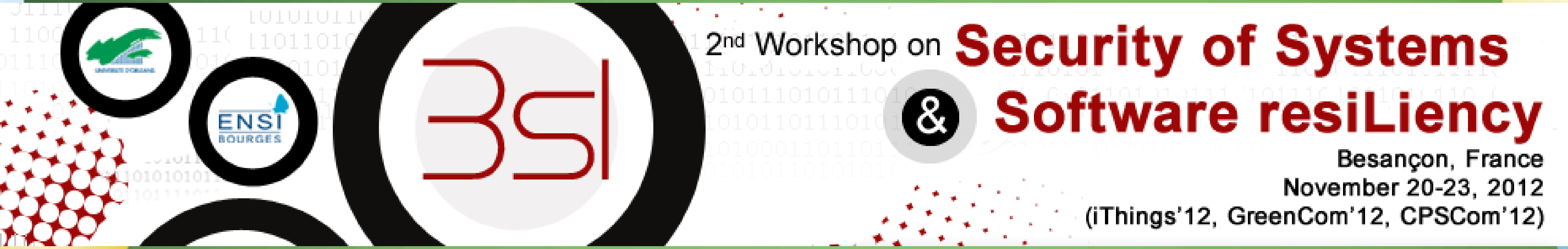
CPqD

TRANSFORMANDO
EM REALIDADE



2nd Workshop on Security of Systems & Software resiLiency

Besançon, France
November 20-23, 2012
(iThings'12, GreenCom'12, CPSCom'12)

Retrieving Information from Malware Encrypted Output Files

Two Case Studies from Brazil

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CPqD

Agenda

- Introduction.
- Cryptanalysis of File #1.
- Cryptanalysis of File #2.
- Final words.

