode *)
    (* link to the old headnode                          *)
    transnode^.nexttrx := headnode;
    (* make the newnode the new headnode                *)
    headnode := transnode;
    (* load the actual data into the fields of the new node *)
    readtrx(transnode^);
  END;
  (* list all trxs entered *)
  listrxs(headnode);
END.      (*main program*)
```

## Sets

Sets in Pascal have the same meaning as they do in the normal mathematical sense. If a group of objects are declared in set A, and a group of objects are declared in set B, a number of operations may be performed on these sets such as :

- (1) Membership and relational testing
- (2) Set arithmetic (union, intersection, difference)

In the case of Pascal, the objects are simply data values. These data values may be Pascal predefined or user defined. An example would be a SET OF CHAR, or a SET OF digits where digits is a user defined subrange type of CHAR. Testing could be performed to see if the SET OF digits is in the SET OF CHAR if desired. The method of declaring set variables is :

```
VAR   A,B : SET OF <type> ;
```

This means that A and B may contain from one to all of the data values declared by the type, however its membership is undefined until it is initialized like any other variable. In the body of the program, a set may be initialized to empty by :

```
A := [];
```

## Membership testing

Once the set variables are initialized, a series of BOOLEAN relational tests may be performed. The relational operators are as follows:

set1 = set2	Set equality- If (all members of first set are in the second set and all members of second set are in the first set) : returns true.
set1 <= set2	Subset- If (all members of first set are in the second set) : returns true.
set1 >= set2	Superset- If (all members of second set are in the first set) : returns true.

```
set1 <> set2
```

Set inequality- If all members of first set are in second set, and all members of second set are in first set : returns false.

Individual element membership may be tested by using the IN operator. If a variable had been declared of the same type as the base set type, the IN operator may be used to check for set membership. An example would be:

Listing 12.1

```
TYPE
  DIGITS = '0'..'9';
VAR
  DIGIT   : SET OF DIGITS;
  D       : CHAR;

BEGIN
  D:='a';
  DIGIT:=['0'..'9'];
  IF(D IN DIGIT)THEN DO (*action*);
  IF(D='0')OR(D='1')OR(D='2')OR(D='3')OR(D='4')OR(D='5')
    OR(D='6')OR(D='7')OR(D='8')OR(D='9') THEN DO (*ACTION*)
```

The two IF statements in the above program segment are equivalent. Notice that the equivalent IF statement using sets is a more concise and readable statement. This represents a simple use for sets for the average programmer.

#### Set arithmetic

There are three set operators in Pascal. Each requires two arguments. Arguments should be sets of the same base type, and the result will be of the same type. The operators are:

A + B	Gives the union of A and B
A * B	Gives the intersection of A and B
A - B	Gives the difference of A and B.

The following segment program illustrates set operator use.

LISTING 12.2

```
PROGRAM TESTSET;
VAR
  DIGITS,LETTERS,LOWERCASE,UPPERCASE : SET OF CHAR;
  ALPHANUMERIC,ALPHA                  : SET OF CHAR;
  D : CHAR;
BEGIN
  D:='1';
  DIGITS:=['0'..'9'];
  LOWERCASE:=['a'..'z'];
  UPPERCASE:=['A'..'Z'];
  LETTERS:=LOWERCASE + UPPERCASE;
  ALPHANUMERIC:=LETTERS + DIGITS;
  ALPHA:=ALPHANUMERIC - DIGITS;
  IF ( D IN ALPHANUMERIC * DIGITS ) THEN
    WRITELN('PUNT');
END.
```

On diskette there is a file named DATABASE/PCL . This source program ties all of the previous program segments in chapters 9 and 10 together, to build a program that will build a data base for business customers. This is not intended to be a comprehensive program, but can serve as a starting point for an expansion. This program requires approximately 15K of stack to RUN or execute. Once compiled, it may be executed by typing:

RUN DATABASE 15K

The number of customers allowed in the data base array is set by the constant "maxarray" , and may be changed to reflect local memory restrictions. Customer transactions are linked to each customer record by dynamic management of linked lists. Customer records are kept on a separate file from the transactions in order to simplify rebuilding of the linked lists when loading an existing data base. The size of the data base accessible during a program invocation is limited by the available memory, as the entire data base is loaded into memory for operations. Large data bases may be accessed by partitioning the data base between files and running the program multiple times.

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## FOREWORD

-----

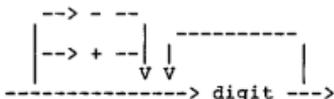
This manual assumes that the reader is already somewhat familiar with the Pascal language. It is organized to be used as a reference manual. As such, the chapters group related topics in order to make them easier to find. The result of this is that the manual does not follow a progression of discussion which is well suited as a teacher of the Pascal language. It is suggested that you first read the Pascal Tutorial if this is your first experience with the language.

The description of any programming language involves both the syntax and the semantics of the language. The syntax refers to the arrangement of program elements into a form which the compiler can understand. The semantics refers to the meaning that the compiler associates with a particular arrangement of the program elements. The semantics of a language can be explained with words but the syntax is best explained through the use of diagrams.

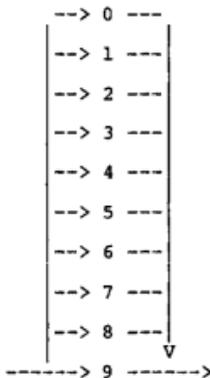
The syntax diagrams used throughout this manual describe the legal syntax of a program. Each diagram has an entering and an exiting point which is denoted by an arrow. Starting with the arrow entering a diagram, the legal syntax can be determined by tracing a path which follows the directions indicated by the arrows until the exiting arrow is reached. Most diagrams have a multiple number of paths from starting point to ending point. All paths describe a syntactically correct form.

The following are sample syntax diagrams which describe the syntax of an integer.

Syntax of an integer:



Syntax of a digit:



The syntax diagram for an integer says that an integer is a concatenation of one or more digits which is optionally preceded by a plus or minus sign. Entering the diagram, you have 3 possible paths from which to choose. One path leads directly to "digit", one leads to "+", and one leads to "-". The paths from both "+" and "-" then lead to "digit". Passing through "digit", you have the option of exiting the diagram or following the arrow which leads back to the beginning of "digit". From this point, you pass through digit again and optionally exit or return for another pass. Thus, an integer may consist of one or more digits.

The second syntax diagram describes the correct forms of a digit. Entering the diagram, you have ten possible paths from which to choose. All paths lead to a single character, each of which is a legal digit. Choosing a path, you follow it through a character and end up at the exiting arrow. At this point, there is no alternative but to exit the diagram. No other paths are available. Some examples of integers then are 10, +963, and -75.

In the diagrams used in this manual, upper case character strings denote reserved words that must be present in the form shown. Lower case character strings denote the parts of the syntax where many legal forms exist. For example, the word integer in a diagram in lower case letters represents any legal integer. The word INTEGER in uppercase letters represents a reserved word of the language.

In some cases, abbreviations are used to shorten a diagram. For example, id is used in place of identifier. Also, expr is used in place of expression. A few other abbreviations may occur but where used, their meaning should be apparent from the surrounding text.

## PROGRAM ELEMENTS

---

The elements of a program consist of the entities (identifiers, numbers, strings, reserved words, and special symbols) which are composed from a character set. The ASCII character set is the most often used and is listed in the appendix.

### A. Identifiers

---

An identifier serves to denote the program name, a constant, a type, a variable, a procedure, or a function. It consists of a letter followed by combinations of zero or more of the following characters:

(the 26 letters of the alphabet in lower or upper case, the digits 0 through 9, the character \$, the character \_).

**Note:**

no distinction is made between upper and lower case letters in identifiers. The two identifiers, Apple and apple, are considered identical.

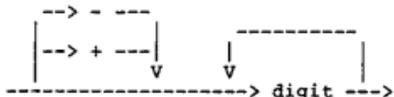
The length of an identifier is arbitrary but only the first 8 characters are significant. For example, the identifiers A2345678 and A23456789 would to the compiler be identical because it discards all characters past the eighth character. Therefore, care should be taken to make identifiers eight characters unique. It should also be noted that an identifier cannot contain embedded blanks or span a line boundary.

Examples: Factor\$ DEPARTMENT A Div\_10 B12345678\$\_

**B. Numbers**

Numbers are integer or real constants. Integers are allocated sixteen bits of storage which imposes a size limitation. The range for an integer is -32768 to +32767.

Syntax of integer numbers:

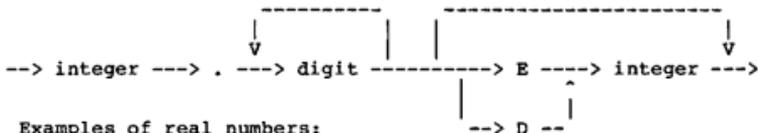


Examples of integer numbers:

30    -28934    0    32739

Real numbers are represented in either exponential or fixed point form. The fixed point form consists of an integer part followed by a decimal point and a fractional part. The exponential form consists of a fixed point part followed by an exponent part. The exponent part is a multiplier. The value of a real number in exponential form is the fixed point part times (10 raised to the exponent part). (See the System Implementation Manual for the size, range, and accuracy of real numbers).

Syntax of real numbers:



Examples of real numbers:

Fixed point form:

50.0    -100000.0    345.22452

Exponential form:

0.239E3    -4.5921E-2    876.0E+33    193.27D-3

0.239E3 is equivalent to 239.0  
 -4.5921E-2 is equivalent to -0.045921

NOTE: Using D instead of E in exponential form represents a double precision real number.

### C. Strings

Strings are sequences of characters enclosed by single quote marks. A string consisting of a single character is a constant of the type CHAR. Strings consisting of n characters, where n is greater than one, are constants of the type PACKED ARRAY[1..n] OF CHAR. If a string is to contain a single quote mark, it must appear twice in the sequence.

Examples: 'ABC'    '12"QZW'    'BEGIN '    '\*\*\*'    ' ¢'

The string consisting of the single character ' is represented as ''.

Characters in strings can also be denoted by hexadecimal numbers. A hexadecimal number is composed from the characters 0 through 9 and A through F. (See the ASCII character set in the appendix). The character # followed by 2 hexadecimal characters represents a single ASCII character. The character represented is the one whose ordinal position in the character set corresponds to the hexadecimal number specified. This feature provides a mechanism for representing nonprintable characters. A consequence of giving the character # a special meaning is that it must appear twice in a string just as the character ' must when the character itself is to be made a part of the string. A string consisting of the single character # then is represented by '##'.

Examples of hexadecimal character representation in strings:

```
'#30'    is equivalent to '0'
'D#4FG' is equivalent to 'DOG'
'#00'    corresponds to the nonprintable null character
'A#B'    is illegal
```

### D. Reserved Words

The following list of words are keywords and have special meaning in a program. They may not be used as identifiers.

AND	DOWNTO	IF	OR	THEN
ARRAY	ELSE	IN	PACKED	TO
BEGIN	END	LABEL	PROCEDURE	TYPE
CASE	FILE	MOD	PROGRAM	UNTIL
CONST	FOR	NIL	RECORD	VAR
DIV	FUNCTION	NOT	REPEAT	WHILE
DO	GOTO	OF	SET	WITH

### E. Special Symbols

---

The special symbols are used as operators and delimiters in a program. Because character sets vary from system to system, alternate representations are provided for some of the symbols.

Symbols with only one representation:

+	-	*	/		
=	<>	<	<=	>=	>
(	)	'	:=	.	,
;	:	#	::		

Symbols with alternate representations:

symbol	alternate
{	(*
}	*)
^	@
[	(.
]	.)

### F. Comments

---

Comments can be used in a program for documentation purposes. The compiler generates no code for comments. The symbol { denotes the beginning of a comment while the symbol } denotes the end. All characters in between are ignored by the compiler. As shown above, the symbol { may be replaced by the symbol (\* and the symbol } may be replaced by the symbol \*).

Examples: {this is a comment}  
 (\*This is a comment  
 that spans more than one line\*)

Note: Comments may not be nested. The following will generate an error:

```
(*outer (*inner level*) level*)
```

### G. The Semicolon

---

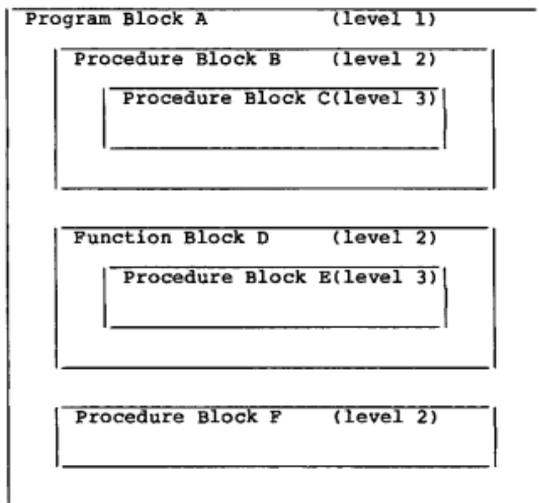
The semicolon is used extensively in the Pascal language. Its purpose is to separate the individual components of a program. For example, block headings must be separated from block parts, block parts must be separated from one another, and individual definitions, declarations, and statements within the block parts must be separated. In general, they may be used freely throughout the program. However, care should be taken not to include a semicolon in the middle of a statement. This is a common source for error when using the IF statement with one or more ELSE clauses. Since the ELSE clauses are a part of the IF statement, they must not be separated from it by a semicolon. An ELSE keyword should never be preceded by a semicolon.

example use of semicolons in an IF statement:

```
IF time > 12 THEN
  BEGIN
    alpha := 'e';
    beta  := 'f';
  END      (*semicolon here would cause an error*)
ELSE
  BEGIN
    alpha := 'g';
    beta  := 'h';
  END;
```

PROGRAM STRUCTURE

Pascal is a block structured language. This means that a program is constructed in a block like manner. At a minimum, a program consists of one block. More blocks are created through the use of procedures and/or functions by placing them inside this outermost "program block". The term for this process is called nesting. The rule for nesting is that a block may lie entirely within another block, but blocks do not overlap in any other way. A level of nesting can be assigned to each block of a program. This provides an appropriate tool for describing scope rules which are discussed in chapter 9. The block structured organization of a program can be represented pictorially by the following example:



A program then consists of at least one block, the program block, and optionally it contains procedure and/or function blocks which are nested within.



The parameter list declares the variables which are used to pass data into and out of a procedure. The variables are called formal parameters. The procedure statement which activates (or calls) a procedure has a corresponding list of parameters which are the actual parameters. The actual parameters must match the formal parameters in order and in type. However, their names need not be the same.

There are two different kinds of formal parameters, pass by value or pass by reference. A formal pass by value parameter causes its corresponding actual parameter to be copied to another location and then the formal parameter references the copied value. Therefore, changing the value of the formal parameter inside the procedure does not change the value of the corresponding actual parameter. In contrast, a formal pass by reference parameter is passed the address of the corresponding actual parameter. The formal parameter references the same location as the actual parameter. Therefore, changing the value of the formal parameter also causes the value of the actual parameter to be changed. Variable declarations in the parameter list which are preceded by the keyword VAR are pass by reference parameters while the absence of the keyword represents pass by value.

Syntax of the parameter list is:

```

----- ; <-----
|
|
V |----- V V |-----
--> ( ----->VAR -----> id -----> : --> type id -----> ) -->

```

Example procedure headings:

```
PROCEDURE out;
```

```
PROCEDURE cpu(pc : INTEGER);
```

```
PROCEDURE delete(VAR i,j :INTEGER; ch :CHAR; VAR x :REAL);
```

In procedure delete above, i and j are integers which are passed by reference, ch is a character which is passed by value, and x is a real which is passed by reference.

As a general rule, pass by value parameters should be used to prevent side effects. However, sometimes side effects are necessary. That is, sometimes you need a change in the value of a formal parameter to also change the value of its corresponding actual parameter. In such a case, pass by reference must be used. Also, when passing large data structures such as arrays, pass by reference should be used. This speeds execution and saves memory because a pointer to the structure is passed rather than copying the whole structure to another location.

### A.3 The Function Heading

---

The function heading signals the start of a function block. It gives the function a name and defines the parameters to be passed to it. Unlike a procedure, a function has a type associated with it. Functions, like variables, are assigned values. A function is referenced by an expression and its value then substituted into the expression.

Syntax of the function heading:

```

-----
|                               |
|--> FUNCTION --> id ---> parameter list ---> : --> type id --> ; -->
|                               |

```

The parameter list has the same form as the parameter list for a procedure discussed on the previous page.

Example function headings:

```
FUNCTION number : REAL;
```

```
FUNCTION nextstate(currentstate : INTEGER) : INTEGER;
```

The function "number" is a real valued function which has no parameters. The function "nextstate" is an integer valued function which has one parameter, also of type INTEGER. In each function, a value should be assigned to the function name. For example, number:=5.3 and nextstate:=currentstate + 1 could appear inside each of the respective functions to define values for them.

Note : a function may be an ordinal type or the type REAL only.

## B. Block Parts

---

A Block is composed from the following list of parts.

1. the label declarations
2. the constant definitions
3. the type definitions
4. the variable declarations
5. the common declarations
6. the access declarations
7. the procedure and function declarations
8. the statement body

The label declarations are used to declare statement labels which can be used for branching. The constant definitions are used to give names to numbers or strings which are constants. Constant names are assigned values at compile time. Type definitions are used to create and give names to data types which are not predefined. Variable declarations are used to associate variable names to specific data types. A type defines the kind of data that can be stored in a variable. It also defines the amount of storage required for the variable. Variables are assigned values at run time. Common declarations are used in the same manner as the variable declarations to associate variable names to specific data types, but common variables have a special property. Storage space for common variables is created statically rather than dynamically. This means that when a block terminates, the common variables declared in it do not become undefined. Access declarations are used to enable a block to access a common variable. Procedures and functions are used for modularity. They provide the mechanism for segmenting a block into subblocks. The statement body contains the program statements which describe the actions to be taken on data as well as the order in which the actions take place.

A block does not have to include all eight parts described above. At a minimum, a block must include the two keywords BEGIN and END which bracket the statement body. The following is an example of a minimum complete program. It contains only the program block which is composed of only the heading and a null statement body.

