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Using the NetWare 3.x Internal Debugger

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NetWare v3.x includes an assembly language-oriented debugger. This AppNote uses a programming example and step-by-step instructions to illustrate how software developers can use the internal debugger when developing NetWare Loadable Modules (NLMs).

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The NetWare v3.x Internal Debugger

NetWare v3.x has an internal assembly language-oriented debugger, which was used as a tool in developing the NetWare kernel and many of the NLMs and drivers that ship with NetWare 3.x. The internal debugger was left in the released code so that third-party NLM developers can also use the internal debugger as a development tool.

This AppNote presents a programming example and step-by-step instructions to illustrate some techniques for using the internal debugger when developing NLMs. Only a few of the debugger's 42 commands are used in the example debugging session included in this AppNote, but if you work along with the commands presented here, you will see how to

- break into the debugger from a running C program
- identify the point in your program's execution where it entered the debugger
- locate your program's code data in memory
- disassemble program code
- examine the contents of CPU registers and the stack
- look at the file server's screen from the debugger
- locate memory locations corresponding to program variables
- traverse a linked list that a program built dynamically
- exit the debugger and return to normal file server operation

The example program given in this AppNote was developed using the NetWork C for NLMs Software Development Kit, version 2.0. The example debugging session was executed on a NetWare v3.11 server. The example program can be developed using any version of Network C, but some of the debugging commands described in this AppNote require NetWare v3.1 or greater.

Debugger Basics

NetWare enters the internal debugger when the CPU executes an interrupt 3. There are four ways to activate the debugger:

- Press <Shift><Shift><Alt><Esc>. This method is not available if the SECURE CONSOLE command has been executed on the file server.
- Execute an INT 3 instruction in an assembly language routine.
- Call the Breakpoint function (part of the Network C library) from a C program.
- Type "386debug" after the server has abended.

In debugger commands, you must enter all numbers (memory addresses, offsets, byte, word, or instruction counts, and so on) are entered in hexadecimal. The debugger's help screens say that the "c" command to change the contents of memory can take a string

parameter, but this version of the command has not yet been implemented.

Network C library functions use stack-based parameter passing. All parameters are passed as four bytes on stack, except doubles and structures or unions larger than four bytes.

NetWare v3.x uses protected mode and a flat memory model, so all addresses are 32 bits. The debugger, therefore, does not even report the value of segment registers (applause, cheers). The mapping of virtual to physical memory addresses changed between NetWare versions 3.1 and 3.11. A simplified memory map for the three 3.x versions of NetWare released to date is given below.

Figure 1: NetWare v3.x memory map.

Example Program: LISTNLMS.NLM

Type in the following program, or download it from NetWire, CompuServe's Novell Forum A, Forum Library 16, Novell Uploads (GO NOVA).

Compile and link the program using the NetWork C for NLMs Software Developer's Kit (a make file is given after the program listing).

```
/*****************************************************************************
*   LISTNLMS.C
*   Illustrate linked list traversal with NetWare internal debugger
*  Builds list of NLMs in SYS:SYSTEM
*
*   Morgan Adair
*   7/11/91
*****************************************************************************/

#include <stdio.h>
#include <nwdir.h>
#include <string.h>
#include <malloc.h>
#include <conio.h>
#include <errno.h>

typedef struct filename {
    char    fname[NAME_MAX+1]; /* 12 + 1 bytes */
    struct filename    *next;
} FILE_NAME;

void CleanUp(void);

DIR     *sysSystem;
FILE_NAME  *fileList = NULL;

void main(void)
{
    DIR         *dirEntry;
    FILE_NAME       *newNode;
    int         numFiles = 0;

    atexit(CleanUp);

    sysSystem = opendir("SYS:SYSTEM\\*.NLM");

    if (!sysSystem) {
        printf("Unable to open SYS:SYSTEM");
        exit();
    }

    Breakpoint(1); /* just for fun, break into the debugger here */

    do {    /* while getting directory entries */
        dirEntry = readdir(sysSystem);
        if (dirEntry) {
            newNode = (FILE_NAME *)malloc(sizeof(FILE_NAME));
            if (!newNode) {
                    printf("Out of memory");
                    exit();
            }
            numFiles++;
            strcpy(newNode->fname, dirEntry->d_name);
            newNode->next = fileList;
            fileList = newNode;
            /* display file name, just to keep up the appearance that
              we're doing something useful (maybe if we sorted the
                file names alphabetically . . .) */
            printf("%-20s", newNode->fname);
        }
    } while (dirEntry);

    Breakpoint(2);
}

void CleanUp(void)
{
    FILE_NAME  *newNode;

    closedir(sysSystem);

    while (fileList) {
        newNode = fileList;
        fileList = fileList->next;
        free(newNode);
```

```
    }
}
```