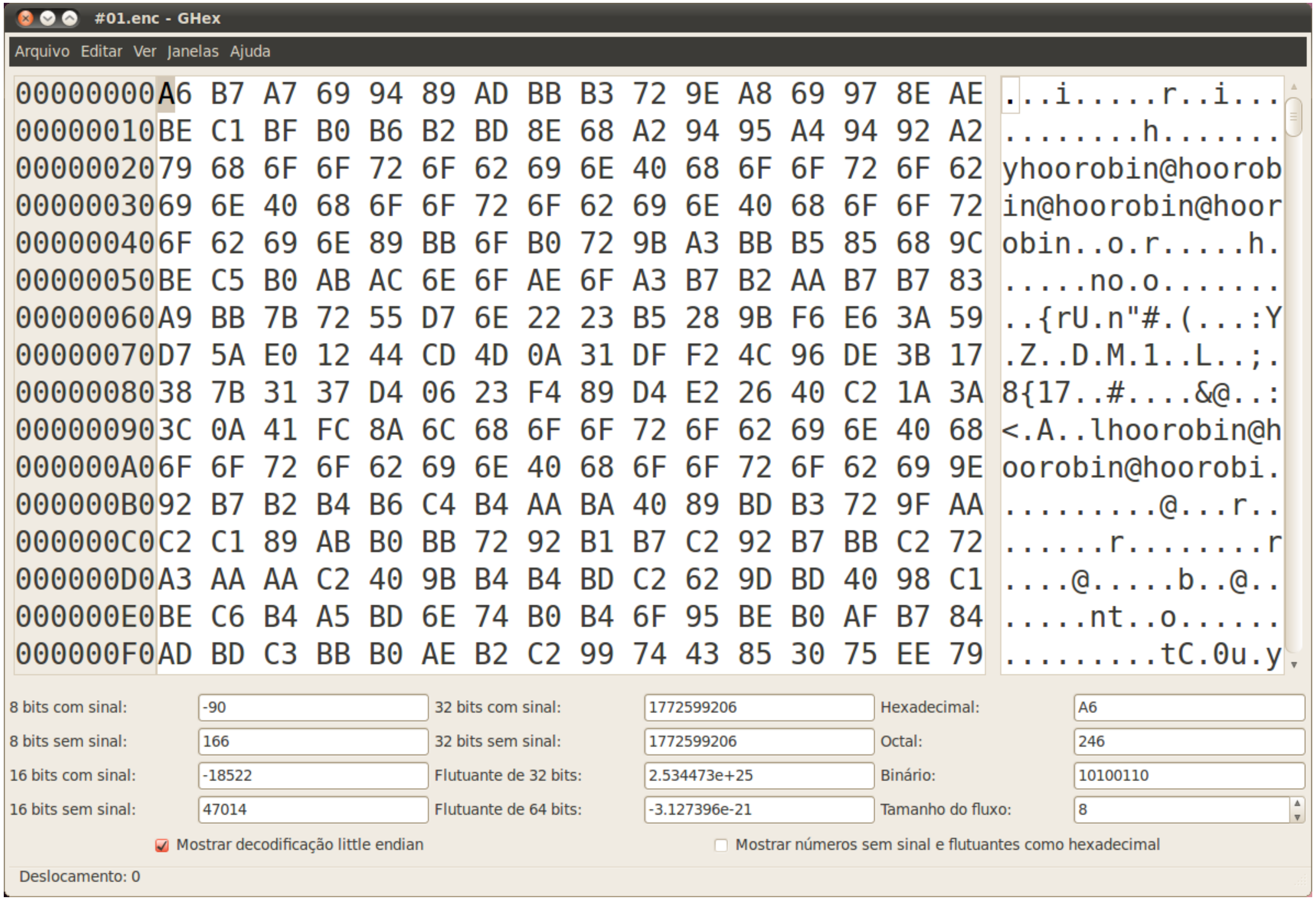
Introduction

- CPqD was hired by a big Brazilian company to find out which information had been stolen by three different malwares, that infected its environment.
- Each one of them stored information in encrypted form using different mechanisms.
- We did only have access to the encrypted files and the malware binaries, meaning we could not use the special purpose hardware targeted by them.
- Due to the sensitivity of the stolen data and signed NDA, this talk will not use the real information we retrieved from those files.

Covered topics

- Detection of weak cryptosystems.
- Cryptanalysis of classical algorithms.
- Block ciphers.
- DES.
- Modes of operation.
- Searching key in malware binary or in memory.
- Worst scenario.

File #1 – Sample



```
00000000A6 B7 A7 69 94 89 AD BB B3 72 9E A8 69 97 8E AE ...i.....r..i...
00000010BE C1 BF B0 B6 B2 BD 8E 68 A2 94 95 A4 94 92 A2 ........h.......
0000002079 68 6F 6F 72 6F 62 69 6E 40 68 6F 6F 72 6F 62 yhoorobin@hoorob
0000003069 6E 40 68 6F 6F 72 6F 62 69 6E 40 68 6F 6F 72 in@hoorobin@hoor
000000406F 62 69 6E 89 BB 6F B0 72 9B A3 BB B5 85 68 9C obin..o.r.....h.
00000050BE C5 B0 AB AC 6E 6F AE 6F A3 B7 B2 AA B7 B7 83 .....no.o.......
00000060A9 BB 7B 72 55 D7 6E 22 23 B5 28 9B F6 E6 3A 59 ..{rU.n"#.(...:Y
00000070D7 5A E0 12 44 CD 4D 0A 31 DF F2 4C 96 DE 3B 17 .Z..D.M.1..L..;.
0000008038 7B 31 37 D4 06 23 F4 89 D4 E2 26 40 C2 1A 3A 8{17..#....&@..:
000000903C 0A 41 FC 8A 6C 68 6F 6F 72 6F 62 69 6E 40 68 <.A..lhoorobin@h
000000A06F 6F 72 6F 62 69 6E 40 68 6F 6F 72 6F 62 69 9E oorobin@hoorobi.
000000B092 B7 B2 B4 B6 C4 B4 AA BA 40 89 BD B3 72 9F AA .........@...r..
000000C0C2 C1 89 AB B0 BB 72 92 B1 B7 C2 92 B7 BB C2 72 ......r........r
000000D0A3 AA AA C2 40 9B B4 B4 BD C2 62 9D BD 40 98 C1 ....@.....b..@..
000000E0BE C6 B4 A5 BD 6E 74 B0 B4 6F 95 BE B0 AF B7 84 .....nt..o......
000000F0AD BD C3 BB B0 AE B2 C2 99 74 43 85 30 75 EE 79 .........tC.0u.y
```