```
PROGRAM donothing;  
BEGIN          (*The statement body contains no statements*)  
END.
```

The order in which the eight parts appear in a block is as follows: The first six parts may be arranged in any order. The only requirement is that an identifier be defined before it is used. For example, a particular type definition must textually precede a variable declaration of that type. The only exception to this is the definition of pointer types which are discussed in chapter 5. It is also worth noting that there may be more than one of a particular part. For example, there could be two separate type definition parts. The procedure and function declarations follow any use of the first six parts. The statement body then follows the last procedure or function declaration.

### B.1 The Label Declarations

---

Label declarations are used in conjunction with the GOTO statement. A label declaration defines a label which can then be used to label a statement. A GOTO statement can then reference the label causing a branch to the statement which is prefixed by the corresponding label. The label declaration part is signaled by the keyword LABEL.

Syntax of the label declaration part:

```

          ----- , <-----
          |
          v
--> LABEL ---> integer constant ---> ; -->

```

**Note:**

A label must be declared in the same block in which a GOTO statement which references it appears. Branching outside a block is not allowed. Also, all declared labels must appear somewhere in the statement body.

Example label declaration part:

```
LABEL 100, 200, 300, 400, 500, 1000 ;
```

Syntax of labeled statement:

```
---> label --> : --> statement --->
```

Example labeled statements:

```
100: x:=47;
200: IF x > 500 THEN GOTO 100;
```

## B.2 The Constant Definitions

---

The constant definitions are used to associate identifiers with values which do not change. A constant identifier is assigned a value at compile time and this value can not be changed. This means that a constant identifier cannot have its value changed by an assignment statement. The use of constant identifiers increases program readability because meaningful names can be used in the place of actual values. The values which can be assigned to constant identifiers are numbers, strings, or other identifiers which are constants. This includes identifiers which are members of an enumeration. The start of the constant definition part is signaled by the keyword `CONST`.

Syntax of the constant definition part:

```

          ----- ; <-----
          |
          v
--> CONST ---> id --> = --> constant ---> ; -->

```

Example constant definition part:

```

CONST   low=32; high=88; pi=3.14159;
        speedoflight=299792.0; separator='-----';
        positive=10; negative=-positive;
        keydefinition=#61;

```

**Note:** Integer constants may also be expressed in hexadecimal by preceding the value with the `#`

There is a predefined constant `MAXINT` which is defined to be equal to the largest positive value an integer can take.

### B.3 The Type Definitions

Type definitions are used to create new data types. A type definition associates a name with a user defined simple or structured data type. The name can then be used in a variable declaration to specify the type of the variable. Although a variable can declare its type directly in the variable declaration part, it is nice and sometimes necessary to have a name associated with a user defined type. Type definitions are especially useful when using structured types whose definitions are long and when more than one variable in the program is to be declared of that type. Associating a name to the type means that the type must be defined only once. In some cases, type definitions are necessary. If comparisons are to be made between two variables of a user defined type, then the variables must be declared as the same type. Defining the type for each variable separately in a variable declaration part will not work. Although the variable declarations will look the same, the compiler will view them as variables of two separate types. Also, declarations of variables in the parameter list of a procedure or function must be to named types. For example, if an array is to be passed as a parameter, the array must be defined in a type definition and then the formal parameter declared as that type.

The type definitions part is signaled by the keyword TYPE.

Syntax of the type definition part:

```

----- ; <-----
      |
      v
--> TYPE ---> id --> = --> type ---> ; -->

```

Example type definition part:

```

TYPE    colors = (red,blue,green,orange,purple);
        weekdays = (sunday,monday,tuesday,wednesday,
                    thursday,friday,saturday);
        workdays = monday..friday;
        daysofmonth = 1..31;
        letters = 'A'..'Z';
        list = ARRAY [0..25] OF CHAR;
        customer = RECORD
            name      : PACKED ARRAY[1..20] OF CHAR;
            address   : PACKED ARRAY[1..40] OF CHAR;
        END;

```







Example function declaration:

```

FUNCTION nextstate(currentstate : INTEGER) : INTEGER;
(* returns the next state given the current state *)

BEGIN
  CASE currentstate OF
    1: nextstate := 3;
    2: nextstate := 4;
    3: nextstate := 1;
    4: nextstate := 2;
  END;
END;                                     (*function nextstate*)

```

### B.8 Statement Body

The statement body of a block contains zero or more statements which describe the actions of the block. The statement body must start with the keyword BEGIN and stop with the keyword END. However, since statements may also include BEGIN and END, the statement body may contain many occurrences of these two keywords. The statement bodies for the three types of blocks are identical, except that the concluding END for the program block statement body must be followed by a period while the concluding END for procedure and function statement bodies must be followed by a semicolon.

Syntax of statement body:

```

--> ; --
      |   ↓
----> BEGIN --> statements --> END ----> . ----->

```

Example statement body:

```

BEGIN          (* begin program block statement body *)
  WHILE NOT EOF DO
    BEGIN
      READ(x,y,z);
      x := SQR(x); y := SQR(y); z := SQR(z);
      WRITE('squaredata ', x , y , z);
    END;
  END.        (* end of program *)

```

## SIMPLE DATA TYPES

The simple data types are the primitive data types of the language. They form the base for building structured types. The simple data types consist of ordinal types and the REAL type.

### A. Ordinal Types

Ordinal types are characterized by a linear ordered set of distinct values which can be mapped on the set of natural numbers. This mapping is actually an enumeration of all the values which the type can take. The predefined ordinal types are INTEGER, CHAR, and BOOLEAN. New ordinal types can be defined by enumerating all the values which the type can take. In addition, new ordinal types may be defined as subranges of other ordinal types.

#### A.1 The Type INTEGER

Variables declared as type INTEGER may take on values in the range -32768 to +32767. All the arithmetic and relational operators can be used with integer constants and variables. However, the relational operator IN is used only in conjunction with sets (see chapter 4).

Note: Integer calculations which cause an overflow will not generate an overflow error. (eg. MAXINT + 1 = -32768)

Syntax of type INTEGER:

--> INTEGER -->

Example declaration:

```
VAR      i,j,k : INTEGER;
```

Example integer constants:

```
59      -1      0      329      -10000      29872
```

## A.2 The Type CHAR

---

Variables declared as type CHAR can take single characters as values. The set of valid single characters is defined by a character set. All characters have an associated ordinal number in the range 0 to 255. A table of ASCII characters with associated ordinal numbers is listed in the appendix. There are two functions which may be used in conjunction with the character set. The function ORD(character) returns the ordinal number of the character specified. The function CHR(ordinal number) returns the character associated with the specified ordinal number. These are known as transfer functions because they are used to transfer a character value to an integer value and vice versa. Constants of type CHAR are denoted by using single character strings. All relational operators may be used with variables and constants of type CHAR.

Syntax of type CHAR:  
 --> CHAR -->

Example declaration:

```
VAR      alpha , beta  : CHAR;
```

Example character constants:      Example relational expression:

```
'9' 'a' '#9F'                      'A' < 'B'
```

## A.3 The type BOOLEAN

---

The boolean type represents logical data. A logical value is represented by the predefined identifiers FALSE and TRUE. These are the only possible values of a boolean variable or expression.

Syntax of type BOOLEAN:  
 --> BOOLEAN -->

The boolean type is defined by the following enumeration:  
 BOOLEAN = (FALSE, TRUE)

The boolean operators AND, OR, and NOT take boolean operands and yield boolean results. The relational operators =, <>, <=, <, >, >=, and IN all yield boolean results. See chapter 7 for examples of boolean expressions.

Example declaration:                      Boolean Constants:

```
VAR switch : BOOLEAN;                    FALSE TRUE
```

#### A.4 The Enumerated Type

---

Pascal allows you to define your own ordinal types. A new type may be created by enumerating all the values that the type may take. This is done by giving the new type a name and listing the values which the new type can take.

Syntax of the enumerated type:

```

      --- , <---
      |     |
      v     |
--> ( ----> id ----> ) -->

```

Example definitions of enumerated types:

```
names = (Fred, Joe, Nancy, Susan);
```

```
foods = (hotdog, hamburger);
```

The values listed are identifiers. The order in which the identifiers are listed defines a relationship. The identifiers can be thought of as being mapped on to a set of natural numbers. The first identifier maps to 0, the second to one, the third to two, and so on. This implies that identifier1 < identifier2 < identifier3...< identifierN. For example, consider the predefined type:

```
BOOLEAN = (FALSE,TRUE)
```

The boolean value FALSE is less than the boolean value TRUE because FALSE appears in the list before TRUE. This kind of ordered relationship applies to any enumerated type. Consider the type definition:

```
colors = (red, blue, green)
```

By this definition, a variable declared as type colors can take on the the value red, blue, or green. The definition also implies that red < blue < green.

The ordering means that enumerated values can be used in relational expressions. It also means that they may be used for range specifications. For example, consider the FOR statement. The range of the loop control variable is defined by specifying a starting and stopping value. These starting and stopping values could be the values of an enumerated type. For example, if color has been declared as type colors, the following statement is valid:

```
FOR color := red to green DO .....
```

### A.5 Subrange Types

---

A subrange type is simply a type defined to take on a subset of the values representing some ordinal type.

Syntax of the subrange type:

```
--> constant --> .. --> constant -->
```

The use of subranges can sometimes save memory. For example, an integer variable whose values are always in the range of 0 to 255 could be declared as a subrange of the type `INTEGER`. You might define a new type as follows:

```
byte = 0..255
```

Now, variables declared as type `byte` would be allocated 8 bits of storage rather than the 16 bits which is allocated for variables declared as type `INTEGER`. The compiler allocates the minimum amount of storage required to represent the range of values specified by a subrange type.

The use of subranges can better document a program by defining the range of valid values a variable declared as the subrange type can take on. Subrange types are also often used in conjunction with `SET` types which are discussed in section B of chapter 4.

### B. The Type REAL

---

The type `REAL` is used to represent fractional numerical data. The implementation of reals is machine dependent. Information on the size, range, and accuracy of reals is discussed in the System Implementation Manual. See section B of chapter 1 for the syntax of real constants.

Syntax of `REAL`:

```
--> REAL -->
```

Example declaration:

```
VAR      x , y , z      : REAL;
```

Example real constants:

```
2.3      -129.345      5.496E-14      -7983.851D+23
```



Example declarations:

```

TYPE    table = ARRAY [0..5,1..10] OF INTEGER;
        colors = (red, blue, green, yellow);
VAR     report : ARRAY [1..20] OF table;
        day    : ARRAY [1..365] OF REAL;
        class  : ARRAY [0..8,0..5] OF INTEGER;
        chart  : ARRAY [colors] OF INTEGER;

```

Elements of variables declared as type ARRAY are accessed by specifying the variable name and listing expressions which evaluate to ordinal values that fall into the range of the ordinal types of the index definition.

Examples of accessing array elements:

```

report[5,3,6]    day[40]    class[0,0]    chart[red]

```

## B. The Type SET

---

A set is a collection of distinct elements which are all of the same ordinal type. The elements of a set are called set members. There may be up to 256 members in a set. The 256 member limit causes the restriction that a set can not be defined to be of ordinal type INTEGER. Also, subranges of type INTEGER which include negative integers are not allowed as set base types. A set can have no members in which case it is called an empty set.

Syntax of the type SET:

```
--> SET --> OF --> ordinal type -->
```

Example declarations:

```

TYPE    days = (sunday, monday, tuesday, wednesday,
               thursday, friday, saturday);
VAR     lowercase, digits, special : SET OF CHAR;
        schooldays, workdays    : SET OF days;
        day                      : days;

```

A variable declared as type SET can take on any values which are subsets (including the empty set) of the values defined by the type of the set. The type of the set is specified after the keyword OF.

Set values are denoted by listing set members within square brackets. The individual members can be specified as ordinal expressions.



<= A set can be compared to another set to see if the first set is a subset of the second set. The operator <= is used to test for set inclusion. If all the members of the set on the left are also members of the set on the right then the operation evaluates to TRUE.

>= A set can be compared to another set to see if the first set is a superset of the second set. The operator >= is used to test for set containment. If there are no members in the set on the right which are not also members of the set on the left then the operation evaluates to TRUE.

Example use of relational operators:

```
IF day IN workdays THEN gotowork; (*gotowork is a procedure*)
IF character IN digit THEN WRITE(character);
IF workdays >= schooldays THEN nowweekendclasses;
```

<u>Relational Expression</u>	<u>Evaluation</u>
monday IN [monday, tuesday]	TRUE
'A' IN ['a'..'z']	FALSE
[1, 2, 3] >= [0]	FALSE
[1, 2, 3] >= [2]	TRUE
['%'] <= ['*', '%']	TRUE
[] <= [tuesday]	TRUE
['a', 'f', 'g'] = ['a', 'f', 'k']	FALSE
[1] = [1]	TRUE

The arithmetic operators which are applicable to sets are ( + , - , and \* ).

+ Two sets can be combined to form a third set containing all elements that are members of either set. The operator + performs the union of two sets.

- A set can be formed as the difference between two sets. The operator - performs set difference. The result is a set containing all members of the set on the left which are not also members of the set on the right.

\*

A set can be formed which contains only the members which exist in both of two other sets. The operator \* performs the intersection of two sets.

Examples:

<u>Expression</u>	<u>Result</u>
[1, 2, 3] + [4, 5, 6]	[1, 2, 3, 4, 5, 6]
[1, 2, 3] + [2, 3, 4]	[1, 2, 3, 4]
[1, 2, 3] - [2]	[1, 3]
[1, 2, 3] - [4]	[1, 2, 3]
[1, 2, 3] * [4, 5, 6]	[ ]
[1, 2, 3] * [2, 3, 4]	[2, 3]

### C. The Type FILE

The data type FILE provides the link between a program and the peripheral equipment of the computer system. Variables declared as type FILE represent logical files. Input and output operations always refer to logical files. Each logical file has an associated physical file. The physical file is the actual device to which an operation is directed. A physical file is a device such as a terminal, printer, disk file, etc... Since all input and output operations reference logical files rather than physical files, a programs input or output can be redirected simply by associating the logical file with a different physical file. The method of associating logical files to physical files is discussed in the System Implementation Manual.

File data elements can be of any type except FILE or structured types containing a component of type FILE.

Structured variables (eg. array or record variables) may contain components of type FILE. However, the I/O routines (see chapter 10) will accept only simple variable names. For example, file names such as "customer.file" or "files[2]" are not accepted by the I/O routines. See the appendix for an example of how to work around this restriction.

Syntax of type FILE:

```
--> FILE --> OF --> type -->
```

Input and output can be greatly simplified by declaring variables as files of structured types. For example, a complete record can be read or written to a file of records simply by specifying the file variable name and the record variable name as parameters to an input or output procedure.

Example of file declarations:

```
Type      sales = RECORD
           salesman : PACKED ARRAY[1..20] OF CHAR;
           quantitysold : INTEGER;
           END;
VAR       salesfile : FILE OF sales;
           numbers   : FILE OF INTEGER;
```

The data elements of files declared as above are read and written in binary format. Binary format is the form in which the data is actually stored in memory. No translation of the data is done during the I/O process to a character readable form. The advantage of this type of I/O is speed of data transfer and minimization of disk storage requirements. The disadvantage is that the data is in a non-readable form.

A special type of file is provided for handling character formatted data. In a TEXT file, data is stored as characters. Input and output then involves a translation to and from the internal binary data format.

### C.1 The type TEXT

There is a predefined type of file called TEXT. Text files have special characteristics. Unlike other file types, a text file is divided into lines. There is some mechanism which is implementation dependent which marks the separation between lines, each line being a sequence of characters. The data types which can be input from and output to text files are not restricted to characters only, even though a text file is actually a file of characters. The characters of a text file may represent string, integer, real, or boolean values. The Pascal I/O routines make the appropriate character to binary and binary to character conversions with TEXT files. There are two predeclared variables of type TEXT (INPUT and OUTPUT). These are the default parameters for the I/O procedures and functions discussed in chapter 10.

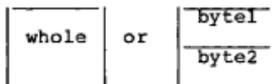








This variant definition would define a storage area of two bytes (assuming an integer is 16 bits) which is the largest amount of storage required for either of the two field lists. You could then access the whole two byte storage area as an integer or you could access each individual byte of the integer. The storage could be pictured as follows:



The type BOOLEAN was chosen as the selector of the CASE because it defines two possible values which is what is needed to specify the two alternatives. Another type could have been defined and used just as well. With the variant defined as above, you could now reference the integer or the bytes simply by specifying the appropriate field name: whole, byte1, or byte2. For example, if "number" is a variable declared as this record type, then "number.whole", "number.byte1", and "number.byte2" are the possible ways of referencing this storage area. Care must be taken when using variants for this purpose. The way in which the fields of the different variants of the variant overlap one another is implementation dependent. Also in the above example, which byte would be the low byte and which would be the high byte is implementation dependent. (See the System Implementation Manual)

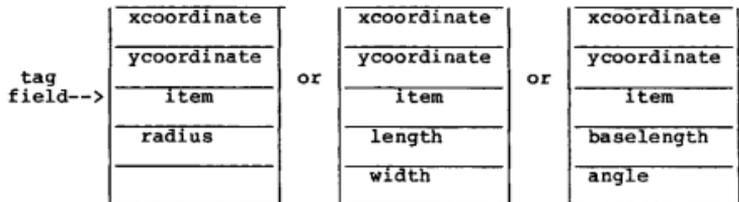
Example using tag field:

Assume the type definition:  
 itemtype = (circle, rectangle, triangle)

```

-----
PACKED RECORD
xcoordinate, ycoordinate :REAL;
CASE item :itemtype OF
  circle      : (radius           :REAL);
  rectangle   : (length,width     :REAL);
  triangle    : (baselength       :REAL;
                angle             :INTEGER);
END;
```

This record definition contains a fixed part as well as a variant part with a tag field. The storage allocation for this record could assume the following structures:



The storage allocated would be the amount required to store the two real numbers of the fixed part, the tag field, and the two real numbers of the rectangle field list. The other field lists of the variant require less storage than the rectangle list. The information of which alternative of the variant is in effect can now be stored as part of each record via the tag field. The tag field is referenced in the same manner as the other fields.

**Note:**

Variants can be nested. That is, a variant can contain a definition of another variant. However, there can be only one variant at any one level and the variant definition must follow any fixed fields of a record.

### POINTER DATA TYPE

---

The pointer data type is used in conjunction with dynamic storage allocation. This refers to the creation of storage space for variables during program execution. This is very useful when the amount of data storage a program will require is unknown. The use of pointer data types provides the ability to allocate storage as it is needed. Variables for which storage is dynamically created cannot be referenced in the usual manner. The reason is that they actually have no identifiers of their own. Instead, they are referenced through the use of pointers. A pointer is actually a variable which points to the location in memory of a dynamically created variable.

The definition of a pointer type specifies the data type for which storage will be allocated. The data type then determines the amount of storage required for each allocation. The definition of a data type does not have to precede the definition of a pointer type which references it. This is the only exception to the rule that identifiers must be defined before they are used. This allows for a field of a record to be declared as a pointer to the record itself. Either the symbol `^` or the symbol `@` may be used to signify a pointer type.

Syntax of type pointer:

```

      ---> ^ ---
      |         |
      |         v
      -----> @ -----> type id -->
  
```

Example pointer declarations:

```

TYPE  transptr = @transaction;
      transaction = RECORD
          item                :INTEGER;
          price               :REAL;
          link                 :transptr;
      END;
  
```

In the above declaration, `transptr` is a pointer type defined to be a pointer to the data type `transaction`. `transaction` is a record consisting of three components (`item`, `price`, and `link`). Dynamic variables of the type `transaction` can be created through the use of pointer variables of type `transptr`. Notice that `link` is declared to be of type `transptr`. This component of the record is a pointer variable which may point to another dynamic variable of type `transaction`. Therefore, a linked list of `transaction` records can be formed with the `link` field of each record pointing to the next record.

The predeclared procedure `NEW` is used to allocate storage for dynamic variables. It has one argument which is a pointer variable. The `NEW` procedure allocates the amount of storage required by the data type associated with the pointer and assigns the address of the allocated storage to the pointer. The pointer is then used to reference the allocated storage. For example, consider the declaration:

```
list : transptr;
```

Then the statement `NEW(list)` would allocate the amount of space required to store the three components of a transaction record at some location in available memory and assign the location in memory to the variable `list`. The available memory is called the heap and its size is set at run time. (See the System Implementation Manual)

References to a variable which is pointed to by a pointer are made by following the pointer name with either the symbol `^` or the symbol `@`. In the above example, `list@` would reference the dynamically created transaction record.

Syntax of referencing dynamic variables:

```

      --> ^ ---
      |       |
      |       v
--> pointer id ----> @ ---->

```

Example referencing of dynamic variables:

<code>list@</code>	references whole record
<code>list@.item</code>	
<code>list@.price</code>	references individual fields
<code>list@.link</code>	
<code>list@.link@</code>	references record pointed to by link field
<code>list@.link@.item</code>	
<code>list@.link@.price</code>	references individual fields
<code>list@.link@.link</code>	

When a dynamically created variable is no longer needed, it may be disposed of. This is the process of freeing the space consumed by the variable for other uses. The predeclared procedure DISPOSE is provided for this purpose. Like the NEW procedure, it has one parameter which is a pointer. The DISPOSE procedure frees the memory allocated to the variable pointed to by the pointer. Referring to the above example, DISPOSE(list) would free the amount of memory which was allocated to the dynamic transaction variable.

A predefined constant NIL can be used to assign a value to a pointer. Other than using the procedure NEW, assignment to the constant NIL is the only way of giving a pointer a defined value. If a pointer's value is NIL, then it does not point to a dynamic variable. This is often used with linked lists to give the pointer of the last element in the list a defined value. It provides a way of detecting when the end of the list has been reached.

Example procedures using pointer variables:

```
PROCEDURE create(VAR translist : transptr);

(* Creates a new transaction
  Adds the transaction to the top of a transaction list
  Returns a pointer to the new transaction via translist
  New transaction becomes top of transaction list*)

VAR
  trans          (*new transaction pointer*)
                :   transptr;

  (*note: translist should be initialized to NIL*)

BEGIN
  NEW(trans);          (*create new transaction*)
  trans@.link:=translist; (*new transaction points to old top of list*)
  translist:=trans;   (*new transaction becomes top of list*)
END;                  (*procedure create*)
```

```
PROCEDURE  destroy(translist, trans : transptr);

(* Removes the transaction pointed to by trans from the list
   Recovers the memory used by the transaction      *)

VAR
    lead,          (*points to next transaction in list*)
    trail          (*saves location of current transaction
                   while lead is advanced to the next
                   transaction*)
    :              transptr;

BEGIN
    lead:=translist;
    While lead <> trans DO (*search for trans*)
        BEGIN
            trail:=lead;      (*save pointer to current transaction*)
            lead:=lead@.link;  (*advance pointer to next transaction*)
        END;
    IF translist <> trans THEN (*check if trans is at top of list*)
        trail@.link:=lead@.link (*link around transaction*)
    ELSE
        translist:=lead@.link;  (*new top of list*)
    DISPOSE(trans);            (*recover memory*)
END;                          (*destroy*)
```

## OPERATORS

---

There are four categories of operators: arithmetic, relational, boolean, and type transfer.

### A. Arithmetic Operators

---

The following table lists all the arithmetic operators, the operations they perform, the type of operands which may be used, and the type of result of the operation. Mixed mode arithmetic is supported. (eg. it is allowed to have an integer value added to a real value) Also, automatic truncation occurs when an integer variable is assigned a real value.

Operator	Operation	Type of Operands	Type of Result
+	addition	integer, real	integer, real
	set union	sets of compatible types	same type as the larger set
-	subtraction	integer, real	integer, real
	set difference	sets of compatible types	same type as the larger set
*	multiplication	integer, real	integer, real
	set intersection	sets of compatible types	same type as the larger set
/	division	integer, real	real
DIV	truncated division	integer	integer
MOD	modulus	integer	integer

Note: For sets to be of compatible types they must have identical base types, one base type must be a subrange of the other, or they may both be subranges of the same base type.

## B. Relational Operators

---

All relational operators perform operations which yield Boolean results. The result is always either TRUE or FALSE. In general, both operands of a relational operator must be expressions of identical type, but the types REAL, INTEGER, and subranges of integer may be mixed.

(Relational operations may be performed on any types except files)

Operator	Result of Operation
-----	-----
=	true if left operand is equal to right
<>	true if left operand is not equal to right
<	true if left operand is less than right
>	true if left operand is greater than right
<=	true if left operand is less than or equal to right
>=	true if left operand is greater than or equal to right

To compare strings, the ordinal numbers of the characters composing both strings are compared to one another until a pair of characters are different or until the end of the strings is reached. If there are no character pairs which differ then the strings are equal. Otherwise, the first pair of characters which differ determine the relationship. The string whose character ordinal number is the largest is greater than the other string.

Operation	Result
-----	-----
'abc' = 'cdf'	FALSE
'abc' < 'abd'	TRUE
'bab' > 'adf'	TRUE

The following operator tests for set membership. The left operand may be any ordinal type and the right operand may be any set of the same ordinal type.

IN true if left operand is a member of the right  
(See section B of chapter 4)

### C. Boolean Operators

The boolean operators, like the relational operators yield boolean results. The result is always either TRUE or FALSE. The operands of a boolean operator must be boolean expressions.

Operator	Result of Operation
OR	true if either one or both of the operands is true
AND	true only if both operands are true
NOT	true if operand is false

Operation	Result
FALSE OR FALSE	FALSE
TRUE OR FALSE	TRUE
FALSE OR TRUE	TRUE
TRUE OR TRUE	TRUE
FALSE AND FALSE	FALSE
TRUE AND FALSE	FALSE
FALSE AND TRUE	FALSE
TRUE AND TRUE	TRUE
NOT TRUE	FALSE
NOT FALSE	TRUE

### D. Operator Precedence

---

Operator precedence defines the order in which operations take place within expressions. In general, expressions are evaluated from left to right. However, operations of higher precedence are performed before operations of lower precedence. All operators are ranked by precedence. Parentheses have the highest precedence and may be used to alter the normal order of evaluation. Nested parentheses are evaluated from the inside out.

Following is a list of the operators arranged by precedence. Operators listed on the same line have equal precedence. The precedence has been slightly altered from the Jensen & Wirth standard to eliminate excessive use of parentheses. The operators NOT, AND, and OR have been altered. In the standard, NOT immediately precedes the unary operators, AND is the same precedence as \* etc., and OR is the same precedence as +, -. This alteration should not effect porting standard Pascal to TRS-80 Pascal. However, if porting from TRS-80 Pascal to some other Pascal, you should parenthesize expressions just as you would had the precedence not been altered.

```

Highest
Precedence--> ( )

+ , - when used as unary operators

* , / , DIV , MOD

+ , -

= , <> , < , > , <= , >= , IN

NOT

AND

Lowest
Precedence--> OR
  
```

Operation	Equivalent To	Result
$8+3*4$	$8+(3*4)$	20
$10-8/4*2$	$10-((8/4)*2)$	6
$5 \text{ MOD } 10-5$	$(5 \text{ MOD } 10)-5$	0
$3<2 \text{ OR } 6>8 \text{ AND TRUE}$	$(3<2) \text{ OR } ((6>8) \text{ AND } (\text{TRUE}))$	FALSE
$\text{NOT } 7*2<5$	$\text{NOT } ((7*2)<5)$	TRUE

### E. Type Transfer

-----

The type transfer operator is used to temporarily change the type of an existing variable. This is useful when there is a need to reference a variable in a manner which would normally not be allowed by Pascal. For example, you might wish to access the lower and upper bytes of an integer variable. The type transfer operator allows you to access parts of variables. Also, it provides a mechanism for avoiding compiler type checking. This may be used in some cases where parameters of differing types must be passed to a procedure.

Syntax of type transfer:

```
---> variable ---> :: ---> type id --->
```

A type transferred variable may be used wherever a variable is allowed. Regardless of its original type, the type transferred variable is then accessed according to the type indicated. The type transfer operator tells the compiler to treat the variable as if it were of the new type. No data conversion takes place. The variable is simply referenced as if it were of the new type. Type transferred variables must adhere to the same type matching rules as normal variables.

Example use of type transfer operator:

```
TYPE      byte = 0..#FF;
          integrec = PACKED RECORD
                    upper, lower   :byte;
                    END;
          pointer = @integrec;

VAR       number : ARRAY[1..10] OF INTEGER;
          integr : integrec;
          address: pointer;
```

Valid type transfer operations:

```
integr.upper := number[1]::byte;
number[1]::byte := integr.lower;
READ(integr::INTEGER);
number[5] := address::INTEGER;
address::INTEGER := 25 + number[3];
```

The fundamental use of type transfer is to overlay a type template on a data structure so that components of the structure may be treated as if they were of any desired type. This requires a precise understanding of how the compiler represents the data type (how it is stored) in order to insure the operation does what was intended. Because of this, it should be used with caution and only when necessary. (See the System Implementation Manual)

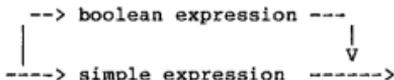
### EXPRESSIONS

---

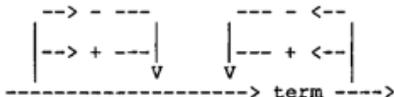
An expression is a variable, a constant, a function call, a set notation, or a combination of these operands with a description of the operations to be performed on them. The operators and operands of an expression define an implicit type for the expression. When evaluated, the expression yields a value of that type. For example, an integer expression is composed of operands and operators which when evaluated yield an integer result, a real expression yields a value of the type REAL, an ordinal expression yields a value which is of one of the ordinal data types, etc...

An expression can be just a simple expression or it can be a boolean expression. A simple expression can yield a value of any data type. A boolean expression is composed of simple expressions but always yields a value of the type BOOLEAN.

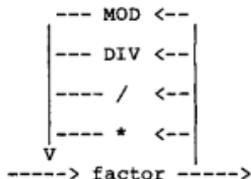
Syntax of expression:



Syntax of simple expression:



Syntax of term:

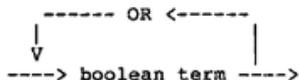




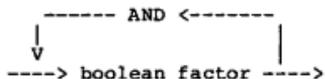
Example simple expressions:

Expression	Result
time	same type as time
weekday + [saturday,sunday]	set
12*payment(interestrate,years)	integer or real depending on type of function "payment"
entry MOD size	integer
-10 DIV 4 + 9.2/6 -45	real
(var1+var2)*153/(var3-var4)	real

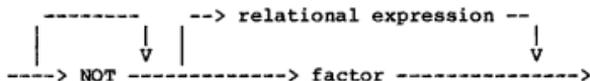
Syntax of boolean expression:



Syntax of boolean term:



Syntax of boolean factor:



note: factor must be of type BOOLEAN

Syntax of relational expression:

--> = --	
--> < --	
--> > --	
--> <> --	
--> <= --	
--> >= --	
	V

---> simple expression ----> IN ----> simple expression --->

Example boolean expressions:

a=b OR c<d AND switch

n1 + n2 >= 20 AND n3-n4 <= 11

NOT here OR there

NOT alpha < beta AND gamma <> 'R'

number IN [1..15] OR NOT letter IN ['a'..'z']





### B. The Compound Statement

---

Statements which are bracketed by the two keywords BEGIN and END make up what is termed a compound statement. The compound statement is used in places where more than one statement is required. The compound statement is essential for most of the control structures of Pascal. For example, the FOR statement is a control structure used for executing a statement repeatedly for a specified number of times. The compound statement provides the ability to use this construct for executing a sequence of statements rather than just one.

Syntax of the compound statement:

```

          ----- ; <-----
          |                   |
          v                   |
--> BEGIN ---> statement ---> END -->
  
```

Example compound statement:

```

BEGIN
  a := b * c;
  d := a/10 + 16.9;
  e := d - 28.3 + 14;
END
  
```

### C. Repetitive Statements

---

Repetitive statements are the structures used for loop control. They specify that a statement or sequence of statements is to be executed repeatedly until some terminating condition occurs. Pascal provides three such control structures.

### C.1 The FOR Statement

The FOR loop is used when a statement is to be executed a predefined number of times. The FOR loop is characterized by a loop variable which serves as a counter for controlling the number of times a statement is executed. The counter has defined starting and ending values which are ordinal expressions. The expressions are evaluated once upon entry into the loop. At the beginning of each time through the loop, the counter's value is compared to the ending value to determine whether or not to end execution of the FOR. At the end of each time through the loop the counter's value changes by 1. If the keyword TO is used, the counter is incremented each time through the loop, while the use of the keyword DOWNTO causes the counter to be decremented. The loop is terminated when the counter has incremented or decremented past the ending value. The FOR statement is not executed if the counter's starting value is such that the ending value would never be reached. For example, if the starting value was -1, the ending value was 2, and DOWNTO was used, the FOR statement would not be executed.

#### Note:

The compiler option FORDECL may be used to cause the compiler to generate temporary variables for FOR loop counters. When this option is used, it is not necessary to declare the counter variable.

Syntax of the FOR statement: (counter must be ordinal type)

```

--> DOWNTO ---
|
--> FOR --> counter id --> := --> ord expr -----> TO -----
|
-----
|
---> ord expr --> DO --> statement -->

```

#### Example FOR statements:

```

FOR i := 1 TO 30 DO WRITELN(' this gets written 30 times')
-----
FOR j := first DOWNTO last DO
  BEGIN
    initials[j] := 0;
    time[j] := 60;
  END

```

### C.2 The WHILE Statement

---

The WHILE statement uses a boolean expression to control repeated execution of a statement.

Syntax of the WHILE statement:

```
--> WHILE --> boolean expr --> DO --> statement -->
```

The evaluation of the boolean expression precedes the execution of the statement. If the expression evaluates to TRUE, the statement is executed and then the expression is reevaluated. This loop continues until the expression evaluates to FALSE. The first occurrence of a FALSE evaluation causes termination of the WHILE statement.

Example WHILE statements:

```
WHILE NOT EOLN DO READ(character)
```

```
-----
```

```
WHILE (a<b) AND (b<c) DO
  BEGIN
    WRITELN(a,b,c);
    a := a + 1;
    c := c - 1;
  END
```

### C.3 The REPEAT Statement

---

The REPEAT statement, like the WHILE, uses a boolean expression to control repeated execution.

Syntax of the REPEAT statement:

```

      ----- ; <-----
      |               |
      v               |
--> REPEAT ---> statement ---> UNTIL --> boolean expr -->

```

The REPEAT statement is defined such that a sequence of statements which are bracketed by the two keywords REPEAT and UNTIL will be executed at least once. Following the keyword UNTIL is a boolean expression. If the expression evaluates to FALSE then execution returns to the first statement following the REPEAT keyword. If the expression evaluates to TRUE then execution continues with the statement following the boolean expression.

Example REPEAT statement:

```

REPEAT
  i   := i+1;
  j   := j-1;
  k[j] := (i + j) MOD 100;
  l[i] := (i + j) MOD 200;
UNTIL i=j

```

#### D. Conditional Statements

---

Conditional statements are used when the execution of a statement must be controlled by some predetermined condition or when one statement out of a group of statements is to be selected for execution. There are two conditional statements.

##### D.1 The IF Statement

---

The IF statement uses a boolean expression to control the execution of statements.

Syntax of the IF statement:

```

--> IF --> bool expr --> THEN --> statement ----- ELSE --> statement --->

```

In its simplest form, the IF statement involves the evaluation of a boolean expression to determine whether or not to execute an associated statement which follows the keyword THEN. If the expression is TRUE, then the statement is executed, otherwise it is not. The IF statement can also contain an ELSE clause. In this form, if the boolean expression is TRUE, then the statement following the keyword THEN is executed, otherwise the statement following the keyword ELSE is executed.

Example IF statements:

```

IF finished THEN WRITELN(' operation complete');

IF number < 10 THEN range := 1 ELSE range :=2;

IF alpha >= '0' AND alpha <= '9' THEN digit(alpha)
ELSE
  IF alpha >= 'A' AND alpha <= 'Z' THEN letter(alpha)
  ELSE
    special(alpha);

IF contextlist = NIL THEN
  BEGIN
    NEW(context);
    context@.link := NIL;
    contextlist := context;
  END
ELSE
  BEGIN
    temp := context;
    NEW(context);
    temp@.link := context;
    context@.link := NIL;
  END;

```

The statements following the keywords THEN or ELSE can themselves be IF statements. In some forms, an ambiguity can exist in determining which ELSE clause goes with which IF. For example, consider the following case where b1 and b2 represent boolean expressions and s1 and s2 represent statements.

```

IF b1 THEN IF b2 THEN s1 ELSE s2

```

The ELSE could go with the first IF or the second IF. The rule used for solving the ambiguity is to associate an ELSE clause with the nearest IF. The above statement would then be equivalent to:

```
IF b1 THEN
  BEGIN
    IF b2 THEN s1 ELSE s2
  END
```

Caution: Semicolons must not appear in the middle of a statement. The most common error for beginning programmers is to put a semicolon in an IF statement which has an ELSE clause. While semicolons are necessary for separation of the individual statements within a compound statement, they must not separate an ELSE from its corresponding IF.

## D.2 The CASE Statement

The CASE statement uses an ordinal expression to select one statement out of a group of statements for execution. The group of statements represent alternatives. When a CASE statement is executed, one of the alternatives is selected and executed and then control passes to the statement following the CASE statement.

Syntax of the CASE statement:

```
--> CASE --> ord expr --> OF -----
|
|-----|
|-----; <-----|
|-----, <-----|
|-----> constant --> : --> statement ----->
|-----|
|-----> OTHERWISE --> statement -----> END -->
```

The alternative statements of a CASE statement are preceded by constants. The ordinal expression is evaluated and compared to the constants preceding the alternative statements. If a match is found, the statement which has the preceding constant that matches the evaluated expression is executed. There are two actions which can take place in the event that no match is found. By using the OTHERWISE clause, you may specify a statement to be executed when no match is found. If the OTHERWISE clause is omitted and no match is found, then execution continues with the statement which follows the CASE statement.

Example CASE statements:

```
CASE n1+n2 OF
  10: x := sin(x);
  11: x := cos(x);
  12: x := ln(x);
END;
```

```
CASE ch OF
  'a','b','c': token := 0;
  'd','e','f': token := 1;
  OTHERWISE   token := 2;
END;
```

```
CASE day OF
  monday       : snack := apple;
  tuesday      : snack := orange;
  wednesday    : snack := grapes;
  thursday     : snack := pear;
  friday       : snack := candy;
  saturday,
  sunday       : BEGIN
                weekend := TRUE;
                snack   := nothing;
                END;
END;
```

#### E. The WITH Statement

The WITH statement is used in conjunction with variables of type RECORD. It makes it possible to use a shorter notation when referencing fields of record variables.

Syntax of the WITH statement:

```

          ----- , <-----
          |
          v
--> WITH -----> variable -----> DO --> statement -->

```

The variable list specifies the record variables whose fields are to be referenced simply by specifying the field name itself. When fields of a record are nested (ie. a record is defined as a field of another record), the record variable and the fields, down to the level of the field which is to be referenced in short notation, may be specified in the variable list. Then the nested field can be referenced in the statement simply by specifying its field name. There is a conflict inside the WITH statement when an identifier corresponds to both a variable name and a field name of one of the specified records. For example, you could have a record variable named "weekday" with a field named "monday" and also a simple variable named "monday". Then the following WITH statement might be used.