Here is the make file I used to build LISTNLMS.

```
.BEFORE
    @set inc386=mba/sys:\nwcnlms\h
    @set wcg386=mba/sys:\nwcnlms\bin\386wcg1.exe

CLIBIMP = mba/sys:\nwcnlms\imp\clib.imp
OBJFILE = listnlms.obj
PRELUDE = mba/sys:\nwcnlms\imp\prelude.obj
NLMNAME = listnlms

.c.obj:
    @echo Compiling $[*.c
    @wcc386p /zq /d1 /3s $[*.c

$(NLMNAME).nlm : $(OBJFILE) $(NLMNAME).def
    @wlink @$(NLMNAME).def
    @del $(NLMNAME).def

$(NLMNAME).def : makefile
    @echo FORMAT   NOVELL NLM 'List NLM files in SYS:SYSTEM'  >$(NLMNAME).def
    @echo FILE $(OBJFILE)                                    >>$(NLMNAME).def
    @echo FILE $(PRELUDE)                                    >>$(NLMNAME).def
    @echo NAME $(NLMNAME)                                    >>$(NLMNAME).def
    @echo MODULE   clib                                          >>$(NLMNAME).def
    @echo OPTION   VERSION=0.10                                  >>$(NLMNAME).def
    @echo OPTION   SCREENNAME 'listnlms'                         >>$(NLMNAME).def
    @echo IMPORT   @$(CLIBIMP)                                   >>$(NLMNAME).def
    @echo MODULE   clib.nlm                                      >>$(NLMNAME).def

$(OBJFILE) : $(NLMNAME).c
```

Preparing for the Debugging Session

Before beginning the debugging session, disassemble LISTNLMS's object file using the Watcom disassembler:

```
wdisasm /s /l listnlms
```

The "/s" option tells the disassembler to include the C source code lines in the disassembly listing. The "/l" option causes the disassembly listing to be saved in a file.