8 bits com sinal: -90
32 bits com sinal: 1772599206
Hexadecimal: A6

8 bits sem sinal: 166
32 bits sem sinal: 1772599206
Octal: 246

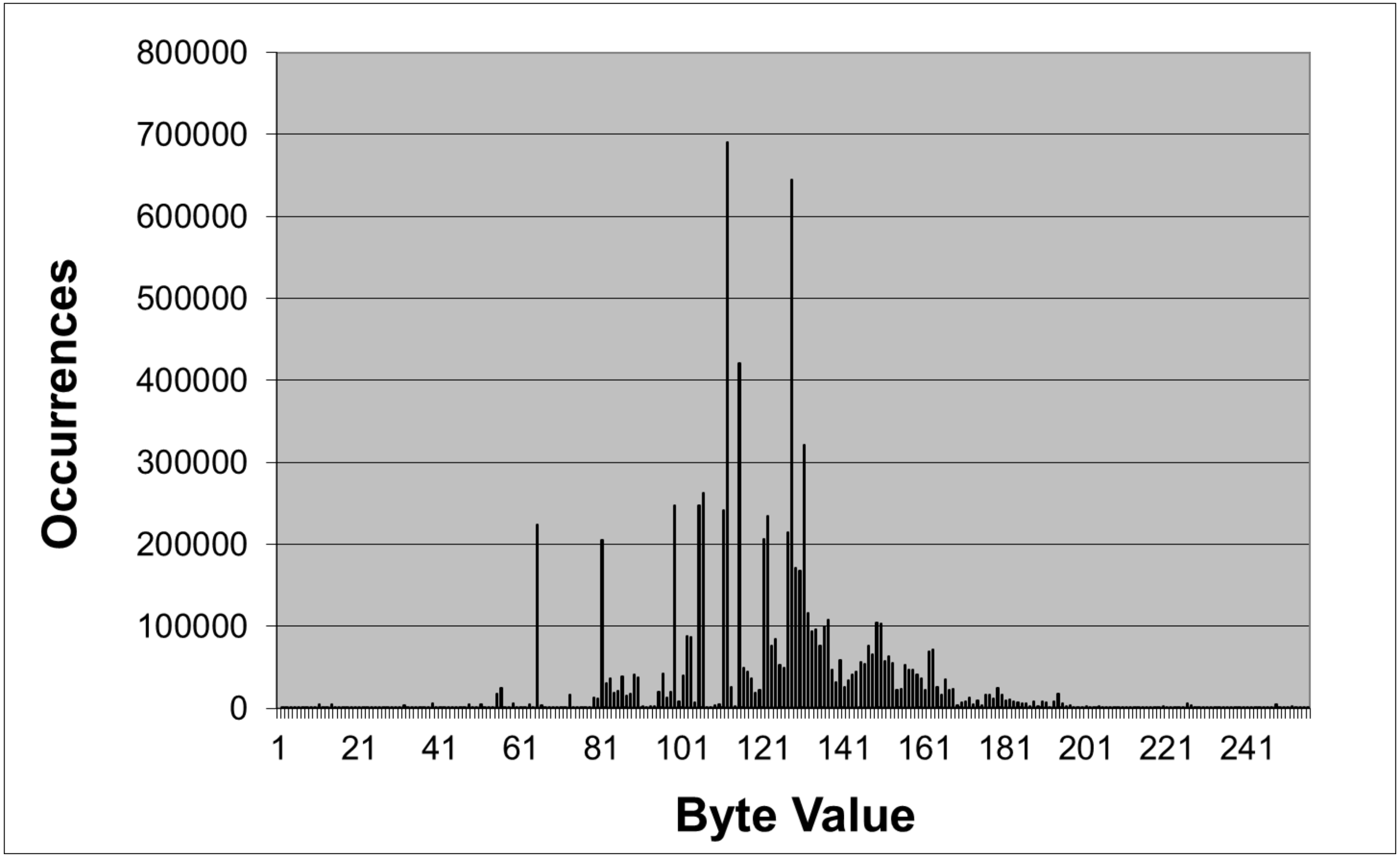
16 bits com sinal: -18522
Flutuante de 32 bits: 2.534473e+25
Binário: 10100110

16 bits sem sinal: 47014
Flutuante de 64 bits: -3.127396e-21
Tamanho do fluxo: 8

☑ Mostrar decodificação little endian
□ Mostrar números sem sinal e flutuantes como hexadecimal