```
WITH weekday DO monday := 1
```

In such a case, the field name takes precedence over the variable name and the field of the record is referenced. If nested WITH statements are used and a field name inside occurs in more than one of the specified records, then the closest WITH takes precedence.

Example WITH statements:

Assume the declarations:

```
customer : RECORD
  name,
  address,
  city    :PACKED ARRAY[1..20] OF CHAR;
  date    :RECORD
    month,
    day,
    year   :INTEGER;
  END;
END;
```

```
WITH customer DO
  BEGIN
    name   := 'JACK SLATE'      ;
    address := '1216 MELODY LANE' ;
    city   := 'TULSA, OKLAHOMA' ;
  END;
```

```
WITH customer.date DO
  BEGIN
    month := 10;
    day   := 23;
    year  := 1981;
  END;
```

### F. The GOTO Statement

---

The GOTO statement is used to cause an unconditional branch to a labeled statement.

Syntax of the GOTO statement:

```
--> GOTO --> label -->
```

The label must be declared in the LABEL declaration part of the same block which contains the GOTO referencing it. The GOTO statement cannot specify a branch to a label outside the block in which it resides. Care must be taken when using the GOTO statement. For example, you should not branch inside a FOR loop from a statement outside the loop. This could cause some very unpredictable results.

Example GOTO statement:

```
FOR i := 1 TO 1000 DO
  IF a(i) <> b(i) THEN GOTO 10
  ELSE a(i) := b(i);
10: a(i) := '#0D';
```

### G. The Procedure Statement

---

The procedure statement causes the activation of a procedure. Control passes to the named procedure and then returns to the statement following the procedure statement when the activated procedure terminates. If a procedure has a parameter list, a procedure statement which activates it must specify an argument for each parameter of the parameter list. The arguments must match the order and type of the parameters specified in the parameter list of the procedure. An argument is specified as an expression. If a parameter of a procedure is a pass by reference parameter (denoted by VAR), the corresponding argument of a procedure statement must be a single variable name. The variable may be a simple variable or a component of a structured variable.

Syntax of a procedure statement:

```

      -----
      |                                     |
      |         ----- , <-----      |
      |         |         |         |     |
      |         v         |         v     |
--> procedure id ---> ( ---> expr ---> ) --->
  
```

Example procedure statement (call):

(See the procedure declaration in section B.7 of chapter 2)

```
getvalue(n+j,8,hexstring,value)
```

```
report
```

```
writeout(x,y,3.7+9.6/z)
```

## PROCEDURES AND FUNCTIONS

---

(See chapter 2 for a description of the syntax of procedure and function declarations. A discussion of parameter passing is included with the discussion of the procedure heading.)

Procedures and functions are the tools used to modularize a program. This is the process of breaking a program up into smaller and more manageable pieces. They make a program much more readable and make possible later modifications much easier to handle.

Procedures and functions can be compiled separately and then linked to programs that use them. This allows for the development of libraries of commonly used procedures and functions. Then all the programs that use them can link them in rather than having to include them in the program itself.

The variables declared in a procedure or function do not occupy storage space until the procedure or function is activated. When activated, storage space is allocated for the variables and when the procedure or function terminates, the allocated space is released. Therefore, the amount of storage (or stack) space required by a program at any point in time is a function of the number of blocks which are activated at that time.

A procedure is activated (or called) by a procedure statement. When a procedure is called, control is passed from the point of the call to the procedure. The statements in the procedure then are executed. When the block END of the procedure is reached or when a call to the ESCAPE procedure is made, control passes back to the statement following that which activated the procedure.

A function is activated by an expression. When an expression which contains a reference to a function is evaluated, the function reference causes control to pass to the named function. The statements in the function then are executed. Unlike procedures, functions have a declared type. At some point inside the statement body of a function, the function name should be assigned a value. The value must be the same type as the type to which the function is declared. When the block END of the function is reached or when a call to the ESCAPE procedure is made, control passes back to the evaluation of the expression which activated the function and the function reference is replaced by the value assigned to the function.

### A. Scope Rules

---

A procedure or function declaration forms a new block which is a subblock of the block in which the declaration appears. The new block formed is "nested" within the block which declares it. This process of nesting which occurs every time a procedure or function is declared produces a program structure such as the one shown on the first page of chapter 2. Any block which is enclosed by another block is said to be nested within that block. The level numbers on the diagram indicate how deep the nesting goes beyond the program block which is arbitrarily assigned level 1. The existence of procedures and functions makes it necessary to talk about scope rules. Scope rules describe the accessibility of identifiers from any particular place in a program. The two terms local and global are helpful in discussing scope rules.

An identifier is considered to be local to a block if the identifier is declared within the same block. If there are no blocks nested within the declaring block, then a local identifier can only be referenced by the block which declares it. Enclosing blocks cannot access a local identifier.

An identifier is considered to be global to blocks which are nested within the block in which the identifier is declared. If an identifier is global to a particular block, then that block can reference the identifier provided that it has not declared an identifier of the same name. If a block declares an identifier with the same name as a global identifier, then the global identifier is no longer accessible from that block. Also, any further nested blocks will not have access to the original global identifier.

Identifiers declared in the program block are accessible from any place in a program because all other blocks are nested within the program block. Therefore, identifiers declared in the program block are global to all procedures and functions of the program. Identifiers declared in a procedure or function are local to that procedure or function. The only places in the program which can access these identifiers are the procedure or function itself and the procedures or functions, if any, which are nested within. The nested procedures or functions can access only the global identifiers which they do not declare themselves.

A procedure or function declaration consists of a heading followed by a block. It is important to note that the procedure or function name of a heading is local to the block which declares it. The parameters of the heading are local to the procedure or function itself. This means for example that a procedure statement in the program block can reference any procedure declared in the program block. However, a procedure statement in the program block can not reference any procedure declared within one of these procedures.

As an example of how scoping effects the accessibility of identifiers, consider the sample diagram on the first page of chapter 2. The following table shows for each block of the diagram, the procedures and functions which are callable from that block, and the constants, types, variables, etc. which can be referenced by the block.

Block	accessible procedures and functions	accessible constants, types, variables, etc.
A	B, D, F	A
B	B, C, D, F	A, B
C	B, C, D, F	A, B, C
D	B, D, E, F	A, D
E	B, D, E, F	A, D, E
F	B, D, F	A, F



### C. EXTERNAL

An external procedure or function can be declared in a program by specifying its heading followed by the keyword `EXTERNAL`.

Syntax of externally declared procedures or functions:

```

--> function heading ---           note: EXTERN also accepted
      |                               |
      |                               v
-----> procedure heading -----> EXTERNAL --> ; -->

```

Note:

for brevity the word "routine" will be used in place of "procedure or function" in the following discussion.

The linking loader may be used to link separately compiled routines to a program. By declaring a routine to be external, the actual declaration does not have to appear in the program. This is very useful when working with large programs. A large program may be broken up into many routines which are declared as external. The external routines can then be compiled individually. The linking loader can then be used to link the compiled program to its individually compiled routines. One advantage to this is that any changes which are made to a particular routine will cause only that routine to have to be recompiled. The linking process is then repeated after the changed routine has been recompiled. Another advantage is that slightly larger programs can be created by compiling them in pieces and then linking the pieces together.

Perhaps one of most frequent use of external routines is to create a file or library of commonly used routines. Then all the programs which use the routines can link to them rather than having to declare them in each program.

A compiler option must be used to compile a routine by itself. The reason is that a routine by itself is not a legal Pascal program. Therefore, a legal program must be constructed around the routine. This would include a program heading, the environment of the routine, the procedure or function declaration, and a statement body. The environment consists of any constants or types which are in the scope of and are used by the external routine. If global constants or types are needed by the routine, they should be given the same names as those used in the programs that use the routine. The scope refers to the identifiers in a program which are accessible to the externally declared routine.

Variables can also be included in the environment but this is not recommended. If an external routine needs to access a global variable, the variable should be passed as a parameter to the routine. Otherwise, extreme care must be taken to assure that the environment around the external routine matches the environment of the programs which use the routine. The statement body contains the compiler option which is called "nullbody". The nullbody option tells the compiler not to generate any code for the program. Only code for the declared routine is generated.

The syntax for using the nullbody compiler option is shown in the appendix along with all the other compiler options. An example using global variables in an external procedure is also given.

Example use of external procedure:

```
PROGRAM sample;
CONST .....
TYPE .....
VAR      xmin,xmax,ymin,ymax : REAL;
        .....

PROCEDURE axes(xmin,xmax,ymin,ymax : REAL); EXTERNAL;
BEGIN
    ....
    axes(xmin,xmax,ymin,ymax);
    ....
END.      (*sample*)

-----
```

Separate compile of procedure axes:

```
PROGRAM axesroutine;
(*global environment, if any, goes here*)
PROCEDURE axes(xmin,xmax,ymin,ymax : REAL);
TYPE ....
VAR ....
BEGIN
    .....
    .....
END;      (*procedure axes*)
BEGIN
    (*$NULLBODY*)
END.
```

D. Recursion

Pascal is a language which supports recursion. Recursion refers to having more than one activation of a particular procedure or function at the same time. There are two forms of recursion. Direct recursion refers to a procedure or function that calls itself. Indirect recursion refers to a procedure or function that makes a call which eventually results in the procedure or function being called again. An example of this is two procedures that call each other. When writing recursive procedures, some conditional statement must exist in the procedure to halt the recursion at some point. Otherwise, there would be an endless loop that would terminate only after the stack was exhausted crashing the program. Recall that each activation of the procedure results in space being allocated for its variables.

Example use of recursion:

```
PROCEDURE XYZ;  
  (*DECLARATION HERE*)  
BEGIN  
  ....  
  XYZ;  (*PROCEDURE CALLS ITSELF*)  
  ....  
END;
```

### E. Predeclared Procedures and Functions

---

The predeclared procedures and functions are accessible from any place in a program. They are declared in an imaginary block which surrounds the program block. The names of predeclared procedures or functions may be used as identifiers in programs. This means that the name of a predeclared procedure or function may be used in a declaration. If so, then the predeclared procedure or function whose name is used in a declaration is no longer accessible to the program. Its name is associated with the new declaration.

#### File Associated Procedures

---

RESET(f)	Positions the file pointer of the specified file to the beginning for the purpose of reading. If the file is empty, then the function EOF becomes true, else it is false.
REWRITE(f)	Replaces the specified file with an empty file. The file pointer is positioned to the beginning of the file.
PAGE(f)	Outputs a formfeed to the specified file. Formfeeds cause skipping to the top of the next page when the file is printed.
CLOSE(f)	Closes the specified file. This procedure may be used to explicitly close a file at any time.
MESSAGE(s)	Outputs the specified string to the terminal. s is char or array of char
READ , READLN	Read data from a device
WRITE, WRITELN	Write data to a device (See chapter 10 for details)

### Arithmetic Functions

-----

	<u>Operation</u>	<u>Type of x</u>	<u>Type of Result</u>
ABS(x)	absolute value	integer, real	same type as x
SQR(x)	square	integer, real	same type as x
SIN(x)	sine	integer, real	real
COS(x)	cosine	integer, real	real
ARCTAN(x)	arctangent	integer, real	real
EXP(x)	natural (base e) exponential	integer, real	real
LN(x)	natural logarithm	integer, real	real
SQRT(x)	square root	integer, real	real

### Boolean Functions

-----

ODD(x)	Operation: Returns true if x is odd, else false Type of x: integer Type of result: boolean
EOLN(x)	Operation: Returns true if the end of a line in the file has been reached Type of x: text Type of result: boolean
EOF(x)	Operation: Returns true if the end of the file has been reached. Type of x: file Type of result: boolean

### Transfer functions

---

- TRUNC(x)**      Operation: Truncates a real value to its  
integer part  
Type of x: real  
Type of result: integer
- ROUND(x)**      Operation: Rounds a real value to the  
nearest integer  
Type of x: real  
Type of result: integer
- ORD(x)**        Operation: Returns the ordinal number of x.  
Type of x: any ordinal type  
Type of result: integer
- CHR(x)**        Operation: Returns the character whose ordinal  
number is x  
Type of x: integer  
Type of result: char
- LOCATION(x)**    Operation: Returns the address of variable x  
Type of x: any type (may also be a procedure name)  
Type of result: integer
- SIZE(x)**        Operation: Returns the size of type x in bytes  
Type of x: any type identifier  
Type of result: integer
- HB(x)**         Operation: Returns the high byte of x  
Type of x: integer  
Type of result: integer
- LB(x)**         Operation: Returns the low byte of x  
Type of x: integer  
Type of result: integer

### Data transfer procedures

---

- PACK(a,i,z)**    Operation: Copy the unpacked array a into the  
packed array z. If the dimension of a  
is m..n and the dimension of z is u..v  
and  $n-m > v-u$  then the operation is  
equivalent to:  
for j:= u to v do z[j] := a[j-u+i]
- UNPACK(z,a,i)** Unpacks the above array.

Dynamic allocation procedures  
-----

- NEW(p)            Allocates a new variable v and assigns the pointer reference of v to the pointer variable p. Tag field values may appear as parameters to NEW but are non-functional.
- DISPOSE(p)       Releases the storage occupied by the variable pointed to by p.

Other functions  
-----

- SUCC(x)           Operation: Returns the successor of x which is next higher value in the enumeration of which x is a member  
Type of x: any ordinal type  
Type of result: same type as x
- PRED(x)           Operation: Returns the predecessor of x which is the next lower value in the enumeration of which x is a member  
Type of x: any ordinal type  
Type of result: same type as x

Other procedures  
-----

- ESCAPE           Causes termination of a block just as if the block end had been reached. If the block is a procedure or function, then control returns to the calling block. If the block is the program block, then program execution is terminated.

note : IF files are declared locally within a procedure, then the files must be closed using the procedure CLOSE before calling ESCAPE. Normal termination of a block results in files automatically being closed.

### INPUT AND OUTPUT

---

Input and output is the communication of a program to the external environment. A program communicates to the external environment through the use of logical files. Logical files are the variables in a program which are declared as type FILE or TEXT. The logical files are then associated with physical files. Physical files are the actual devices of the computer system. A physical file could be a disk file, a terminal, a printer, or some other device. The method of associating logical files to physical files is discussed in the System Implementation Manual.

Predeclared procedures and functions are provided for handling input and output. These procedures and functions have a characteristic unlike other procedures and functions. The number of parameters passed to them can vary. They may be called with no parameters or with several parameters. Since each input and output routine performs an operation on a file, it must know which file to operate on. If a routine is passed the logical file name, then it operates on the specified file, otherwise it operates on a default logical file. The two predeclared variables INPUT and OUTPUT are the default logical files. They are both declared as type TEXT. The one used as the default depends on the routine called. The input routines default to INPUT and the output routines default to OUTPUT.

#### I/O Routines

Procedures			Functions
input	output	general	EOF EOLN
RESET	REWRITE	CLOSE	
READ	WRITE		
READLN	WRITELN		
	PAGE		
	MESSAGE		

A file has associated with it a file pointer. The file pointer is used to point to an individual component of a file. There are two predeclared boolean functions which may be used to check the status of a files pointer. Both functions may or may not take a logical file name as a parameter. If no file parameter is passed, the default is INPUT. The function EOF(file) returns the value TRUE if the pointer is at the end of the file. Otherwise, the value returned is FALSE. The function EOLN(file) can only be used with files of type TEXT. It returns the value TRUE when the files pointer is at the end of a line. Otherwise, the value returned is FALSE.

Syntax of function EOF or EOLN: (default: file = INPUT)

```

--> EOLN ---
      |           |           |
      |           v           |
-----> EOF-----> ( --> file --> ) ---->

```

Examples of using EOF and EOLN:

```

WHILE NOT EOF(datain) DO          IF EOF THEN quit
  BEGIN                            ELSE
  WHILE NOT EOLN(datain) DO      READ(number);
  BEGIN
  READ(ch);
  .....
  END;
  .....
  END;

```

#### A. RESET

The RESET procedure opens a file so that it can be read. No input can be received from a file without this operation first being performed.

Syntax of RESET: (default: file = INPUT)

```

----->
      |           |           |
      |           v           |
--> RESET ----> ( --> file --> ) ---->

```





If the variable is of type CHAR, then a single character is read from the file. If the variable is an array of CHAR, then the dimension of the array determines the number of characters read from the file. If an end of line or file mark is encountered before the array is full, then the characters read up to that point are left justified in the array and the remaining elements are filled with blanks. Integer and real numbers are represented in files as strings of characters. Individual numbers in a file are separated by blanks or by an end of line mark. When a number is read, the character string representing the number is automatically converted to its real or integer value before being assigned to the variable. With text files, consecutive read operations automatically skip end of line marks when reading integer, real, or boolean variables. When reading character or string variables, the end of line mark is not skipped. In this case, the procedure READLN must be executed to cause the file pointer to advance to the next line.

Example use with text files:

Consider the following file of data:

```
SAM JONES    25    183.5    369
MARY SMITH   23    105.4    356
.....
.....
```

and the declarations:

```
VAR      name           : PACKED ARRAY[1..10] OF CHAR;
         number, total  : INTEGER;
         score          : REAL;
         students       : TEXT;
```

If the file pointer of "students" points to the beginning of a line (it does immediately after a RESET) then:

```
READ(students,name,number,score,total)
```

would assign a string, integer, real, and integer value to the 4 specified variables. The file pointer would then point to the character immediately following the last value read.

Non-text files

If the file is not of type TEXT, then all components of the file are of the same type. The components of a file may be declared to be of any type except the type FILE or structured types containing a component of type FILE. This means for example, that you could declare a file of records. Then an entire record can be read into a variable of the same record type. This however, requires that the file of records has previously been created through the use of the procedure WRITE. The reason for this is that all files which are not of type TEXT are read and written in binary form.

Example use with non-text files:

assume the following declarations:

```

TYPE      food = RECORD
           fruit      : (orange, grape, apple);
           vegetable  : (corn, okra, beans);
           cost       : INTEGER;
           END;

VAR       groceries : FILE OF food;
           item      : food;

```

then:

```

           READ(groceries, item)
would assign one record from the file to the variable "item".

```

Care should be taken not to read past the end of a file. The function EOF is provided for preventing this from occurring. The program will not abort if you try to read past the end of file, but the value assigned to the variable will be some unknown value.

D. WRITE

The procedure WRITE appends values to a file. The number of values passed to the procedure determines the number of values output to the file. If a file is declared as type TEXT, then output values can be specified as strings or expressions. If a file is declared as a type other than type TEXT, then the output values are restricted to variables of the same type only.

## Syntax of WRITE:

For non-text files:

```

      ----- , <-----
      |         |
      v         v
--> WRITE --> ( --> file --> , --> variable --> ) -->

```

For text files: (default: file = OUTPUT)

```

      ----- , <-----
      |         |         |
      v         v         v
--> WRITE --> ( --> file --> , --> write parameter --> ) -->

```

## Syntax of write parameter:

```

      -----
      |         |         |
      v         v         v
--> real expr --> : --> integer expr -----> : --> integer expr -->
|
--> integer expr ---
|
--> boolean expr ---|-----
|         |         |         |
|         v         v         v
-----> string -----> : --> integer expr ----->

```

Syntax of string: (string variable = packed array of char)

```

      ----- string variable -----
      |         |         |
      v         |         v
-----> ' -----> character -----> ' ----->

```

### Text files

-----  
If the file is of type TEXT, then the values output to the file may be specified as strings or as boolean, integer, or real expressions. If a string is specified, then the characters of the string are output to the file. If a boolean expression is specified, then either the characters 'TRUE ' or 'FALSE' are output to the file depending on the value of the expression. If an integer or real expression is specified, then the value of the expression is converted to a character string before being output to the file. An integer expression may be output in hexadecimal or decimal base representation.

The number of characters to output for a value can be specified by an integer expression which follows the value, separated by ":". If the number of characters is not specified for a particular value, then a default number of characters will be output.

---For a string---

If the number is less than the length of the string, then all the characters of the string are output. If the number is greater than the length of the string, then blanks will be appended to the string. The default number is the length of the string.

Example: WRITE(' literal string' : 20)

---For a boolean expression---

The same rule applies for the strings 'FALSE' and 'TRUE'.

Example: WRITE(a AND b : 10)

---For an integer expression---

If the number is less than the number of digits in the integer, then all the digits are output. If the number is greater than the number of digits, then the excess characters are output as blanks before the integer is output. The default number of digits for integers is 8. An integer value may be written in hexadecimal base format by specifying : width HEX

Example: WRITE(outfile, n+5 :i, j :4 HEX)

---For a real expression---

Two numbers may be specified for real values. The first number specifies the total field width. The second specifies the number of digits after the decimal point. If both are specified, the number will be written in fixed format. Otherwise, the number will be written in exponential format. The default field width for single precision is 12. The double precision default is 20. The maximum field width is 32.

Example: WRITE(2.5\*random :5, random/x:9:6)





The WRITELN procedure may be called without passing any values to written. When no values are specified, then the procedure just appends an end of line mark to the file.

The statement:           WRITELN(var1,var2,var3)  
is equivalent to:        BEGIN WRITE(var1,var2,var3); WRITELN END

Example use of WRITELN:

```
(*writes 2 values on each line*)
FOR k := 1 TO 100 DO WRITELN(a[k],b[k]);
```

---