The disassembly listing for LISTNLMS follows. When debugging your own NLMs, you will probably want to have copies of both the source code and the disassembly listing for your NLM, either printed or on a workstation screen.

```
Module: listnlms.c
Group: 'DGROUP' CONST,_DATA,_BSS

Segment: '_TEXT' BYTE USE32  000000f2 bytes

/*****************************************************************************
*   LISTNLMS.C
*   Illustrate linked list traversal with NetWare internal debugger
*  Builds list of NLMs in SYS:SYSTEM
*
*   Morgan Adair
*   7/11/91
*****************************************************************************/

#include <stdio.h>
```

```
#include <nwdir.h>
#include <string.h>
#include <malloc.h>
#include <conio.h>
#include <errno.h>

typedef struct filename {
    char    fname[NAME_MAX+1]; /* 12 + 1 bytes */
    struct filename    *next;
} FILE_NAME;

void CleanUp(void);

DIR     *sysSystem;
FILE_NAME  *fileList = NULL;

void main(void)
{
    DIR         *dirEntry;
    FILE_NAME       *newNode;
    int         numFiles = 0;

0000  b8 14 00 00 00    main            mov     eax,00000014H
0005  e8 00 00 00 00                    call    __STK
000a  53                                push    ebx
000b  56                                push    esi

    atexit(CleanUp);

000c  68 00 00 00 00                    push    offset CleanUp
0011  e8 00 00 00 00                    call    atexit
0016  83 c4 04                          add     esp,0004H

    sysSystem = opendir("SYS:SYSTEM\\*.NLM");

0019  68 04 00 00 00                    push    offset L7
001e  e8 00 00 00 00                    call    opendir
0023  83 c4 04                          add     esp,0004H
0026  a3 00 00 00 00                    mov     sysSystem,eax

    if (!sysSystem) {
002b  85 c0                             test    eax,eax
002d  75 12                             jne     L1

        printf("Unable to open SYS:SYSTEM");
002f  68 15 00 00 00                    push    offset L8
0034  e8 00 00 00 00                    call    printf
0039  83 c4 04                          add     esp,0004H

        exit();
    }

    /* just for fun, break into the debugger here */
003c  e8 00 00 00 00                    call    exit

    Breakpoint(1);

    do {    /* while getting directory entries */
0041  6a 01             L1              push    01H
0043  e8 00 00 00 00                    call    Breakpoint
0048  83 c4 04                          add     esp,0004H

        dirEntry = readdir(sysSystem);
004b  ff 35 00 00 00 00 L2              push    sysSystem
0051  e8 00 00 00 00                    call    readdir
0056  83 c4 04                          add     esp,0004H
0059  89 c6                             mov     esi,eax

        if (dirEntry) {
005b  85 c0                             test    eax,eax
005d  74 4b                             je      L4

            newNode = (FILE_NAME *)malloc(sizeof(FILE_NAME));
005f  6a 11                             push    11H
0061  e8 00 00 00 00                    call    malloc
```

```
0066  83 c4 04                        add     esp,0004H
0069  89 c3                           mov     ebx,eax

           if (!newNode) {
006b  85 c0                           test    eax,eax
006d  75 12                           jne     L3
```

```
                    printf("Out of memory");
006f  68 2f 00 00 00                    push    offset L9
0074  e8 00 00 00 00                    call    printf
0079  83 c4 04                          add     esp,0004H

                    exit();
               }
               numFiles++;
007c  e8 00 00 00 00                    call    exit

               strcpy(newNode->fname, dirEntry->d_name);
0081  8d 46 2c          L3              lea     eax,+2cH[esi]
0084  50                                push    eax
0085  53                                push    ebx
0086  e8 00 00 00 00                    call    strcpy
008b  83 c4 08                          add     esp,0008H

               newNode->next = fileList;
008e  a1 00 00 00 00                    mov     eax,fileList
0093  89 43 0d                          mov     +0dH[ebx],eax

               fileList = newNode;
               /* display file name, just to keep up the appearance that
                  we're doing something useful (maybe if we sorted the
                    file names alphabetically . . .) */
0096  89 1d 00 00 00 00                 mov     fileList,ebx

               printf("%-20s", newNode->fname);
          }
009c  53                                push    ebx
009d  68 3d 00 00 00                    push    offset L10
00a2  e8 00 00 00 00                    call    printf
00a7  83 c4 08                          add     esp,0008H

    } while (dirEntry);

00aa  85 f6             L4              test    esi,esi
00ac  75 9d                             jne     L2

    Breakpoint(2);
00ae  6a 02                             push    02H
00b0  e8 00 00 00 00                    call    Breakpoint
00b5  83 c4 04                          add     esp,0004H

}

00b8  5e                                pop     esi
00b9  5b                                pop     ebx
00ba  c3                L5              ret

void CleanUp(void)
{
    FILE_NAME  *newNode;

00bb  b8 08 00 00 00    CleanUp         mov     eax,00000008H
00c0  e8 00 00 00 00                    call    __STK

    closedir(sysSystem);

00c5  ff 35 00 00 00 00                 push    sysSystem
00cb  e8 00 00 00 00                    call    closedir
00d0  83 c4 04          L6              add     esp,0004H

    while (fileList) {
00d3  83 3d 00 00 00 00
      00                                cmp     dword ptr fileList,0000H
00da  74 de                             je      L5

       newNode = fileList;
00dc  8b 15 00 00 00 00                 mov     edx,fileList

       fileList = fileList->next;
00e2  8b 42 0d                          mov     eax,+0dH[edx]
00e5  a3 00 00 00 00                    mov     fileList,eax
```

```
        free(newNode);
    }
```

```
              00ea  52                                  push    edx
00eb  e8 00 00 00 00                    call    free
00f0  eb de                             jmp     L6

}

No disassembly errors

------------------------------------------------------------
Segment: 'CONST' DWORD USE32  00000043 bytes
0000  00 00 00 00             _main_entry_    DD      __Null_Argv
0004  53 59 53 3a 53 59 53 54 L7              - SYS:SYST
000c  45 4d 5c 2a 2e 4e 4c 4d                 - EM\*.NLM
0014  00                                      - .
0015  55 6e 61 62 6c 65 20 74 L8              - Unable t
001d  6f 20 6f 70 65 6e 20 53                 - o open S
0025  59 53 3a 53 59 53 54 45                 - YS:SYSTE
002d  4d 00                                   - M.
002f  4f 75 74 20 6f 66 20 6d L9              - Out of m
0037  65 6d 6f 72 79 00                       - emory.
003d  25 2d 32 30 73 00       L10             - %-20s.

No disassembly errors
------------------------------------------------------------
Segment: '_DATA' DWORD USE32  00000004 bytes
0000  00 00 00 00             fileList        - ....

No disassembly errors
------------------------------------------------------------
Segment: '_BSS' DWORD USE32  00000004 bytes

No disassembly errors
------------------------------------------------------------
```