Deslocamento: 0

File #1 – Histogram



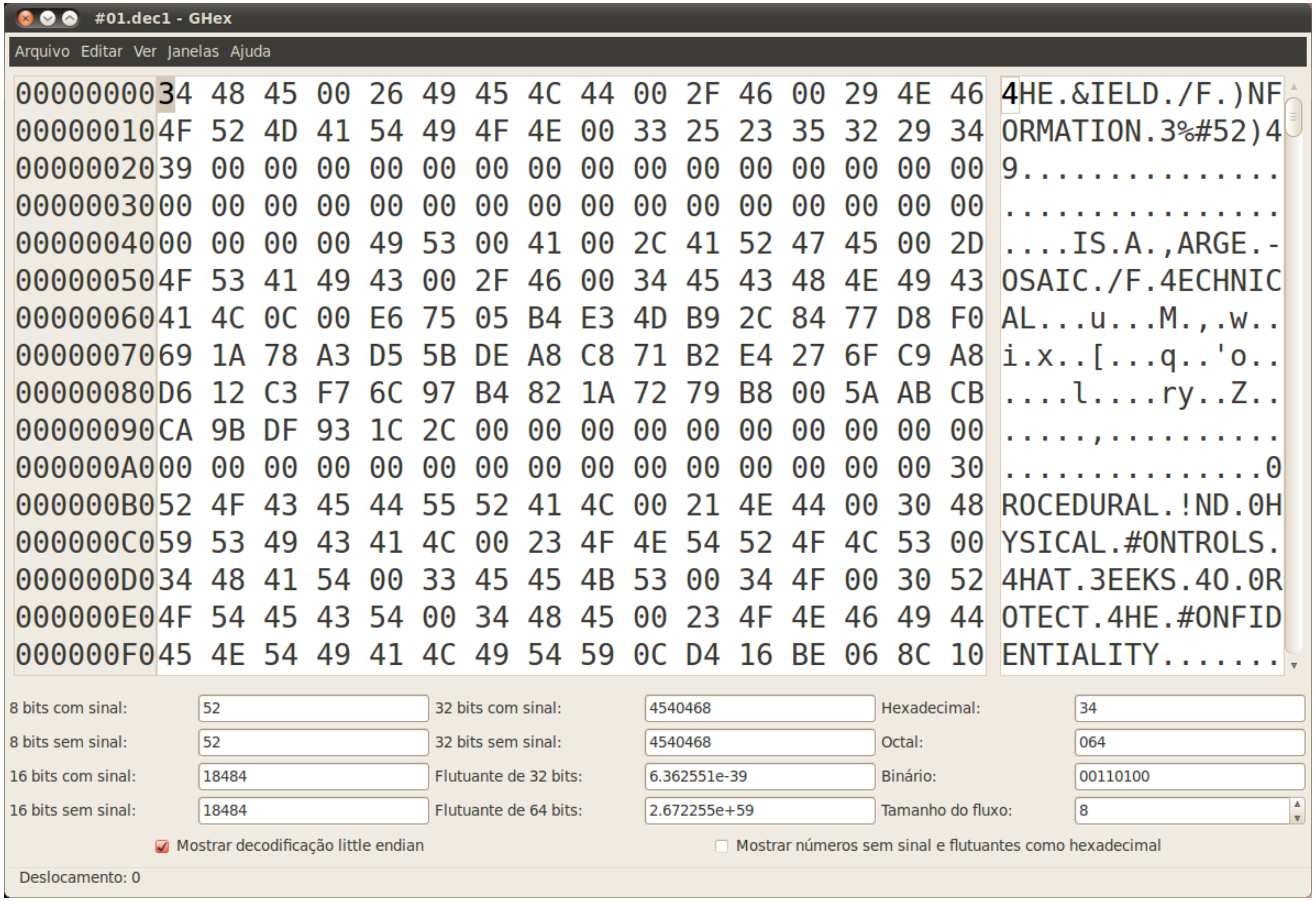
File #1 – Important facts

- File#1 is pretty redundant.
  - This means a weak cryptosystem was used.
- The distance between occurrences of the string “robin@hoo” is always multiple of its length.
- Most of the bytes has values between 80 and 180.