```
FOR j := 1 TO maximum DO
  BEGIN
    i := 0;
    REPEAT
      i := i+1;
      WRITE(number[j]);
    UNTIL (i=5) OR (number[j]>100);
    WRITELN;                   (*advance file pointer to next line*)
  END;
```

#### G. CLOSE

---

The use of the CLOSE procedure will assure that file data will not be lost if the program abnormally terminates and does not properly close the file. The CLOSE procedure must be used with files which are components of structured variables. (see the appendix)

Syntax of CLOSE:

```
--> CLOSE --> ( --> file --> ) -->
```

H. PAGE

The PAGE procedure appends a formfeed to a file. Formfeeds cause printers to skip to the top of the next page. This procedure provides a way of controlling the number of lines printed on a page.

This procedure may only be used with files of type TEXT.

Syntax of PAGE: (default: file = OUTPUT)

```

-----
|                                     |
|                                     |
--> PAGE ---> ( --> file --> ) --->
|                                     |
|                                     |

```

I. MESSAGE

The procedure MESSAGE may be used to output strings to the terminal. It takes one parameter which is either a string constant or variable. A string constant is a sequence of characters enclosed in single quotes. A string variable is a variable declared as a packed array of characters.

Syntax of MESSAGE:

```
--> MESSAGE --> ( --> string --> ) -->
```

Programs which require only string output to the terminal can use this procedure rather than the WRITE procedure.

Example use of MESSAGE:

```
MESSAGE(' time to quit');
MESSAGE(string);
```

A. COMPILER OPTIONS

Compiler options are provided to change the behavior of the Pascal compiler. These options allow features to be enabled or disabled and can alter the code generated at compile time.

Compiler options are specified in comments. A comment that contains a dollar sign as the first character specifies an option. All compiler options have two states, on and off. An option is turned on by placing its name after the dollar sign. If the option name is preceded by the word "NO", then the option is turned off. Except where noted, the options may appear any place in a program.

DOUBLE

This option specifies that all real variables within the program should be double precision. This option must precede the program statement. If it occurs anywhere else in the program, it will be ignored. If the option is off (the default), then real variables are single precision.

Example:

```
(*DOUBLE*)  
PROGRAM DBL;  
VAR  
    R : REAL;  
BEGIN  
END.
```

In this program, the variable "R" will be declared as double precision.

## FORDECL

-----

This option is used to change the behavior of loop counters in FOR statements. If the option is turned on (default is off), then all FOR loop counters are treated as temporary variables. They do not need to be declared, and even if a declaration is present, a new variable is used rather than the declared variable. These FOR loop counters are defined only within the loop and disappear when the loop is exited.

Example:

```
PROGRAM FORLOOP;
(*$FORDECL*)
VAR
  A,I : INTEGER;
BEGIN
  A := 0;
  I := 0;
  FOR I := 0 TO 4 DO A := A + I;
  WRITELN(OUTPUT,I,A);
END.
```

In the above program, the I used as a FOR loop counter is a different variable from the I declared in the VAR section. When the write statement is executed, the values 0 and 10 will be printed.

## INOUT

-----

This option enables the predeclared files: INPUT and OUTPUT (default is on). If this option is turned off before the PROGRAM statement, then the files input and output will not be declared. This option prevents the reset of INPUT and the rewrite of OUTPUT and can be used to avoid the prompts "INPUT =" and "OUTPUT =" when a program is run.

Example:

```
(* $NO INOUT *)
PROGRAM NOPROMPTS;
BEGIN
  MESSAGE('I WAS NOT PROMPTED FOR INPUT AND OUTPUT')
END.
```

IF

-----

The if option provides conditional compilation. The word IF is followed by the name of a boolean constant. If the constant has the value "TRUE", then compilation continues as if the option had not been present. If the constant has the value "FALSE" then compilation stops at that point, and all text is treated as comments until a (\*\$NO IF\*) is encountered. Note that IF options do not nest. That is, an IF option should not occur within the scope of another if option. The if option can be used to configure a program for different environments with minimum changes to the source. It is also useful for removing debugging statements once the program is working properly.

Example:

```
PROGRAM Test;
CONST
  debug = false;

FUNCTION FACTORIAL(I : INTEGER) : REAL;
BEGIN
  IF I = 0 THEN FACTORIAL := 1
  ELSE BEGIN
    (*$IF DEBUG*)
    WRITELN(OUTPUT, 'CALLING FACTORIAL(', I-1, ')');
    (*$NO IF*)
    FACTORIAL := I * FACTORIAL(I-1);
  END;
END; (* FACTORIAL *)

BEGIN
  WRITELN(OUTPUT, 'FACTORIAL(20)=', FACTORIAL(20));
END.
```

In the above program, the write statement within the recursive function FACTORIAL could be turned on during debugging by setting debug to TRUE. Once the program is running, it can be recompiled with debug set to FALSE. The write statement will be effectively removed. In fact, since no code is generated for it, the resulting object program will be shorter. This has the same effect as removing the statement with an editor or placing open and close comments around it. The advantage is that many statements can be disabled or enabled with a single change to the source program. Also, it is simple to reenable debugging statements should it become necessary in the future.

## NULLBODY

-----

The nullbody option is used to disable code generation for a procedure, function or program. The nullbody option should occur after the BEGIN that starts the block and before any executable statements. Nullbody will prevent code from being generated and can be used when procedures are being compiled separately. Since every program must have a program statement and a main program body, it is necessary to use nullbody to disable code generation for the main program when a subroutine library is being compiled.

For example:

```
PROGRAM SUBLIBRARY;
TYPE
  STRING = PACKED ARRAY[1..80] OF CHAR;

PROCEDURE CONCATENATE(VAR S1, S2, RESULT: STRING);
BEGIN
  (* BODY OF CONCATENATE *)
END;

PROCEDURE MID$(VAR S : STRING; FIRST, LAST : INTEGER;
  VAR RESULT : STRING);
BEGIN
  (* BODY OF MID$ *)
END;

BEGIN
  (*$NULLBODY*)
END.
```

If the above program is compiled, the object file will contain code only for the two procedures: CONCATENATE and MID\$. There will be no main program. This allows these procedures to be linked to another program.

## INCLUDE

-----

The include option is used to specify within a program, the name of a file which contains Pascal statements which you want included in the compilation process. When the compiler encounters an include option, it opens the specified file and compiles all the Pascal source in the file before continuing compilation of the current file. The include option allows you to include commonly used routines or declarations in a program without actually having the code present. You simply tell the compiler the name of the file containing the Pascal statements and it will include those statements as it compiles.

The include options may be nested. That is, you may include a file which also contains an include compiler option. There is no limit to the number of nested includes. However, the compiler must maintain a file descriptor for each file that is open at any given time. The file descriptors are allocated memory from the heap. If too many files are open at a time, the compiler may run out of heap during the compile process.

Example use of the INCLUDE option:

```
PROGRAM sample;
{DECLARE contains the declarations for this program}
(*$INCLUDE 'DECLARE'*) {note the quotes}
BEGIN
  {BODY contains the statement body for this program}
  (*$INCLUDE 'BODY'*)
END.
```

## LIST

----

The list option allows you to turn the compiler listing on and off within a program. The default is on. Therefore, the compiler will by default generate a listing which contains all the lines of a program. If it is desired to discard some of the lines of a program from the compiler generated listing, (\*\$NO LIST\*) may be used to tell the compiler to discard all subsequent lines of the program from the listing. The compiler does not stop compiling subsequent lines, it just does not output them to the listing. Object code is still generated. If you wish to turn the compiler listing back on, then (\*\$LIST\*) tells the compiler to start outputting all subsequent lines to the listing again.

The LIST option may be useful when compiling frequently used routines which you know will compile correctly. It provides a method to shorten compiler listings, saving paper when printing, and making it easier to locate other procedures or functions by uncluttering lengthy program listings.

Example using the compiler LIST option:

```
PROGRAM sample;
VAR ...
  PROCEDURE useoften;
    (*$NO LIST*)      {turn off listing for useoften}
  VAR ...
  BEGIN
    ...
  END;                {end of procedure useoften}
(*$LIST*)            {turn listing back on for program}
BEGIN                {beginning of main program}
  ...
END.
```

## PAGESIZE

-----

The listing generated by the compiler has printer control information (formfeed) between each page. The compiler outputs a formfeed (hex 0C) to the listing every 62 lines. The formfeed causes most printers to advance the paper to the top of the next page. The PAGESIZE option allows you to change the number of lines that the compiler will output to the listing between formfeeds. The actual number of lines output between formfeeds is 2 more than the number specified by the PAGESIZE option. This is to allow for the heading.

Most operating systems control paging when outputting data to a line printer. The operating system itself maintains a line counter and outputs a formfeed to the line printer after so many lines have been sent to the printer. A command is typically provided to set the number of lines per page or to turn paging control off entirely. If the operating system is controlling paging, the listing generated by the compiler may not be paged properly (i.e. the compiler heading may not appear at the top of each page). The number of lines per page used by the operating system should be equal to the number of lines per page used by the compiler, or the operating system paging must be turned off, if compiler generated listings are to be printed properly.

Example use of the compiler PAGE option:

```
(* $PAGESIZE 50*)      {set the number of lines/page to 50}
PROGRAM sample;
{the operating system paging should be set to 52
 or be turned off entirely}
...
BEGIN
...
END.
```

## WIDELIST

-----

The compiler now generates line numbers for each line of a listing. The WIDELIST option is used to specify that you want the compiler to additionally generate hexadecimal addresses which show the location of the object code for a particular line relative to the start of the procedure, function, or program in which the line appears. This information is useful when used in conjunction with the linking loader to determine the location within a program of a fatal error. You may use the S command of the linking loader to display the starting address of each routine loaded. Then use the R command to run the program. When the program terminates with a fatal error, the absolute hex address of the error is displayed. You may use this address along with the addresses displayed by the S command to determine in which routine the error occurred. By subtracting the address of the error from the starting address of the routine in which the error occurred, you obtain the relative address of the error within that routine. This address corresponds to the address printed on the listing.

Example use of the compiler WIDELIST option:

```
(*WIDELIST*) {tell the compiler to print hex addresses}
PROGRAM sample;
...
BEGIN
...
END.
```

## RANGECHK

-----

A common error which occurs in programs which utilize arrays is to index the array with a value which is outside the array bounds (eg. an array with bounds 1..10 is indexed with the value 11). A common error in programs which utilize subranges is to assign a value which is outside the subrange (eg. a variable is declared as type 0..255 and is assigned the value 275). A common error in programs which utilize enumerations is to increment or decrement past the first or last value of the enumeration (eg. SUCC(color) is executed when color is equal to blue and color is of type (red, green, blue)).

All of these errors may be trapped, causing an appropriate runtime error message to be displayed when such an error occurs during program execution. The RANGECHK option tells the compiler to generate extra code to detect and report errors of the above type when the compiled program is executed.

Since the RANGECHK option does cause additional object code to be generated, you should generally use it only during the debugging stage of program development. The RANGECHK option may be turned on and off throughout a program. The default is off. The IF compiler option may be used to conditionally turn the RANGECHK option on and off as needed for debugging purposes. Example use of the compiler RANGECHK option:

```
PROGRAM sample;
VAR   A,B : ARRAY[1..200] OF CHAR;
      J,K : INTEGER;
      ...
BEGIN
  WRITE(OUTPUT,'Enter size of array: ');
  (*$RANGECHK*)           {turn range checking on}
  ...
  FOR K := 1 TO J DO A[K] := B[K+1];
  (*$NO RANGECHK*)       {turn range checking off}
  ...
END.
```

Note: The RANGECHK option will not detect an error on subrange variables which are assigned invalid values via a read statement. To trap these errors, you must assign the read in value to a subrange variable.

```
  READ(VALUE);
  SUBRANGE_VARIABLE := VALUE;
```

## PTRCHECK

-----

A common error which occurs in programs which utilize dynamic pointer variables is the inadvertent assignment of the value NIL to a pointer and then the subsequent attempt to use the value pointed to in an expression or in an assignment to a static variable. Another common error is the attempt to utilize an uninitialized pointer. An uninitialized pointer may not point to a location within the allocated heap of the program. It may point into the executing code of the program, making it possible to write data over the instructions, causing very unpredictable results.

The PTRCHECK option is used to tell the compiler to generate extra code in the compiled program to detect and report either of the above types of errors when the program executes. This extra code causes the program to terminate and display an appropriate error message when an invalid use of a pointer variable is detected. The PTRCHECK option may be turned on and off throughout a program. The default is off.

Example use of the compiler PTRCHECK option:

```
PROGRAM sample;
TYPE customer = RECORD name,add : ARRAY[1..9] OF CHAR END;
VAR cust      : ^customer;
BEGIN
  (*$PTRCHECK*)
  ...
  WHILE cust<>NIL DO
    ...
  END.
```

## B. ERROR MESSAGES

---

### B.1 Compiler Error Codes

---

2 IDENTIFIER EXPECTED  
3 'PROGRAM' EXPECTED  
4 ')' EXPECTED  
5 ':' EXPECTED  
6 ILLEGAL SYMBOL  
8 'OF' EXPECTED  
9 '(' EXPECTED  
10 ERROR IN TYPE  
11 LEFT BRACKET '[' OR '(' EXPECTED  
12 RIGHT BRACKET ']' OR ')' EXPECTED  
13 'END' EXPECTED  
14 ';' EXPECTED  
15 INTEGER EXPECTED  
16 '=' EXPECTED  
17 'BEGIN' EXPECTED  
20 ',' EXPECTED  
22 '..' EXPECTED  
23 '.' EXPECTED  
49 'ARRAY' EXPECTED  
50 CONSTANT EXPECTED  
51 ':=' EXPECTED  
52 'THEN' EXPECTED  
53 'UNTIL' EXPECTED  
54 'DO' EXPECTED  
55 'TO'/'DOWNTO' EXPECTED  
57 'FILE' EXPECTED  
58 INVALID OR MISSING OPERAND IN AN EXPRESSION  
62 DECIMAL PLACE ALLOWED ONLY FOR REAL  
66 TYPE IDENTIFIER EXPECTED  
80 OPEN COMMENT WITHIN A COMMENT  
81 UNKNOWN OPTION  
82 # REQUIRES A 2 CHARACTER HEX VALUE OR ##  
101 IDENTIFIER DECLARED TWICE  
102 LOWER BOUND EXCEEDS UPPER BOUND  
103 IDENTIFIER IS NOT OF APPROPRIATE CLASS  
104 UNDECLARED IDENTIFIER  
105 CLASS OF IDENTIFIER IS NOT VARIABLE  
107 INCOMPATIBLE SUBRANGE TYPES  
113 ARRAY BOUNDS MUST BE SCALAR  
117 UNSATISFIED FORWARD REFERENCE TO A TYPE IDENTIFER OF A POINTER  
119 ';' EXPECTED (PARAMETER LIST NOT ALLOWED)  
120 FUNCTION RESULT MUST BE SCALAR, SUBRANGE, OR POINTER  
123 FUNCTION RESULT EXPECTED  
126 IMPROPER NUMBER OF PARAMETERS  
127 TYPE OF ACTUAL PARAMETER DOES NOT MATCH FORMAL PARAMETER  
129 TYPE CONFLICT OF OPERANDS IN AN EXPRESSION  
132 COMPARISON WITH '>' OR '<' NOT ALLOWED ON SETS  
134 ILLEGAL TYPE OF OPERANDS  
135 TYPE OF EXPRESSION MUST BE BOOLEAN

136 SET ELEMENT TYPE MUST BE SOME ENUMERATION TYPE  
138 TYPE OF VARIABLE IS NOT ARRAY  
140 TYPE OF VARIABLE IS NOT RECORD  
141 TYPE OF VARIABLE IS NOT POINTER  
148 SET BOUNDS OUT OF RANGE  
152 NO SUCH FIELD IN THIS RECORD  
154 ACTUAL PARAMETER MUST BE A VARIABLE  
156 MULTIDEFINED CASE LABEL  
161 PROCEDURE OR FUNCTION ALREADY DECLARED AT A PREVIOUS LEVEL  
165 LABEL ALREADY DEFINED  
167 UNDECLARED LABEL  
168 LABEL NOT DEFINED  
182 "FOR" EXPRESSION MUST BE OF SOME ENUMERATION TYPE  
183 "CASE" EXPRESSION MUST BE OF SOME ENUMERATION TYPE  
184 "FOR" VARIABLE MUST BE LOCAL  
185 OPERATION DEFINED FOR TEXT ONLY  
186 OPERATION NOT DEFINED FOR TEXT FILES  
193 ACCESS STATEMENT MISSING FOR COMMON  
199 FEATURE NOT IMPLEMENTED  
202 STRING CONSTANT CANNOT SPAN LINES  
203 INTEGER CONSTANT TOO LARGE  
210 FIELD WIDTH MUST BE INTEGER  
211 FRACTION LENGTH MUST BE OF TYPE INTEGER  
212 HEX FORMAT ALLOWED ONLY FOR TYPE INTEGER  
219 PARAMETER MUST BE OF TYPE FILE  
220 PARAMETER MUST BE OF TYPE INTEGER  
223 PARAMETER MUST BE OF TYPE POINTER  
230 ILLEGAL TYPE OF PARAMETER IN STANDARD PROCEDURE CALL  
250 TOO MANY NESTED SCOPES - LIMIT IS 15  
401 OPEN COMMENT ENCOUNTERED IN A COMMENT  
403 TO MANY PROCEDURE NESTING LEVELS  
404 ARRAY BOUNDS MUST BE SCALAR

## B.2 Runtime Error Codes

-----

- 01) OUT OF STACK  
cause: insufficient amount of stack available  
cure : If compiling  
with PASCAL : switch to PASCALB  
with PASCALB : specify more stack space  
PASCALB <stack> file  
If executing  
with RUN : specify more stack space  
RUN file stack  
with /CMD : specify more stack space when using B  
command of LINKLOAD
- 02) OUT OF HEAP  
cause: insufficient amount of heap available  
cure : If compiling  
with PASCAL : switch to PASCALB  
with PASCALB : specify less stack space  
If executing  
with RUN : specify less stack space  
with /CMD : specify less stack space when using B  
command of LINKLOAD
- 03) BAD POINTER  
cause: damaged object file or error in program which causes  
executing code to be overwritten with data  
cure: If executing one of the system /CMD files:  
restore defective /CMD file from the original master  
disk.  
If executing a user written program:  
recompile the program using the RANGECHK and  
PTRCHECK options and execute once again. Invalid  
array indexing and most invalid pointer referencing  
will be trapped. If a range or pointer error  
message is displayed, locate and fix the programming  
error.
- 04) BAD LEVEL  
see error 03
- 05) DIVIDE BY 0  
cause: an integer or real divide operation with a divisor of 0  
cure : prevent divisor from becoming 0
- 06) UNDEFINED PCODE  
see error 03
- 07) INVALID SET  
cause: set operation results in set with more than 256 members  
cure : restrict set operations to 256 member sets
- 08) BAD RUNTIME CALL  
see error 03

- 09) IO ERROR  
 cause: 1 - file does not exist  
       2 - disk is full  
       3 - bad disk or hardware  
 cure: 1 - specify correct file name  
       2 - clear some space on the disk  
       3 - run diagnostics
- 0A) SET ELEMENT TOO LARGE  
 cause: attempt to assign an ordinal value > 256 to a set  
 cure: limit sets to 256 members
- 10) RANGE CHECK  
 cause: invalid array index, subrange value, or enumeration value  
 cure: correct invalid array indexing and/or invalid values
- 11) BAD DIGIT IN NUMBER  
 cause: attempt to read or DECODE an invalid number  
 cure: make sure all numbers read or decoded are legal numbers
- 12) PUT ERROR  
 cause: attempt to output an undefined file buffer variable  
 cure: assign a proper value to the file buffer variable
- 13) OVERFLOW  
 cause: a real arithmetic calculation overflows  
 cure: limit real numbers to the maximum size
- 15) UNDERFLOW  
 cause: a real divide operation causes underflow  
 cure: limit real numbers to the minimum non-zero size
- 16) LOG NEGATIVE  
 cause: attempt to take the natural log of a number  $\leq 0$   
 cure: log is valid positive numbers only
- 17) SQRT,X<sup>Y</sup> NEGATIVE  
 cause: attempt to take the square root of a negative number or  
       attempt to raise a negative number to a real power  
 cure: square root is valid only for number  $\geq 0$   
       only positive numbers may be raised to a real power
- EB) ATTEMPT TO WRITE TO INPUT FILE  
 cause: opening an output file using RESET  
 cure: open the output file using REWRITE
- EC) FILE NOT OPEN  
 cause: attempt to read or write an unopened file  
 cure: open the file using RESET or REWRITE
- ED) ATTEMPT TO READ OUTPUT FILE  
 cause: opening an input file using REWRITE  
 cure: open the input file using RESET
- EE) NO MEMORY FOR FILE BUFFER  
 cause: not enough space for file buffer in heap  
 cure: execute program using less stack

C. Standard 7-bit USASCII Character Set

Decimal	Octal	Hex	Graphic	Name
0.	000	00	^@	NUL (used for padding) <null>
1.	001	01	^A	SOH (start of header)
2.	002	02	^B	STX (start of text)
3.	003	03	^C	ETX (end of text)
4.	004	04	^D	EOT (end of transmission)
5.	005	05	^E	ENQ (enquiry)
6.	006	06	^F	ACK (acknowledge)
7.	007	07	^G	BEL (bell or alarm)
8.	010	08	^H	BS (backspace) <bs>
9.	011	09	^I	HT (horizontal tab) <tab>
10.	012	0A	^J	LF (line feed) <lf>
11.	013	0B	^K	VT (vertical tab)
12.	014	0C	^L	FF (form feed, new page) <ff>
13.	015	0D	^M	CR (carriage return) <cr>
14.	016	0E	^N	SO (shift out)
15.	017	0F	^O	SI (shift in)
16.	020	10	^P	DLE (data link escape)
17.	021	11	^Q	DC1 (device control 1, XON)
18.	022	12	^R	DC2 (device control 2)
19.	023	13	^S	DC3 (device control 3, XOFF)
20.	024	14	^T	DC4 (device control 4)
21.	025	15	^U	NAK (negative acknowledge)
22.	026	16	^V	SYN (synchronous idle)
23.	027	17	^W	ETB (end transmission block)
24.	030	18	^X	CAN (cancel)
25.	031	19	^Y	EM (end of medium)
26.	032	1A	^Z	SUB (substitute)
27.	033	1B	^[	ESCAPE (alter mode, SEL) <esc>
28.	034	1C	^\ ^]	FS (file separator)
29.	035	1D	^]	GS (group separator)
30.	036	1E	^^	RS (record separator)
31.	037	1F	^_	US (unit separator)
32.	040	20	" "	space or blank <sp>
33.	041	21	!	exclamation mark
34.	042	22	"	double quote
35.	043	23	#	number sign (hash mark)
36.	044	24	\$	dollar sign
37.	045	25	%	percent sign
38.	046	26	&	ampersand sign
39.	047	27	'	single quote (apostrophe)
40.	050	28	(	left parenthesis
41.	051	29	)	right parenthesis

42.	052	2A	*	asterisk (star)
43.	053	2B	+	plus sign
44.	054	2C	,	comma
45.	055	2D	-	minus sign (dash)
46.	056	2E	.	period (decimal point)
47.	057	2F	/	(right) slash
48.	060	30	0	numeral zero
49.	061	31	1	numeral one
50.	062	32	2	numeral two
51.	063	33	3	numeral three
52.	064	34	4	numeral four
53.	065	35	5	numeral five
54.	066	36	6	numeral six
55.	067	37	7	numeral seven
56.	070	38	8	numeral eight
57.	071	39	9	numeral nine
58.	072	3A	:	colon
59.	073	3B	;	semi-colon
60.	074	3C	<	less-than sign
61.	075	3D	=	equal sign
62.	076	3E	>	greater-than sign
63.	077	3F	?	question mark
64.	100	40	@	atsign
65.	101	41	A	upper-case letter ABLE
66.	102	42	B	upper-case letter BAKER
67.	103	43	C	upper-case letter CHARLIE
68.	104	44	D	upper-case letter DELTA
69.	105	45	E	upper-case letter ECHO
70.	106	46	F	upper-case letter FOXTROT
71.	107	47	G	upper-case letter GOLF
72.	110	48	H	upper-case letter HOTEL
73.	111	49	I	upper-case letter INDIA
74.	112	4A	J	upper-case letter JERICO
75.	113	4B	K	upper-case letter KAPPA
76.	114	4C	L	upper-case letter LIMA
77.	115	4D	M	upper-case letter MIKE
78.	116	4E	N	upper-case letter NOVEMBER
79.	117	4F	O	upper-case letter OSCAR
80.	120	50	P	upper-case letter PAPP
81.	121	51	Q	upper-case letter QUEBEC
82.	122	52	R	upper-case letter ROMEO
83.	123	53	S	upper-case letter SIERRA
84.	124	54	T	upper-case letter TANGO
85.	125	55	U	upper-case letter UNICORN
86.	126	56	V	upper-case letter VICTOR
87.	127	57	W	upper-case letter WHISKY
88.	130	58	X	upper-case letter XRAY
89.	131	59	Y	upper-case letter YANKEE
90.	132	5A	Z	upper-case letter ZEBRA

91.	133	5B	[	left square bracket
92.	134	5C	\	left slash (backslash)
93.	135	5D	]	right square bracket
94.	136	5E	^	uparrow (carat)
95.	137	5F	~	underscore
96.	140	60	`	(single) back quote
97.	141	61	a	lower-case letter able
98.	142	62	b	lower-case letter baker
99.	143	63	c	lower-case letter charlie
100.	144	64	d	lower-case letter delta
101.	145	65	e	lower-case letter echo
102.	146	66	f	lower-case letter foxtrot
103.	147	67	g	lower-case letter golf
104.	150	68	h	lower-case letter hotel
105.	151	69	i	lower-case letter india
106.	152	6A	j	lower-case letter jericho
107.	153	6B	k	lower-case letter kappa
108.	154	6C	l	lower-case letter lima
109.	155	6D	m	lower-case letter mike
110.	156	6E	n	lower-case letter november
111.	157	6F	o	lower-case letter oscar
112.	160	70	p	lower-case letter pappa
113.	161	71	q	lower-case letter quebec
114.	162	72	r	lower-case letter romeo
115.	163	73	s	lower-case letter sierra
116.	164	74	t	lower-case letter tango
117.	165	75	u	lower-case letter unicorn
118.	166	76	v	lower-case letter victor
119.	167	77	w	lower-case letter whisky
120.	170	78	x	lower-case letter xray
121.	171	79	y	lower-case letter yankee
122.	172	7A	z	lower-case letter zebra
123.	173	7B	{	left curly brace
124.	174	7C		vertical bar
125.	175	7D	}	right curly brace
126.	176	7E	~	tilde
127.	177	7F	<rubout>	DEL <del>

## D. Differences from Standard

---

The standard used is defined by "User Manual and Report", second edition, Jensen and Wirth, Springer-Verlag. The following sections pertain to the differences in Alcor Systems implementation of Pascal as compared to the standard. The extensions are added to provide extra power to the language. All implementations of Pascal by Alcor Systems contain these added features. If a program is to be transported to a computer system using some other implementation of Pascal, these features should not be used in the program.

### D.1 Omissions

-----

- 1) Procedures or functions may not be passed as parameters to other procedures or functions.

### D.2 Extensions

-----

- 1) Common variables which provide a mechanism for statically allocating local variables are implemented through the use two new declaration parts: COMMON and ACCESS.
- 2) The declaration sections LABEL, CONST, TYPE, VAR, COMMON, and ACCESS may appear any number of times and in any order within a block.
- 3) The Type Transfer Operator allows variables to be referenced through the use of a type template.
- 4) Single elements of packed structures may be passed as parameters.
- 5) The OTHERWISE clause is implemented in the CASE statement. If omitted, and there is no match, execution transfers to the next statement.
- 6) Identifiers can include the characters '\_' and '\$'. Also, no distinction is made between upper and lower case letters.
- 7) Integer constants or characters may be represented in hex.

- 8) Mixed mode arithmetic is implemented.
- 9) The procedures READ or READLN will accept string and boolean variables.
- 10) External procedures or functions may be declared. This feature provides a way of accessing external routines.
- 11) Input files are not opened until necessary. This eliminates the synchronization problem when doing interactive input from a terminal.
- 12) Labels may range from -32768 to 32767.
- 13) Alternate symbols are implemented for brackets and the pointer symbol.
- 14) The LOCATION function allows the determination of the address of a variable or a procedure.
- 15) The SIZE function allows the size of a type to be determined.
- 16) The HB function returns the high byte of an integer variable.
- 17) The LB function returns the low byte of an integer variable.
- 18) The procedure MESSAGE provides an additional method for handling string output to a terminal.
- 19) The procedure CLOSE allows files to be explicitly closed.
- 20) The procedure ESCAPE allows exiting a block at any point within the block.
- 21) The type STRING is a predefined dynamic data type. A string function library is provided for use with this data type.
- 22) Libraries are provided to access the hardware features of the specific machine.
- 23) Compiler options are provided to control various functions.

### D.3 Other Implementation Characteristics

---

The following is a list of specific implementation decisions which are not defined by the standard.

- 1) Only the first 8 characters of an identifier are stored. This means that identifier names should be selected such that the first 8 characters form a unique name.
- 2) There is a limit of 256 elements for sets, enumerations, CASE statement labels, and parameters to a procedure or function.
- 3) Pascal source is restricted to 80 columns.
- 4) The association of logical files to physical devices is made either interactively from the terminal or through a procedure call.

The following is a list of characteristics which are slightly altered from the standard.

- 1) Operator precedence has been altered to eliminate the need for excessive use of parentheses in expressions. The precedence is the same as that used in BASIC. The difference is the precedence assigned to the Boolean operators. The precedence defined by the standard makes the Boolean operator OR equal in precedence with + and -, the Boolean operator AND equal in precedence with \*, /, DIV, and MOD, and NOT has the highest precedence of any operator except the parentheses. Parentheses may be used when transportable programs are being written to maintain compatibility with the standard. This alteration of precedence should not cause any problems when transferring programs written in standard Pascal to Alcor Pascal.
- 2) Although structured variables may contain components of type FILE, the I/O routines will accept only simple variable names. Therefore, use of files within structured variables may be used only in a restricted manner.
- 3) A GOTO statement may not reference a label outside the block in which the statement appears.

## E. THE TYPE STRING

---

The standard Pascal string is defined to be a PACKED ARRAY OF CHAR. Variables of this type are restricted to a predetermined size. (ie. the size of the array must be specified and cannot be altered during program execution). The predefined type STRING is dynamic. The size of a variable declared as type STRING is determined during program execution. Variables of this type may change in size as the program executes. In addition, variables of type STRING may be used in conjunction with a runtime library of string manipulation functions.

Syntax of type STRING:

```
---> STRING --->
```

Example:

```
VAR str1, str2, str3 : STRING;
```

Assigning values to dynamic string variables

-----

A dynamic string may be created through the use of the predeclared transfer function BLDSTR. This function has one parameter which may be either a variable of the type PACKED ARRAY OF CHAR or a string constant. The function returns a dynamic string of the same length as the array or string constant passed to it.

Example:

```
str1 := BLDSTR('literal string constant');  
str2 := BLDSTR(stringconstant);  
str3 := BLDSTR(arrayvariable);
```

The procedures READ and READLN have been extended to accept variables of the type STRING. When a variable of type STRING is specified, all characters from the current file pointer to the end of line mark are read. The size of the string is then equal to the number of characters read. If a read is performed while at the end of line mark, the string variable is assigned an empty string. An empty string is a string of zero length.

Example:

```
    READ(str1);  
  
    READLN(filename,str2);
```

A string variable may be assigned to another string variable. An assignment between two string variables results in both string variables referencing the same string. (ie. both string variables point to the same location in memory)

Example:

```
    str1 := str2;
```

NOTE: For most applications, the preferred method of assignment between two string variables is through the use of the library function CPYSTRING. If two string variables point to the same location and one is disposed (using DISPOSE), then both string variables will become undefined.

A string variable may be assigned a string formed by one of the string manipulation functions in the runtime library. For example, there is a function provided which may be used for assignment between two string variables. The function CPYSTR takes a string variable as a parameter and copies it to another location. The string appearing on the left side of the equal sign then references the new location. In other words, instead of having one copy of the string as in the above example, there are now two copies.

Example:

```
    str1 := CPYSTR(str2);
```

## Outputting dynamic string variables

---

The WRITE and WRITELN procedures have been extended to accept variables of the type STRING. When a dynamic string is output, the number of characters written is equal to the length of the string.

## Converting a dynamic string into an array

---

Dynamic strings can only be accessed as a whole. (ie. the individual characters of the string cannot be accessed) The predeclared procedure GETSTR will copy a dynamic string variable into a variable of the type PACKED ARRAY OF CHAR. It accepts two parameters. The first parameter is the dynamic string variable. The second parameter is the array variable. The string is left justified in the array. If the string is longer than the array, then it is truncated. If the string is shorter than the array, then the array is padded with blanks.

Example:

```
GETSTR(str1, arrayvariable);
```

## Recovering memory used by a dynamic string

---

The memory used by a dynamic string may be recovered through the use of the standard procedure DISPOSE. When a string variable is passed to the DISPOSE procedure, the memory used by the string is freed and the string variable becomes undefined. In addition, any other string variable which points to the same string will become undefined. Each time a string variable is assigned a value, it points to a new string and the old string is then lost. The memory it uses cannot be recovered. Therefore, before assigning the string variable a new value, the memory used by the old value should be recovered if space is important.

Example:

```
str1 := BLDSTR('this is the first value');  
...  
DISPOSE(str1);  
str1 := BLDSTR('this is the second');
```

## Using the string library

-----

There is a long list of string manipulation functions available in the runtime library. In order for a program to have access to these functions, it must include an external declaration for each function used. A file of external declarations for all the string functions is supplied on disk. The text editor may be used to insert this file into the programs that use these functions. The declarations for any functions which are not used may be deleted if desired. If only one or two functions are used, you may prefer just to type in the external declaration. (See the System Implementation Manual for a description of the string manipulation functions)

Example use of dynamic strings:

PROGRAM sample;

```
VAR  firstname, lastname,
     space, fullname      : STRING;
```

```
FUNCTION CONC(s1,s2 : STRING) : STRING; EXTERNAL;
(*CONC is a string library function which concatenates 2 strings*)
```

```
BEGIN
  space := BLDSTR(' ');
  WRITELN(' enter first name');
  READLN(firstname);
  WRITELN(' enter last name');
  READLN(lastname);
  fullname := CONC(CONC(firstname,space),lastname);
  WRITELN(fullname)
END.
```

File buffer variables and the procedures GET and PUT are I/O features of Pascal which are not often used. The procedures READ and WRITE are abbreviated forms for accomplishing the same I/O tasks. However, file buffer variables do provide a means of performing lookahead in a file. (ie. you may check the value of the next component in a file before actually reading it) The ability to perform lookahead may offer some advantages in certain applications. (eg. the scanner of a compiler)

#### File Buffer Variables

-----

There is a file buffer variable associated with each file in a program. The buffer variable is used as temporary storage for file components as they are passed to or from the associated file. The buffer variable is the same size and type as an individual component of the file. The individual components of TEXT files are characters. Therefore, the file buffer variable associated with a file of type TEXT has a size of one byte (8 bits) and is of type CHAR. A file declared as FILE OF INTEGER consists of individual components of type INTEGER. The associated file buffer variable will have a size of two bytes (ie. integers require two bytes of storage) and be of type INTEGER.

The buffer variable associated with a particular file may be referenced in the same manner as pointer variables, using either the ^ or @ symbol. The buffer variable of a particular file is referenced by following the logical file name with either of these two symbols. For example, the buffer variable of the logical file INPUT is referenced by either INPUT^ or INPUT@.

Files are opened for reading or writing by the procedures RESET or REWRITE respectively. When a file is opened by RESET, the buffer variable associated with the file is assigned the value of the first component in the file. If the file is empty at the time it is opened, then the value of the buffer variable is undefined. When a file is opened by REWRITE, its associated buffer variable is undefined.

File buffer variables may be assigned values using the assignment statement. For example, OUTPUT@ := 'A' will assign the character A to the file buffer variable associated with logical file OUTPUT. Additionally, the procedures READ, READLN, and GET will alter values of file buffer variables associated with input files. The buffer variables associated with output files become undefined after performing the operation specified by the WRITE, WRITELN, or PUT procedures.



Example use of GET and PUT and file buffer variables:

The following program copies the contents of logical file "infile" to logical file "outfile".

```
PROGRAM filecopy;
VAR   infile, outfile : TEXT;
BEGIN
  RESET(infile);           {infile@ = first character}
  REWRITE(outfile);       {outfile@ is undefined}
  WHILE NOT EOF(infile) DO
  BEGIN
    WHILE NOT EOLN(infile) DO
    BEGIN
      outfile@ := infile@; {define outfile@}
      PUT(outfile);       {write outfile@}
      GET(infile);        {get next character}
    END;
    READLN(infile);       {advance to next line}
    WRITELN(outfile)      {advance to next line}
  END
END.
```

## G. USING FILES IN STRUCTURED VARIABLES

---

This implementation of Pascal does not fully support the use of files which are components of structured variables. The following declarations are examples of the use of files in structured variables:

```
VAR files   : ARRAY [1..5] OF TEXT;      (array of files)
    student : RECORD
        name   : ARRAY[1..20] OF CHAR;
        scores : FILE OF INTEGER; (file in record)
    END;
```

The above declarations are legal but the I/O routines (see chapter 10 of reference manual) will not accept file names which are not simple. An example of a simple name is "outfile". With the above declarations, the file names are not simple names. I/O statements like the following would generate compile errors:

```
READLN(files[2],...
WRITELN(files[5],...
READ(student.scores,...
WHILE NOT EOF(student.scores) DO ....
```

For applications that need to use files as components of structures, there is a method of avoiding the simple name restriction to file names. Simply write your own I/O routines which act as interface to the Pascal I/O routines. You may pass non-simple file names to these interface routines which then use simple names in the actual I/O operations. (see the example program on the following page) It is important to note that the file variables should be passed by reference.(preceded by VAR in the parameter list)

When using files which are components of structures, make sure that the following two operations are always performed on the files:

- 1) Before opening the file, the file must first be initialized. The following operation will initialize a file. The filename may be simple or non-simple when performing this operation.

```
filename::INTEGER := 0 (initializes file "filename")
```

- 2) Before exiting the program, the file must be explicitly closed by the CLOSE procedure. Failure to do so will probably result in loss of the file.