Starting to Debug

Load LISTNLMS on your test file server. As soon as LISTNLMS begins executing, it breaks into the internal debugger, and displays messages similar to those shown below.

```
Break at 003876C8 because of CLib Breakpoint call
EAX = 00000001 EBX = 00000001 ECX = 00000000 EDX = 0038305C
ESI = 00383228 EDI = 003833A4 EBP = 0037F1F6 ESP = 0037F134
EIP = 003876C8 FLAGS = 00007202 (IF)
00876C8 83C404         ADD     ESP,00000004
```

The sample program contained two calls to Breakpoint, each one passing a different value to the function. If we did not know which call interrupted execution of the NLM, the ".a" command displays the value passed to Breakpoint.

```
# .a
Debug entry: 1110
Break caused by: CLib Breakpoint call

Error code: 00000001
```

Since the NetWork C for NLMs library functions use stack-based parameter passing, the value that was passed to Breakpoint is also the top value on the stack. To look at the stack, use the debugger's "d" command to dump memory at the address contained in the stack pointer, ESP (0037F134 in the example).

Because the address of the memory location we want to examine is contained in a register, we can either specify the address explicitly:

```
# d 0037F134
0037F134  01 00 00 00 70 28 30 00-01 00 00 00 51 44 3A 00  ....p(8.....QD:.
```

or by the name of the register containing the address:

```
# d esp
0037F134  01 00 00 00 70 28 30 00-01 00 00 00 51 44 3A 00  ....p(8.....QD:.
```

Restart LISTNLMS by issuing a "g" command. The program is interrupted again by another breakpoint call.

```
# g
Break at 00387735 because of CLib Breakpoint call
EAX = 00000002 EBX = 00383654 ECX = 0005F158 EDX = 00000000
ESI = 00000000 EDI = 003833A4 EBP = 0037F1F6 ESP = 0037F134
EIP = 00387735 FLAGS = 00007202 (IF)
00387735 83C404         ADD     ESP,00000004
```

Notice that the value of the stack pointer has not changed since the last breakpoint. We can re-execute the command to dump the stack by pressing the up arrow key until the previous "d" command is displayed again, then pressing <Enter>.

```
# d esp
0037F134  02 00 00 00 C4 8B 03 00-01 00 00 00 51 44 3A 00  ....D.......QD:.
```

At this point, you may want to view the list of file names displayed on LISTNLMS's screen. You can do this by executing the debugger's "v" command. Then press any key to cycle through each of the server's screens.