File #1 – Hypothesis

- **Hypothesis #1:** a constant number is added to each byte modulo 256 and a given string is repeated several times in the plain text.
  - Not likely, but it should be tested.
  - How?
- **Hypothesis #2:** a Vigenère cipher over an alphabet of 256 elements and period equals 9 was used.
  - Candidate key: robin@hoo

File #1 – First attempt



```
0000000034 48 45 00 26 49 45 4C 44 00 2F 46 00 29 4E 46 4HE.&IELD./F.)NF
000000104F 52 4D 41 54 49 4F 4E 00 33 25 23 35 32 29 34 ORMATION.3%#52)4
0000002039 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 9...............
0000003000 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
0000004000 00 00 00 49 53 00 41 00 2C 41 52 47 45 00 2D ....IS.A.,ARGE.-
000000504F 53 41 49 43 00 2F 46 00 34 45 43 48 4E 49 43 OSAIC./F.4ECHNIC
0000006041 4C 0C 00 E6 75 05 B4 E3 4D B9 2C 84 77 D8 F0 AL...u...M.,.w..
0000007069 1A 78 A3 D5 5B DE A8 C8 71 B2 E4 27 6F C9 A8 i.x..[...q..'o..
00000080D6 12 C3 F7 6C 97 B4 82 1A 72 79 B8 00 5A AB CB ....l....ry..Z..
00000090CA 9B DF 93 1C 2C 00 00 00 00 00 00 00 00 00 00 .....,..........
000000A000 00 00 00 00 00 00 00 00 00 00 00 00 00 00 30 ...............0
000000B052 4F 43 45 44 55 52 41 4C 00 21 4E 44 00 30 48 ROCEDURAL.!ND.0H
000000C059 53 49 43 41 4C 00 23 4F 4E 54 52 4F 4C 53 00 YSICAL.#ONTROLS.
000000D034 48 41 54 00 33 45 45 4B 53 00 34 4F 00 30 52 4HAT.3EEKS.4O.0R
000000E04F 54 45 43 54 00 34 48 45 00 23 4F 4E 46 49 44 OTECT.4HE.#ONFID
000000F045 4E 54 49 41 4C 49 54 59 0C D4 16 BE 06 8C 10 ENTIALITY.......
```

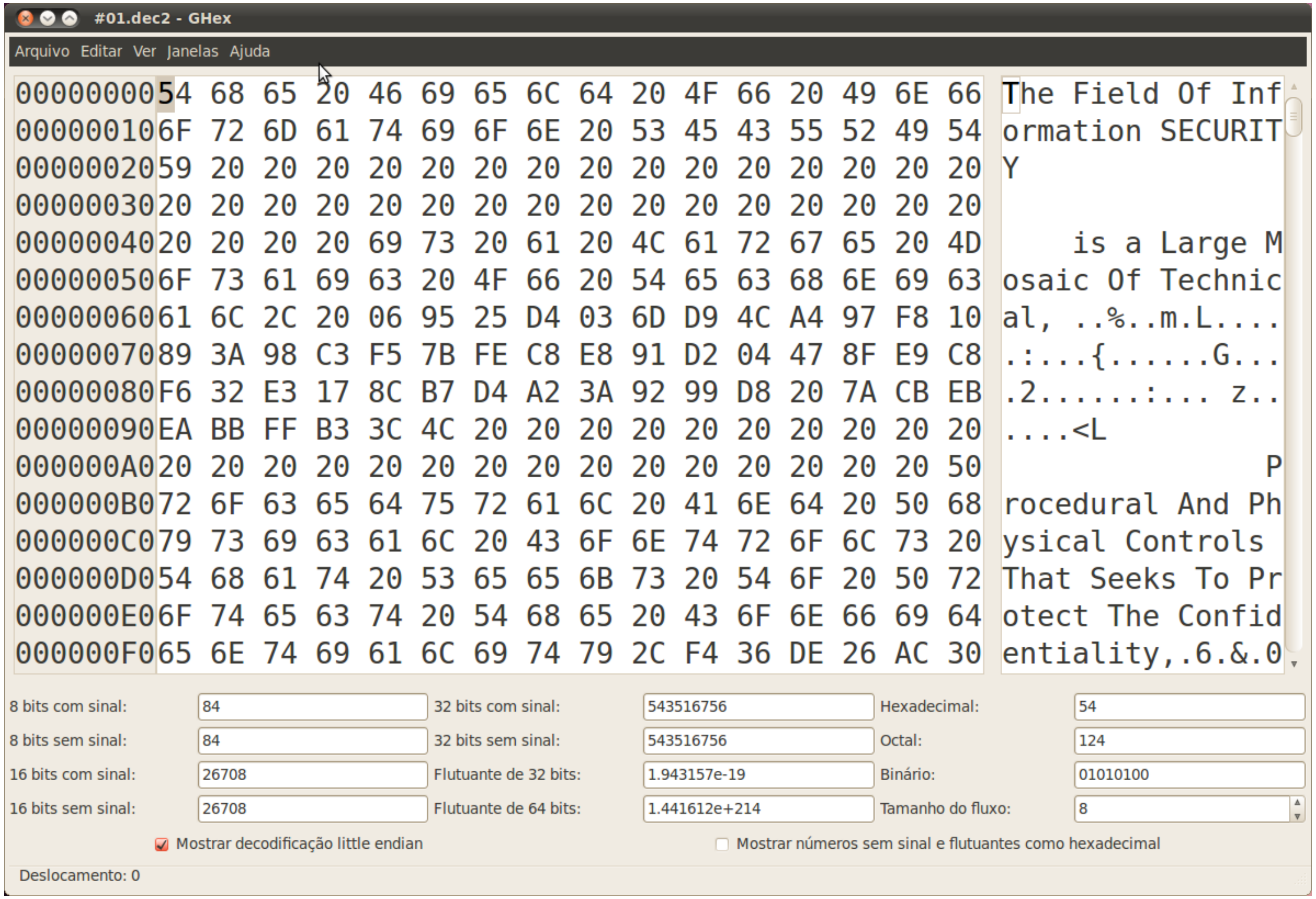
8 bits com sinal:	52	32 bits com sinal:	4540468	Hexadecimal:	34
8 bits sem sinal:	52	32 bits sem sinal:	4540468	Octal:	064
16 bits com sinal:	18484	Flutuante de 32 bits:	6.362551e-39	Binário:	00110100
16 bits sem sinal:	18484	Flutuante de 64 bits:	2.672255e+59	Tamanho do fluxo:	8