```

(*$NO INOUT*)
PROGRAM files_in_structures;

(* Sample program which uses array of files *)
(* This program prompts for a file name and
   then sends the file to the line printer *)

VAR   ch       : CHAR;
      files    : ARRAY[1..2] OF TEXT;

PROCEDURE openr(VAR filename : TEXT);
BEGIN
  filename::INTEGER:=0;  {initialize file}
  RESET(filename)      {open file for reading}
END;

PROCEDURE openw(VAR filename : TEXT; name : STRING);
  PROCEDURE SETACNM(VAR f : TEXT; name : STRING); EXTERNAL;
BEGIN
  filename::INTEGER:=0;  {initialize file}
  SETACNM(filename,name); {eliminate prompt for filename}
  REWRITE(filename)     {open file for writing}
END;

PROCEDURE closefile(VAR f : TEXT);
BEGIN
  CLOSE(f)              {close file}
END;

PROCEDURE readfile(VAR f : TEXT; VAR data : CHAR);
BEGIN
  READ(f,data)          {read from file}
END;

PROCEDURE writefile(VAR f : TEXT; data : CHAR);
BEGIN
  WRITE(f,data)         {write to file}
END;

```

```

PROCEDURE writeline(VAR f : TEXT);
BEGIN
    WRITELN(f)          {advance to next line of output file}
END;

PROCEDURE readline(VAR f : TEXT);
BEGIN
    READLN(f)          {advance to next line of input file}
END;

FUNCTION endfile(VAR f : TEXT) : BOOLEAN;
BEGIN
    IF EOF(f) THEN endfile := TRUE else endfile := FALSE
END;

FUNCTION endline(VAR f: TEXT) : BOOLEAN;
BEGIN
    IF EOLN(f) THEN endline := TRUE else endline := FALSE
END;

BEGIN
    openr(files[1]);           {open input file}
    {note to CP/M users --> :L should be changed to LST;}
    openw(files[2],BLDSTR(':L')); {open output file}
    WHILE NOT endfile(files[1]) DO
        BEGIN
            WHILE NOT endline(files[1]) DO
                BEGIN
                    readfile(files[1],ch);
                    writefile(files[2],ch);
                END;
            readline(files[1]);
            writeline(files[2])
        END;
        closefile(files[1]);
        closefile(files[2]);
    END.

```

## E. USING GLOBAL VARIABLES IN EXTERNAL ROUTINES

---

It is recommended that whenever possible, variables should be passed to routines rather than allowing the routines to access global variables. However, sometimes the use of global variables is necessary. When using global variables in an external routine (ie compiled separately), it is necessary to duplicate the exact global environment when the external routine is compiled. Otherwise, referencing of global variables within the external routine will not be correct.

The use of the compiler INCLUDE option is very helpful to insure that the declarations used in the main program are exactly duplicated in the separately compiled routine. The following example illustrates the use of global variables in a separately compiled procedure.

----- file containing the main program -----

```
PROGRAM main;
{the file GLOBAL contains the declarations for the main program}
{$INCLUDE 'GLOBAL'}
PROCEDURE separate; EXTERNAL;
BEGIN
  letter:='a';
  digit:=10;
  separate;
END.
```

----- file containing the external procedure -----

```
PROGRAM compile separately;
{duplicate the global environment}
{$INCLUDE 'GLOBAL'}
PROCEDURE separate;
BEGIN
  WRITELN('letter = ',letter);
  WRITELN('digit = ',digit:2);
END;
BEGIN
  {$NULLBODY}
END.
```

----- the file 'GLOBAL' -----

```
VAR  letter : CHAR;
     digit  : INTEGER;
```

## I. USING COMMON VARIABLES

---

Often when creating libraries, such as a set of graphics routines, it is difficult to avoid the need for using global variables. There is usually a routine which does some initial processing to define variables which are needed by many of the other routines in the library. If these variables are local to the routine, they become undefined when the routine terminates. Of course, these variables could be retained if they were included as parameters to the routine. However, often these variables are not pertinent to the functionality from an end users point of view. Making them a part of the parameter list complicates the use of the library routines. Another alternative is to make these variables global. This is a problem too, because each programmer who uses the library must know of these variables and make appropriate declarations for them. Common variables offer a clean solution to this type of programming problem. They essentially provide the ability to use global variables in libraries without the need for programs which use the library to even be aware of their existence. The following example illustrates the use of common variables.

```
----- file containing library of routines -----

PROGRAM library;
COMMON xscale, yscale : REAL;

PROCEDURE axis(xmin,xmax,ymin,ymax : REAL);
ACCESS xscale, yscale;
BEGIN
    xscale := 512/(xmax-xmin);
    yscale := 256/(ymax-ymin);
END;

PROCEDURE scale(x,y : REAL);
ACCESS xscale, yscale;
VAR ix,iy : INTEGER;
BEGIN
    ix := ROUND(xscale*x);
    iy := ROUND(yscale*y);
    WRITE('original values: x,y = ',x:6:1,',',y:6:1);
    Writeln('scaled values: x,y = ',ix:3,',',iy:3);
END;

BEGIN
    {$NULLBODY}
END.

----- user program -----

PROGRAM user;
VAR i : INTEGER;
PROCEDURE axis(xmin,xmax,ymin,ymax : REAL); EXTERNAL;
PROCEDURE scale(x,y : REAL); EXTERNAL;
BEGIN
    axis(0.0,10.0,0.0,5.0);
    FOR i := 0 TO 10 DO scale(i,i/2);
END.
```



ADVANCED DEVELOPMENT PACKAGE

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## INTRODUCTION

=====

The advanced development package (ADP) is a software tool which adds a great deal of power and versatility to the TRS-80 Pascal System. The advanced development package consists of two programs. One program is an optimizer which reduces the size of programs. The other is a code generator which increases the speed of programs. The combination gives the programmer the ability to customize each application program, allowing for maximum utilization of the systems capabilities.

The need for the optimizer occurs when writing large programs. All programs require memory to store instructions and memory to store data. Large programs require a lot of memory to store instructions. The memory used for storing instructions subtracts from the memory available for storing data (ie. the more memory used for storing instructions, the less available for storing data). The optimizer's purpose is to reduce the amount of memory used by the instructions in order to make more memory available for storing data.

The need for the code generator occurs when execution speed is important. The compiler translates Pascal source programs to instructions known as p-code. The computer cannot directly execute instructions in p-code form. Instead they are executed by another program known as an interpreter. Maximum execution speed can be achieved by translating programs to machine code (the form which the computer hardware can understand and execute directly without interpretation). The purpose of the code generator is to translate p-code instructions to machine instructions. This provides a method for achieving maximum execution speed.

The addition of the ADP to TRS-80 Pascal provides the programmer with a very flexible language system which offers a unique ability. This is the ability to mix p-code with machine code. P-code has the advantage of compactness while machine code has the advantage of speed. The ability to mix the two makes it possible to customize application programs in order to achieve optimum performance. The bottle neck areas of a program may be translated to machine code for maximum speed while the rest of the program can be left in p-code form. This allows programs to benefit from both compactness and speed.

The optimizer is a program which takes the compiler generated p-code as input and outputs an optimized form of the same p-code. Although optimized p-code will execute faster than non-optimized p-code, the main purpose of the optimization is to make the p-code more compact. The difference in size of the optimized versus non-optimized p-code is dependent on the types of language features utilized by the original source program. Typically, the percent reduction in size due to optimization will fall in the range of 10 to 30 percent. This size reduction is sometimes very important. By making the program smaller, there is more room for data. Often times, it will enable the execution of a program that otherwise would run out of memory.

#### A. When to Use the Optimizer

-----

The optimizer should be used any time program size is an important factor. A programs memory requirements are determined by the number of executable instructions and by the number and sizes of the variables used. The factor that the optimizer addresses is the number and length of instructions. The greatest benefit will then be realized when optimizing long programs (>1000 lines). However, in many cases optimized code is slightly faster than non-optimized code and even short programs will sometimes benefit enough to make optimization worth while. In addition, if a short program requires lots of data storage, optimization will maximize the amount of memory available for the data.

#### B. How to Use the Optimizer

-----

Any p-code object file may be used as input to the optimizer program. The compiler uses a /OBJ extension as a default for p-code object files. Whole programs or separately compiled parts of a program may be optimized. In either case, simply compile the Pascal source and then run the compiler generated p-code through the optimizer.

NOTE: Only p-code object files may be optimized. Do not attempt to optimize command files (/CMD) or files generated by the code generator (/COD)

The optimizer program is stored as a command file and therefore may be executed simply by typing OPTIMIZE from the top level of the operating system. Like the compiler, it has two forms for input, a short form and a long form.

The short form:

```
OPTIMIZE filename
```

NOTE: Filename may include a drive specification.

Example: DATABASE:1

When a drive is specified the /OPT file is placed on the same drive as the /OBJ file, otherwise the operating system decides which drive to use.

The filename should not include an extension. The optimizer appends the default extension /OBJ to the file name. The output of the optimizer (the optimized p-code) is placed in a file of the same name but with the extension /OPT. The /OPT file may then be used just as any /OBJ file is used in conjunction with the RUN and LINKLOAD commands.

The long form:

```
OPTIMIZE  
LISTING = listingfile/ext or device (:C,:L,or :D)  
INP_OBJ = inputfile/ext  
OUT_OPT = outputfile/ext
```

NOTE: File names may also include drive specifiers.

Example: DATABASE/OPT:1

The long form requires that you enter the full file name, including extension, for both the input file (non-optimized) and output file (optimized). The LISTING will show the name of each separate module in the input p-code file as it is processed. After each name will appear its original size in bytes followed by its optimized size in bytes. The LISTING may be directed to a file or device. Typing a carriage return will direct the listing to the CRT.

At completion, the optimizer program will display on the listing the size of the non-optimized p-code used as input and the optimized p-code generated as output.

```
ORIGINAL LENGTH = size in bytes  
OPTIMIZED LENGTH= size in bytes
```

## C. Example Use of the Optimizer

-----

The following is an example of optimizing the DATABASE/PCL program which was supplied with the TRS-80 Pascal System. The example demonstrates use of the optimizer in both the short and long forms.

step 1 ---> compile the database program

PASCAL DATABASE

step 2 ---> optimize the p-code in file DATABASE/OBJ

short form example:

OPTIMIZE DATABASE

long form example:

OPTIMIZE  
LISTING = :L  
INP\_OBJ = DATABASE/OBJ  
OUT\_OPT = DATABASE/OPT

Both the short form and long form above would produce the same result. The p-code in file DATABASE/OBJ would be optimized and output to the file DATABASE/OPT. The short form would direct the listing to the CRT while the long form would direct the listing to the line printer. The listing output to the line printer would appear as below.

NOCUSTMR	15	13
PRESS	56	49
NEWSPACE	43	29
READDDBAS	226	162
WRITEDBA	389	312
CUSTOMROU	525	423
READTRAN	269	208
WRITETRA	415	325
DISPLAYD	114	84
LISTTRAN	130	91
LISTCUST	64	50
HEADING	70	64
MAINMENU	743	667
QUERYMEN	462	416
ADDCUSTM	193	153
QUERYTRA	213	161
ADDTRANS	349	266
SEARCHCU	284	218
QUERY	170	132
DATABASE	302	264

ORIGINAL LENGTH = 5437

OPTIMIZED LENGTH= 4418

## USING THE CODE GENERATOR

=====

The code generator is a program which translates p-code instructions to native machine instructions. Any compiler generated p-code object file or optimized p-code file may be used as input to the code generator program. Whole programs or separately compiled parts of programs may be translated (codegened) to machine code to increase execution speed. The speed increase realized from code generation is dependent on the nature of the program. Typically, codegened programs will gain a factor of 3 to 5 times increase in speed over that of pure p-code programs.

### A. When to Use the Code Generator

-----

The code generator increases execution speed by translating p-code instructions to machine instructions. Since each p-code is equivalent to several machine instructions, code generation also causes an increase in size. Therefore, the decision of whether or not to perform code generation on a program must not only be based on speed requirements, but also on program size. Typically, code generation will cause the size of the object to increase by a factor of 2 to 3 over that of pure p-code.

The execution speed of most programs will be adequate even when left in p-code form. However, programs which do lots of calculations within loops may benefit significantly through code generation. Also, when a program contains one or more procedures which are frequently called, code generation on these sections of the program can provide quite an improvement in execution speed. For example, the scanner of the compiler is a procedure which reads the text of a pascal program and distributes it to other parts of the compiler. Since it is called frequently, much of the time spent during a compile is inside this one procedure. Code generation of the scanner can increase compile speed significantly. By selecting the parts of a program which most effect speed and performing code generation only on those parts, speed can be increased without significant increase in size.

The determination of whether or not to codegen a program can be made by observation. First run the program in p-code form. If execution speed is observed to be slow, the next step is to determine whether or not to codegen the whole program or selected parts of the program. As a general rule, small programs should be totally codegened. The size increase for small programs will probably be insignificant. However, for large programs, the size increase may be very significant.

For large programs ( >1000 lines ), a factor of 2 or 3 increase in object size will significantly reduce the amount of memory left for the program data area (stack and heap). In cases where the size increase would not allow enough room for data area, selected procedures should be declared as externals and compiled separately. The procedures selected should be the ones which most effect execution speed. These procedures may then be codegened and linked to the main program. This process will allow for an increase in speed without causing the size to increase to a level that prevents the program from being executed.

The code generator performs most of the optimizations performed by the optimizer. Therefore, it is not necessary to optimize a program before performing code generation.

#### B. How to Use the Code Generator

-----

Any compiler generated or optimized p-code file may be used as input to the code generator. The compiler generates files with the default extension of /OBJ. The optimizer generates files with a default extension of /OPT. Whole programs or separately compiled programs may be codegened. In either case, simply compile the Pascal source and run the code generator program, using the compiler generated object file as input. Of course, optimized p-code files may also be used as input.

The code generator program is stored as a command file and therefore may be executed simply by typing CODEGEN from the top level of the operating system. Like the compiler and optimizer, it has two forms, a short form and a long form.

The short form:

CODEGEN filename

NOTE: Filename may also include a drive specifier.

Example: BENCHMK:2

When a drive is specified, the /COD file is placed on the same drive as the /OBJ file, otherwise the operating system decides which drive to use.

The filename should not include an extension. The code generator appends the default extension /OBJ to the file name. The output of the code generator is placed in a file of the same name but with the extension /COD. The /COD file may then be used just as any /OBJ or /OPT object file in conjunction with the RUN or LINKLOAD commands. However, do not attempt to optimize a /COD file. The /COD files contain machine instructions and the optimizer accepts only p-code instructions.

The long form:

```
CODEGEN
INP_OBJ = inputfile/ext
OUT_COD = outputfile/ext
DO YOU WANT ASSEMBLY LANGUAGE SOURCE? (Y,N): y or n
```

NOTE: File names may also include drive specifiers.  
Example : BENCHMK/COD:2

The long form requires that you enter the full file name, including extension, for both input and output files. If assembly language output is desired, answer Y to the last prompt, otherwise answer N. If assembly language output is requested, the following prompt will appear.

```
SOURCE = file/ext
```

The additional assembly language output will be directed to the file specified. The assembly language output is discussed in chapter 5.

NOTE : The file CODEINIT/DAT must be on line when executing CODEGEN. CODEGEN uses this file for initialization.

### C. Example Use of the Code Generator

-----

The following is an example of codegening a program.

```
step 1 ---> compile BENCHMK/PCL
              PASCAL BENCHMK

step 2 ---> codegen the compiled program
              short form example:
              CODEGEN BENCHMK
```

The above example uses BENCHMK/OBJ as input and directs the codegened output to file BENCHMK/COD.

long form example 1:

```
CODEGEN
INF_OBJ = BENCHMK/OBJ
OUT_COD = BENCHMK/COD
DO YOU WANT ASSEMBLY LANGUAGE SOURCE ? (Y,N): N
```

The above example does exactly the same thing as the short form example.

long form example 2.

```
CODEGEN
INF_OBJ = BENCHMK/OBJ
OUT_COD = BENCHMK/COD
DO YOU WANT ASSEMBLY LANGUAGE SOURCE ? (Y,N): Y
SOURCE = BENCHMK/SRC
```

The above example does the same thing as the previous examples except that it also generates an assembly language output which is directed to the file BENCHMK/SRC. The assembly language output is explained in chapter 5.

## MIXED MODE OPERATION

=====

Through the use of the linking loader (the LINKLOAD command), pure p-code object (/OBJ) files may be linked with codegened (/COD) files. Executable programs (/CMD files) may then be built which contain mixed instructions, both p-code and machine code. This ability is important when writing large programs. It allows you to select and codegen only those parts of a program which most effect the speed of execution. The remaining parts of the program can be left in p-code form. This mixed mode operation allows you to increase execution speed without dramatically increasing program size.

### A. When to Use Mixed Mode

-----

The use of mixed mode is usually not important until you start developing large programs. Small programs can be totally codegened without the size increase becoming a significant factor. However, completely codegening large programs (>1000 lines) may cause a size increase which will prevent the program from being executed. The code size of the program can become so large that there is no longer enough room for data storage. This of course depends on the data storage requirements of the program.

When developing large programs, you should not consider code generation until after executing the program in p-code form. Observe the execution speed to determine whether or not it is adequate for your application. If not, the next step is to decide what areas of the program are most effecting the speed. Long loops are typical areas of a program where most of the execution time is spent. Another area might be a low level procedure or several procedures which are called frequently throughout a program. After deciding which areas of the program are effecting execution speed the most, separate them from the rest of the program and codegen them. The selection and separation process is easiest if the program is well modularized. That is, the program is already segmented into modules, each performing a distinct and well defined function.

## B. How to Use Mixed Mode

-----

Once the particular areas of a program have been selected for codegening, they must be separated from the rest of the program. Any selected modules (procedures and/or functions) should be declared as externals. (See the Pascal Reference Manual) The separated areas should then be compiled separately from the remainder of the program. The compiler nullbody option is required to compile procedures and/or functions which are separated from the main program body. Once compiled, the selected areas may be codegened and then linked to the remainder of the program using the linking loader. Once linked, a command file can be built using the BUILD command of the linking loader.

NOTE: There is an alternative way of separating modules of a program without separating them in the Pascal source. The p-code object (/OBJ) file can be split. (See chapter 5)

## C. Example of Mixed Mode Operation

-----

The process for mixed mode operation is summarized in the following list of steps.

- 1) Select the areas which most effect program speed.
- 2) Separate the selected parts of the program from the remainder of the program. Any selected procedures or functions should be declared as EXTERNAL in the main program. Place the separated modules in a separate file or files. Use the nullbody compiler option to put the separated modules in a form suitable for the compiler.
- 3) Compile all parts of the program.
- 4) CODEGEN the parts of the program which were selected to increase execution speed.
- 5) LINKLOAD all compiled parts of the program together and build an executable command file.

The following example demonstrates this process. The program used for this demonstration does not perform any useful function, but merely demonstrates mixed mode operation. In reality, a program of the size demonstrated should be totally translated to machine instructions rather than using mixed mode. The size increase due to code generation is insignificant for such small programs.

## Program listing

```

(*$NO INOUT*)
PROGRAM MIXED_MODE;
TYPE  ALPHA = ARRAY(1..8.) OF CHAR;
FILENM = ARRAY(1..72.) OF CHAR;
VAR   FN : FILENM;
ID,T  : ALPHA;
OUTPUT :TEXT;

PROCEDURE TIME(VAR T : ALPHA); EXTERNAL;
PROCEDURE SET$ACNM(VAR F : TEXT;VAR FN : FILENM; LEN : INTEGER;
                  ID : ALPHA); EXTERNAL;

PROCEDURE LOOP;
(* MODULE TO BE CODEGENED *)
VAR CALCULATION,I : INTEGER;
BEGIN
  FOR I:=1 TO 10000 DO
    BEGIN
      CALCULATION:=1+2+3+4+5+6+7+8+9+10+11+12+13+14+15
    END
  END; (* END LOOP *)
BEGIN (* MAIN PROGRAM *)
  (* DIRECT OUTPUT TO THE SCREEN *)
  FN(1.):=': '; FN(2.):='C';
  ID:='OUTPUT ' ;
  SET$ACNM(OUTPUT,FN,2,ID);
  REWRITE(OUTPUT);
  TIME(T);
  WRITELN(OUTPUT,'STARTING TIME : ', T);
  LOOP;
  TIME(T);
  WRITELN(OUTPUT,'FINISHING TIME : ', T);
END.      (* END PROGRAM *)

```

Step 1) Select the areas effecting execution speed the most.

Examining the above program, you can see that the procedure named LOOP contains a very long FOR loop (1 to 10000). Inside this loop is a long calculation. Any long loop containing a significant number of statements or calculations will benefit substantially from code generation. The procedure LOOP is where the majority of program execution time is spent. Therefore, it is a good choice for code generation.

Step 2) Separate the selected modules from the rest of the program, declaring them as externals in the main program and putting them into a form suitable for compiling.

The following listing shows the procedure LOOP separated from the main program. It is declared as an external procedure within the main program and the compiler nullbody option is used to turn the procedure into a valid Pascal program. The main program and the procedure LOOP must be placed in separate files. For example, the main program could be placed in a file named MAIN/PCL and the procedure placed in a file named LOOP/PCL.