At this point in LISTNLM's execution, the program has built a linked list of all NLM files in SYS:SYSTEM. To examine the linked list, we have to find where the first node in the list is stored in memory. To do so, start by finding where NetWare has loaded LISTNLMS.NLM into memory by executing the ".m" command. The debugger displays a list of all modules (server, NLM, LAN drivers, disk drivers) that have been loaded.

```
# .m
SERVER.NLM       NetWare Server Operating System
    Code Address: 00100000h  Length: 0007C620h
    Data Address: 0017C620h  Length: 00039350h
LISTNLMS.NLM     List NLM files in SYS:SYSTEM
    Version 0.10   July 11, 1991
    Code Address: 00387680h  Length: 000001ABh
    Data Address: 00387830h  Length: 00000050h
        .
        .
        .
```

Use the debugger's "u" command to disassemble LISTNLMS,

beginning at the program's code address. Pressing <Enter> continues program disassembly, 16 lines at a time. Disassemble LISTNLMS until the line shown in bold is displayed.

```
# u 00387680
00387680 B814000000     MOV     EAX,00000014
00387685 E8E0CE0100     CALL    CLIB.NLM|__STK
0038768A 53             PUSH    EBX
0038768B 56             PUSH    ESI
0038768C 683B773800     PUSH    0038773B
00387691 E836D20100     CALL    CLIB.NLM|atexit
00387696 83C404         ADD     ESP,00000004
00387699 6834783800     PUSH    00387834
0038769E E81A5E0100     CALL    CLIB.NLM|opendir
003876A3 83C404         ADD     ESP,00000004
003876A6 A378783800     MOV     [00387878],EAX
003876AB 85C0           TEST    EAX,EAX
003876AD 7512           JNZ     003876C1
003876AF 6845783800     PUSH    00387845
003876B4 E850A00300     CALL    CLIB.NLM|printf
003876B9 83C404         ADD     ESP,00000004
#
003876BC E8ADDB0100     CALL    CLIB.NLM|exit
003876C1 6A01           PUSH    01
003876C3 E8D8020400     CALL    CLIB.NLM|Breakpoint
003876C8 83C404         ADD     ESP,00000004
003876CB FF3578783800   PUSH    dword ptr [00387878]
003876D1 E878620100     CALL    CLIB.NLM|readdir
003876D6 83C404         ADD     ESP,00000004
003876D9 89C6           MOV     ESI,EAX
003876DB 85C0           TEST    EAX,EAX
003876DD 744B           JZ      0038772A
003876DF 6A11           PUSH    11
003876E1 E869A40100     CALL    CLIB.NLM|malloc
003876E6 83C404         ADD     ESP,00000004
003876E9 89C3           MOV     EBX,EAX
003876EB 85C0           TEST    EAX,EAX
003876ED 7512           JNZ     00387701
#
003876EF 685F783800     PUSH    0038785F
003876F4 E810A00300     CALL    CLIB.NLM|printf
003876F9 83C404         ADD     ESP,00000004
003876FC E86DDB0100     CALL    CLIB.NLM|exit
00387701 8D462C         LEA     EAX,[ESI+2C]
00387704 50             PUSH    EAX
00387705 53             PUSH    EBX
00387706 E87FD50300     CALL    CLIB.NLM|strcpy
0038770B 83C408         ADD     ESP,00000008
0038770E A174783800     MOV     EAX,[00387874]
00387713 89430D         MOV     [EBX+0D],EAX
00387716 891D74783800   MOV     [00387874],EBX
0038771C 53             PUSH    EBX
0038771D 686D783800     PUSH    0038786D
00387722 E8E29F0300     CALL    CLIB.NLM|printf
00387727 83C408         ADD     ESP,00000008
```

The boldface line in the disassembly listing above corresponds to the following line in the disassembly listing produced by wdisasm.

```
          newNode->next = fileList;
008e  a1 00 00 00 00                  mov     eax,fileList
```

Since wdisasm does not know where NetWare will load an NLM into memory, it uses variable names to represent the memory address where the variables will be stored. The internal debugger's disassembly listing shows that fileList, the address of the first node in the linked list, is stored at address 00387874.