```
(* $NO INOUT *)
PROGRAM MIXED_MODE;
TYPE  ALPHA = ARRAY(.1..8.) OF CHAR;
FILEM = ARRAY(.1..72.) OF CHAR;
VAR   FN : FILENM;
ID,T  : ALPHA;
OUTPUT : TEXT;

PROCEDURE TIME(VAR T : ALPHA); EXTERNAL;
PROCEDURE SET$ACNM(VAR F : TEXT; VAR FN : FILENM; LEN : INTEGER;
                  ID : ALPHA); EXTERNAL;

PROCEDURE LOOP; EXTERNAL;

BEGIN                                (* MAIN PROGRAM *)
  (* DIRECT OUTPUT TO THE SCREEN *)
  FN(.1.):=' ':'; FN(.2.):='C';
  ID:='OUTPUT  ';
  SET$ACNM(OUTPUT,FN,2,ID);
  REWRITE(OUTPUT);
  TIME(T);
  WRITELN(OUTPUT,'STARTING TIME : ', T);
  LOOP;
  TIME(T);
  WRITELN(OUTPUT,'FINISHING TIME : ', T);
END.

-----

PROGRAM SEPARATE_COMPILATION;
PROCEDURE LOOP;
(* MODULE TO BE CODEGENED *)
VAR CALCULATION,I : INTEGER;
BEGIN
  FOR I:=1 TO 10000 DO
    BEGIN
      CALCULATION:=1+2+3+4+5+6+7+8+9+10+11+12+13+14+15
    END
  END; (* END LOOP.*)

BEGIN                                (* MAIN PROGRAM *)
  (* $NULLBODY *)
END.
```

Step 3) Compile all parts of the program.

TRSDOS Ready  
PASCAL MAIN

TRS80 PASCAL VER: 02.00.00 13000000 00:01:28 05/03/83 PAGE 1

```
-----
1 | (*$NO INOUT*)
2 | PROGRAM MIXED_MODE;
3 | TYPE   ALPHA = ARRAY(1..8.) OF CHAR;
4 |       FILENM = ARRAY(1..72.) OF CHAR;
5 | VAR    FN : FILENM;
6 |       ID,T : ALPHA;
7 |       OUTPUT :TEXT;
8 |
9 | PROCEDURE TIME(VAR T : ALPHA); EXTERNAL;
10 | PROCEDURE SET$ACNM(VAR F : TEXT;VAR FN : FILENM; LEN : INTEGER;
11 |                   ID : ALPHA); EXTERNAL;
12 |
13 | PROCEDURE LOOP; EXTERNAL;
14 |
15 | BEGIN                                (* MAIN PROGRAM *)
16 |   (* DIRECT OUTPUT TO THE SCREEN *)
17 |   FN(1.):=' ':'; FN(2.):='C';
18 |   ID:='OUTPUT ' ;
19 |   SET$ACNM(OUTPUT,FN,2,ID);
20 |   REWRITE(OUTPUT);
21 |   TIME(T);
22 |   WRITELN(OUTPUT,'STARTING TIME : ', T);
23 |   LOOP;
24 |   TIME(T);
25 |   WRITELN(OUTPUT,'FINISHING TIME : ', T);
26 | END.
NO ERRORS DETECTED
```

TRSDOS Ready  
PASCAL LOOP

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```
-----
1 | PROGRAM SEPARATE_COMPILATION;
2 | PROCEDURE LOOP;
3 |   (* MODULE TO BE CODEGENED *)
4 |   VAR CALCULATION,I : INTEGER;
5 |   BEGIN
6 |     FOR I:=1 TO 10000 DO
7 |       BEGIN
8 |         CALCULATION:=1+2+3+4+5+6+7+8+9+10+11+12+13+14+15
9 |       END
10 | END; (* END LOOP *)
11 | BEGIN                                (* MAIN PROGRAM *)
12 |   (*$NULLBODY*)
13 | END.
NO ERRORS DETECTED
```

Step 4) CODEGEN the parts selected to increase speed.

```
TRSDOS Ready
CODEGEN LOOP
LOOP
```

STACK USED = 15915 OF 17344 HEAP USED = 882 OF 3756

Step 5) LINKLOAD all compiled parts of the program and build an executable command file.

The executable program will be placed in file MIXED/CMD.

```
TRSDOS Ready
LINKLOAD
L=LOAD, R=RUN, T=TRSDOS, I=INIT, S=SYMBOLS, B=BUILD CMD
>> L
FILE      = MAIN/OBJ
MIXED MO
32239 BYTES LEFT
>> L
FILE      = LOOP/COD
LOOP
32046 BYTES LEFT
>> L
FILE      = TRSLIB/OBJ
SETCSR
GOTOXY
GETKEY
INKEY
CLEARSCR
CLEARGRA
WRITECH
WRITESTR
INP
GET$PROC
IO$ERROR
HP$ERROR
TIME
DATE
ITIME
SETPOINT
RSETPOIN
TESTPOIN
USER
CALL$
$MEMORY
NOBLANK
READCURS
PEEK
POKE
INIT$FIL
```

```
FILE$STA
SET$ACNM
30669 BYTES LEFT
>> B
STACK SIZE :
FILE      = MIXED/CMD
```

The program may now be executed by typing MIXED.

```
TRSDOS Ready
MIXED
STARTING TIME : 00:02:48
FINISHING TIME : 00:02:53
```

The execution time spent inside the LOOP procedure may be calculated by subtracting the starting time from the finishing time. With the LOOP procedure codegened, the execution time program with the procedure LOOP not translated to machine instructions produces a result of 28 seconds, a factor of 5.6 difference in execution speed. This may be tested by linking the file LOOP/OBJ instead of the file LOOP/COD and running the program over.

## SYSTEM OVERVIEW

=====

The TRS-80 Pascal Compiler is an 8500 line Pascal program which has itself been compiled into a very compact p-code form. The p-code form of the compiler has further been reduced in size by the optimizer supplied with the ADP. The optimization was necessary in order to make the compiler run in a 48k system. The p-code form of the compiler was reduced in size by approximately 28%, from 39k down to 28k.

For larger systems, where more memory is available, selected parts of the compiler have been translated to machine instructions by the code generator which is also supplied with the ADP. The code generator translates p-code instructions to native machine instructions for the purpose of increasing execution speed. Since code generation also increases size, only those sections which effected execution speed the most were translated to machine instructions.

The ADP provides the tools that were essential in the development of the compiler. These tools provide the same capability in the development of application programs.

### A. The Pcode

-----

The p-code generated by the compiler was specifically designed for the Pascal language. The p-code resembles an assembly language for a stack machine. The p-code was designed to efficiently implement Pascal functions. Therefore, each p-code instruction performs a much more complex function than a machine instruction. In fact, a p-code instruction is equivalent to an assembly language subroutine. This is the reason that p-code is so much more compact than native machine code.

### B. The Interpreter

-----

The interpreter is a highly optimized assembly language program whose purpose is to interpret p-codes. Since the computer hardware cannot understand p-code instructions, the interpreter is necessary to execute programs which have been compiled into p-code instructions. The interpreter can be thought of as a processor whose instruction set is the set of p-codes. The interpreter has the ability to switch between p-code and machine code. A particular p-code instruction tells the interpreter that native machine instructions follow. The interpreter then points the program counter (PC) register to the first of the native machine instructions and the hardware

begins executing instructions. The ability of the interpreter to switch between p-code and machine code allows programs to contain mixed instructions. This means that parts of a program may be codegened for speed while the remainder of the program is left in p-code form for compactness.

#### C. The Runtime Support

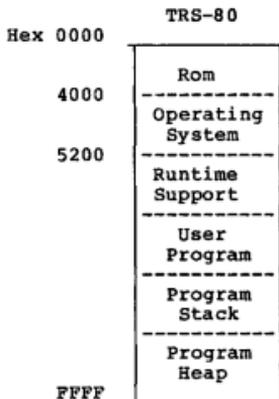
-----

The runtime support consists of the interpreter, a loader, a routine to set up the Pascal stack and heap, and all the input/output (I/O) routines. When building command files with the linking loader, all the runtime support is included with the program being built. Therefore, the total size of an executable program is determined by adding the size of the runtime to the size of the object program. The object program may be p-code, native code, or a mixture of both. The size of the object also includes any libraries which are linked, such as the string library.

#### D. The Memory Map

-----

The following diagram shows the layout of memory usage by the Pascal system. The runtime area is approximately 10K bytes long. The memory remaining after subtracting off the operating system, the runtime, and the program area is allocated to stack and heap. This is the data area for the program. The stack is used for storing the programs static variables. The size of the stack is specified at the time the program is run (using the RUN command) or built (using the LINKLOAD command). The remainder of memory is allocated to the heap which is used for storing dynamic variables.



### E. How the Optimizer Works

-----

The optimizer is a program which contains a loader for loading p-code object files. The loader loads and operates on one module (procedure and/or function) at a time, maintaining context as it operates on each individual module. The p-code instructions are analyzed to determine whether or not they may be compressed into shorter instructions.

Since the compiler is one pass, it must generate some branch and addressing instructions without knowing the actual displacements. This makes it necessary to allocate two byte operands for unknown displacements in order to handle all cases. However, in many cases the displacements can be specified using only one byte. The optimizer looks for such cases and compresses the p-code instructions in order to take advantage of the need for only a single byte operand.

The optimizer also looks for other types of situations where compression of instructions is possible. For example, all multiply by two instructions are converted to add instructions. In certain cases, consecutive instructions can cancel one another out (eg. an increment followed by a decrement). The optimizer eliminates such cases. The optimizer also performs constant folding (ie. it replaces arithmetic operations involving only constant operands with a single constant value). For example,  $2+2$  would be replaced by the single constant 4.

### G. How the Code Generator Works

-----

The code generator is a program which contains a loader for loading p-code object files. The code generator loads one module (procedure or function) at a time and translates the p-code instructions to machine instructions. As noted earlier, a p-code instruction is equivalent to several machine instructions, so the translation process will increase the total number of instructions in the object (/COD) file.

There are a few p-code instructions which perform very complex functions. To perform equivalent functions in machine code would require a very large number of instructions. Therefore, a few selected p-code instructions are not translated to machine instructions. They are left in p-code form and executed as subroutine calls to assembly language routines within the interpreter. Handling complex functions in this manner prevents the /COD file from becoming as large as it would with complete translation.

## SYSTEM OUTPUT

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### A. Assembly Language

-----

The native code generator has the capability of producing assembly language source in addition to object code. It is not necessary in normal circumstances to assemble the source, since the object code emitted by CODEGEN is exactly equivalent to the result of assembling the source. The assembly language is provided as a means for the programmer to examine the code produced by the native code generator. In some cases, the programmer may wish to optimize this code by hand and assemble it. It is expected that the need to do this will be rare, since the effort is substantial and the improvements that can be made are minor. If you wish to assemble the source output of CODEGEN, then the Alcor Systems multiprocessor assembler is required.

The source output of codegen is useful to the assembly language programmer who wishes to link assembly language modules to pascal and to call them as pascal procedures or functions. A possible technique to accomplish this is to write a pascal procedure or function with the same name and calling sequence as the assembly language routine. The actual code can be left out and perhaps replaced by a template that merely accesses the parameters that will be used in assembly language.

The dummy procedure produced above can be compiled by pascal and run through the code generator with the source option enabled. Pascal and codegen will generate the proper pascal procedure or function linkage and will calculate the addresses of variables and parameters referenced in the body of the procedure. The generated code can then be used as a skeleton for the assembly language that actually implements the functions required.

### B. Assembly Language Structure

-----

The assembly language code emitted by CODEGEN is designed for assembly by the Alcor Systems multiprocessor assembler. This assembler provides the features required to support pascal and the ability to mix Z80 code (or 6502 code, or 1802 code, or 8080 code) with P-code. Essential assembler features include the ability to switch among target processors (Z80 to P-code), the ability to define and reference external symbols (externals are resolved at link edit or load time), and the ability to generate pcode addressing modes (program counter relative, stack displacement, access to common blocks).

Each pascal procedure or function forms a separate module. All symbols, labels, and instructions are local to the module and reference other modules only via explicit external references. Modules begin with a module identification. For pascal generated code, the module name is the name of the procedure or function truncated to 8 characters. Each procedure or function also contains an external definition of the procedure name. This is signaled with the "DEF" assembler directive. The DEF statement causes the name and its value to be defined externally, so that other modules can call it.

Switching between modes (native vs. p-code) takes place within the procedure. Some operations performed by Pascal are sufficiently complex that they are implemented with subroutines. Inclusion of the actual code in-line would make the generated code unreasonably large. When these operations (such as input, output, or set operations) are performed, the code generator produces a call to a runtime procedure. These runtime procedures are already part of the Pcode interpreter. Rather than reference them again (and require another copy), the processor is switched back to p-code mode and the interpreter is allowed to perform the operation.

When in mixed mode, all procedure calling is performed using the p-code interpreter. Since code for each module is separate, and since modules may be split before being loaded, it is unknown whether the procedure being called is p-code or native code. Therefore, every module is entered in p-code mode. If the module is native code, the processor is switched to native mode immediately after entry to the procedure.

### C. Assembly Language Format

-----

The native code emitted by CODEGEN uses extended 8080 mnemonics. This is done primarily for historical reasons and since the 8080 instruction set more clearly distinguishes instructions by format. Use of 8080 extended mnemonics affects only the source output of codegen, as the Z80 instruction set is used and converted directly to object code by codegen. Each instruction occupies one line. Labels are left justified and begin with a letter. Each instruction has an op-code which is either an 8080 instruction or a Z80 instruction. There are also pseudo-operators (pseudo-ops) that provide instructions to the assembler rather than generating code.

Operands use standard register names. In many cases, the names of the Z80 index registers are merged with the op-code (e.g. PUSHIX pushes the IX index register). This simplifies interpretation by the assembler. Operands may also use symbolic labels and constants. Constants are normally expressed in hexadecimal (base 16) with a leading greater than sign ">") to specify hexadecimal to the assembler.

**Pseudo-operators**  
-----

IDT	identifies the module and gives it a name
EQU	defines the value of the label to the result of evaluating the operand
DEF	defines the operand as an external symbol
REF	specifies that the operand is an external symbol that is defined in another module
CSEG	Specifies the name and size of a common block
QLIST	Selects the compact format for the assembler listing
END	Signals the end of the module
ENTRY	Defines an entry point into the module
SETCPU	Selects the processor whose assembly language is being assembled

#### D. Object Format

-----

TRS-80 Pascal uses its own format for object code. The main reason for this is that support for many of the features of TRS-80 Pascal are not present in existing object formats. For example, TRS-80 Pascal supports common blocks for statically allocated variable storage and the object format must in turn allow for this.

The p-code generated by the compiler is address independent. That is, it contains no absolute memory addresses and can execute without change when loaded anywhere in memory. All branching and calling of procedures within the pcode is done relative to the current program counter. Since procedures are compiled into separate modules, calculation of these relative addresses must be done when the code is loaded. The object format supports external references that are program counter relative.

The object code is tagged hexadecimal and is emitted in a line oriented stream that is compatible with a pascal text file. In particular, the object code is character oriented and contains only printable ASCII characters. This allows the object to be manipulated by text editors or transmitted over modems. This is not possible with bit oriented formats.

Each item in the object file begins with a tag which is usually an upper case letter. The tag defines the type of item and the number and size of the fields to follow. Tags are followed by one or more fields that specify the information to be loaded. Three types of fields exist. Bytes are specified with a two character hexadecimal number. Words consist of a four character hexadecimal number with the most significant byte first. Labels consist of eight character names that are the names of external symbols, common blocks, etc...

Following is a table which lists all the tags used in an object file. All tags are followed by one to three fields of information, each field being either a byte, word, or label. The meaning of each tag is also shown.

Tag	Field1	Field2	Field3	Meaning
A	byte			Absolute(non-relocatable byte)
E				End of module
F				End of line
G	word	label		Definition of external symbol
I	word	label		External reference declaration
J	label			Module name
Q	word			Reference to external symbol
M	word	word	label	Definition of common block
N	word			Reference to common
O	word	word		Overlay definition
P	word			Code (PC) origin
K	word			Relative reference to external
W	word			Relocatable word
X	word			Absolute word
Y	word			Entry point definition
:				End of file

### E. Splitting Object Modules

Since object files are in ASCII format, they may be edited with a text editor or used as input to a Pascal program. The following is a list of the pure pcode output (/OBJ) file for the LOOP procedure in the mixed mode operation example. Following it is a listing of the object (/COD) file which results from running the pcode object through the code generator. As you can see, the code generation has caused approximately a factor of 2 increase in size.

#### Pure Pcode Listing (/OBJ)

```
JLOOP      P0000G0000LOOP      A01X0000A38A02A03X0001A15A04A10A04A03X2710A07F
A15A06A2BA4EX0000A03X0001A03X0002A22A03X0003A22A03X0004A22A03X0005A22A03F
X0006A22A03X0007A22A03X0008A22A03X0009A22A03X000AA22A03X000BA22A03X000CF
A22A03X000DA22A03X000EA22A03X000FA22A15A02A10A04A30X0004A10A06A27A21AB9F
P0014X0047P005DA3AP0001X0006E
```

```
:
```

## Native Code Listing (/COD)

```

-----
JLOOP    G0003LOOP    AC1AEBAE9A01X0006A38A02A55A21X0001ADDA75A04ADDA74F
A05ADDA6EA04ADDA66A05AE5A21X2710AE5ADDA75A06ADDA74A07AC1AE1A78AACAE42F
A28A09A47A3FALFAA8A07AE6A01A18A02A3EA00AA7AC2X0000A21X0001AE5A21X0002AC1F
A09AE5A21X0003AC1A09AE5A21X0004AC1A09AE5A21X0005AC1A09AE5A21X0006AC1A09F
AE5A21X0007AC1A09AE5A21X0008AC1A09AE5A21X0009AC1A09AE5A21X000AAC1A09AE5F
A21X000BAC1A09AE5A21X000CAC1A09AE5A21X000DAC1A09AE5A21X000EAC1A09AE5A21F
X000FAC1A09ADDA75A02ADDA74A03ADDA6EA04ADDA66A05AE5ADDAE5AE1A01X0004A09F
A4EA23A46A03A70A2BA71ADDA6EA06ADDA66A07AC1AAFAEDA42A20A01A3CAA7ACAW003AF
P0038W00BDP00BDACDW0000A3AE
:

```

Each module in an object file begins with the module name. Therefore, it is possible to split a file containing several modules into several files, each containing one module. This is an alternate method of segmenting large programs where it is desired to perform code generation on only selected parts.

There are two ways to split the object modules. One is to text edit them. The other more desirable method is to write a Pascal program to split them. A simple program may be written to read the pcode (/OBJ) file. Each time a module is encountered, open a file of the same name as the module and write the module to that file. Once all the modules are separated into different files, selected modules may be input to the code generator and translated to native machine instructions. The linking loader may then be used to link the individual modules and build an executable command (/CMD) file.

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 S = System Guide        T = Tutorial        A = Advanced Development Package

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