Because we may want to refer to the first node of the linked list more than once, we can define a symbol with a value equal to its address:

```
n fileList 00387874
```

To dump just the address of the first file name node, tell the "d" command to dump just the four bytes at 00387874.

```
# d fileList 4
00387874  54 36 38 00                                        T68.
```

The first node is at memory address 00383654. To begin traversing the linked list, modify the last "d" command to use the value of fileList as the memory address of the first node. The syntax of the debugger's "dl" command is

dl{+linkOffset} address {length}

where linkOffset is offset of the pointer to the next node in the linked list, and length is the number of bytes to be dumped. Nodes in LISTNLMS's linked list have the structure

```
typedef struct filename {
    char    fname[NAME_MAX+1]; /* 12 + 1 bytes */
    struct filename    *next;
} FILE_NAME;
```

so the offset of the link to the next node is 13 (0Dh). The total length of the structure is 17 (11h) bytes.

```
# dl+0d [d fileList] 11
Link node 00000001
00383654  4C 49 53 54 4E 4C 4D 53-2E 4E 4C 4D 00 78 36 38
LISTNLMS.NLM.x68
00383664  00                                                 .
```

The square brackets indicate an indirect reference through the specified address. The d in front of fileList specifies that the dword value at fileList is to be used as the address to be dumped.

You can now press <Enter> to traverse through each node of the linked list, until the debugger reaches the node with a null pointer to the next node.

```
#
Link node 00000002
00383678  54 45 53 54 2E 4E 4C 4D-00 00 00 00 FF 9C 36 38  TEST.NLM......68
00383688  00                                               .
#
    .
    .
    .
Link node 0000002A
0003C3D0  52 53 50 58 2E 4E 4C 4D-00 00 00 00 00 00 00 00  RSPX.NLM........
0003C3E0  00                                               .
#
No more nodes in linked list
```

Conclusion

This AppNote touches only a few of the internal debugger's commands, but by now you should know enough to use the debugger as a tool in your NLM development process. The appendix on the following pages gives a quick reference to all internal debugger commands.

Appendix A: Internal Debugger Quick Reference

The table below summarizes NetWare v3.x internal debugger commands. Optional parameters are given in [square brackets].

Figure 2: NetWare v3.x internal debugger commands.

Command	**Description**
b	Display all current breakpoints.
bc *number*	Clear the breakpoint specified by *number* (0-3).
bca	Clear all breakpoints.
b = *address [expression]*	Set an execution breakpoint at *address*. Break will occur if EIP=*address*, and *expression* evaluates to TRUE.
br = *address [expression]*	Set a read/write breakpoint at *address*. Break will occur if memory at *address* is referenced, and *expression* evaluates to TRUE.
bw = *address [expression]*	Set a write breakpoint at *address*. Break will occur if memory at *address* is changed, and *expression* evaluates to TRUE.
c *address[=value(s)]*	Change memory at address to the specified value(s). If value(s) are not specified, debugger prompts for new values.
d *address [count]*	Dump *count* bytes (default 256) at *address*.*
dl*[+linkOffset] address [length]*	Dump memory starting at *address* for *length* bytes and traverse a linked list by following pointer *linkoffset* bytes from *address* (default *linkoffset* is 0). Press <Enter> to dump the next link node (v3.1/v3.11).
f *FLAG=value*	Change the *FLAG* to *value* (0 or 1), where *FLAG* is CF, AF, ZF, SF, IF, TF, PF, DF or OF.
g *[address(es)]*	Begin execution at EIP and set temporary breakpoint(s) at *address(es)*.
h	Display general help.
hb	Display breakpoint help.
he	Display expression help.
i *[size] PORT*	Input *size* from *PORT*, where *size* is B (byte), W (word), or D (dword) (default is byte).
m *address [*L *length] byte(s)*	Search memory beginning at *address* for *byte(s)* (if *length* is not specified, the rest of memory will be searched). Byte values must be given in hexadecimal and separated by spaces or commas.*
n *[symbolName value]*	Define new symbol *symbolName* equal to *value*. If *symbolName* and *value* are not specified, all symbols and values are displayed.
n *-symbolName*	Remove user-defined symbol *symbolName* (n-- remove all symbols) (v3.1/v3.11).

o *[size] PORT=value*	Output *size value* to *PORT*, where size is B (byte), W (word), or D (dword) (default is byte).
p	Single step, proceed over CALLs, REPs, and LOOPs.*
q	Quit and exit back to DOS (or reboot if DOS has been removed).
r	Display registers and flags (v3.1/v3.11).
REG=value	Change the specified register to *value*, where *REG* is EAX, EBX, ECX, EDX, ESI, EDI, ESP, EBP or EIP.
s	Single step, trace into CALLs, REPs or LOOPs.*
t	Same as s.*
u *address [count]*	Unassemble *count* instructions starting at *address*.*
v	View file server screens (press any key to go to next screen).
z *expression*	Evaluate *expression*.
? *[address]*	If symbolic information has been loaded, display the closest symbols to *address* (default is EIP).
.a	Display the abend or break reason (v3.1/v3.11).
.c	Dump diagnostic data to diskette.
.h	Display dot command help.
.m	Display names and addresses of all loaded modules.
.p *[address]*	Display *address* as a process control block (if *address* is not specified, display all process names and addresses).
.r	Display the process control block for the running process.
.s *[address]*	Display *address* as a screen structure (if *address* is not specified, display all screen names and addresses).
.v	Display server version.

*The d, m, p, s, t, and u commands can be continued or repeated by pressing <Enter> at the # prompt.

Breakpoints

A breakpoint condition can be any expression. If a breakpoint condition is specified, the condition is evaluated when the break occurs. If the condition is not true, execution resumes without entering the debugger.

Figure 3: NetWare v3.x internal debugger expression operators (continued).

There are four breakpoint registers, allowing a maximum of four breakpoints to be set at a time. These breakpoints can be permanent breakpoints (set using the "b" command) or temporary breakpoints (set using the "g" command). In addition, the "p" command also sets a temporary breakpoint if the current instruction can not be single-stepped (a CALL, or one of the REP or LOOP families). Because of the limited number of breakpoint registers, you might not be able to execute a "g" or "p" command when four permanent breakpoints are set.

Here are some examples of commands that use breakpoints:

```
b = PushNode [d esp+4] == 0
```
Set a breakpoint at PushNode (which you must have previously declared with the n command). Break if the first parameter on the stack is NULL.

```
bw = 16fe60 eip >= listnlms && eip <= (listnlms+1ab)
```
Break if any instruction in LISTNLMS tries to modify memory address 16fe60.

```
g [d esp]
```
Execute until the current function returns to its caller.

Debugger Expressions

Expressions consist of terms and operators. Terms in expressions can be hexadecimal constants, symbols, or register or flag names. You can use grouping operators to cause terms to be interpreted as indirect memory addresses or hardware port addresses. The following are register and flag names as they are used in debugger expressions.

Registers: EAX, EBX, ECX, EDX, ESI, EDI, ESP, EBP and EIP
Flags: FLCF, FLAF, FLZF, FLSF, FLIF, FLTF, FLPF, FLDF and FLOF

The table below gives debugger expression operators in order of precedence.

Figure 3: NetWare v3.x internal debugger expression operators.

Symbol	Description	Precedence
Grouping operators		
(*expression*)	Evaluate *expression* at higher precedence.	0
[*size expression*]	Read *size* from the memory address specified by *expression*, where *size* is B (byte), W (word), or D (dword).	0
{*size expression*}	Evaluate *expression* and resulting value as a port address. The bracketed expression is replaced with the byte, word, or double word input from the port.	0
Unary operators		

Figure 3: NetWare v3.x internal debugger expression operators (continued).

!	logical NOT	1
-	2's complement	1
~	1's complement	1
Binary operators		
*	multiply	2
/	divide	2
%	mod	2
+	add	3
-	subtract	3
>>	bit shift right	4
<<	bit shift left	4
>	greater than	5
<	less than	5
>=	greater than or equal to	5
<=	less than or equal to	5
!=	not equal to	6
==	equal to	6
&	bitwise AND	7
^	bitwise XOR	8
|	bitwise OR	9
&&	logical AND	10
||	logical OR	11
Ternary operator		
expression1 ? expression2 , expression3	If expression1 is true then the result is the value of expression2, otherwise the result is the value of expression3.	12

Figure 3: NetWare v3.x internal debugger expression operators (continued).