☑ Mostrar decodificação little endian

□ Mostrar números sem sinal e flutuantes como hexadecimal

Deslocamento: 0

File #1 – Correction



```
0000000054 68 65 20 46 69 65 6C 64 20 4F 66 20 49 6E 66 The Field Of Inf
000000106F 72 6D 61 74 69 6F 6E 20 53 45 43 55 52 49 54 ormation SECURIT
0000002059 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 Y
0000003020 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
0000004020 20 20 20 69 73 20 61 20 4C 61 72 67 65 20 4D     is a Large M
000000506F 73 61 69 63 20 4F 66 20 54 65 63 68 6E 69 63 osaic Of Technic
0000006061 6C 2C 20 06 95 25 D4 03 6D D9 4C A4 97 F8 10 al, ..%..m.L....
0000007089 3A 98 C3 F5 7B FE C8 E8 91 D2 04 47 8F E9 C8 .:...{......G...
00000080F6 32 E3 17 8C B7 D4 A2 3A 92 99 D8 20 7A CB EB .2......:... z..
00000090EA BB FF B3 3C 4C 20 20 20 20 20 20 20 20 20 20 ....<L
000000A020 20 20 20 20 20 20 20 20 20 20 20 20 20 20 50                P
000000B072 6F 63 65 64 75 72 61 6C 20 41 6E 64 20 50 68 rocedural And Ph
000000C079 73 69 63 61 6C 20 43 6F 6E 74 72 6F 6C 73 20 ysical Controls 
000000D054 68 61 74 20 53 65 65 6B 73 20 54 6F 20 50 72 That Seeks To Pr
000000E06F 74 65 63 74 20 54 68 65 20 43 6F 6E 66 69 64 otect The Confid
000000F065 6E 74 69 61 6C 69 74 79 2C F4 36 DE 26 AC 30 entiality,.6.&.0
```

8 bits com sinal:	84	32 bits com sinal:	543516756	Hexadecimal:	54
8 bits sem sinal:	84	32 bits sem sinal:	543516756	Octal:	124
16 bits com sinal:	26708	Flutuante de 32 bits:	1.943157e-19	Binário:	01010100
16 bits sem sinal:	26708	Flutuante de 64 bits:	1.441612e+214	Tamanho do fluxo:	8

☑ Mostrar decodificação little endian

☐ Mostrar números sem sinal e flutuantes como hexadecimal

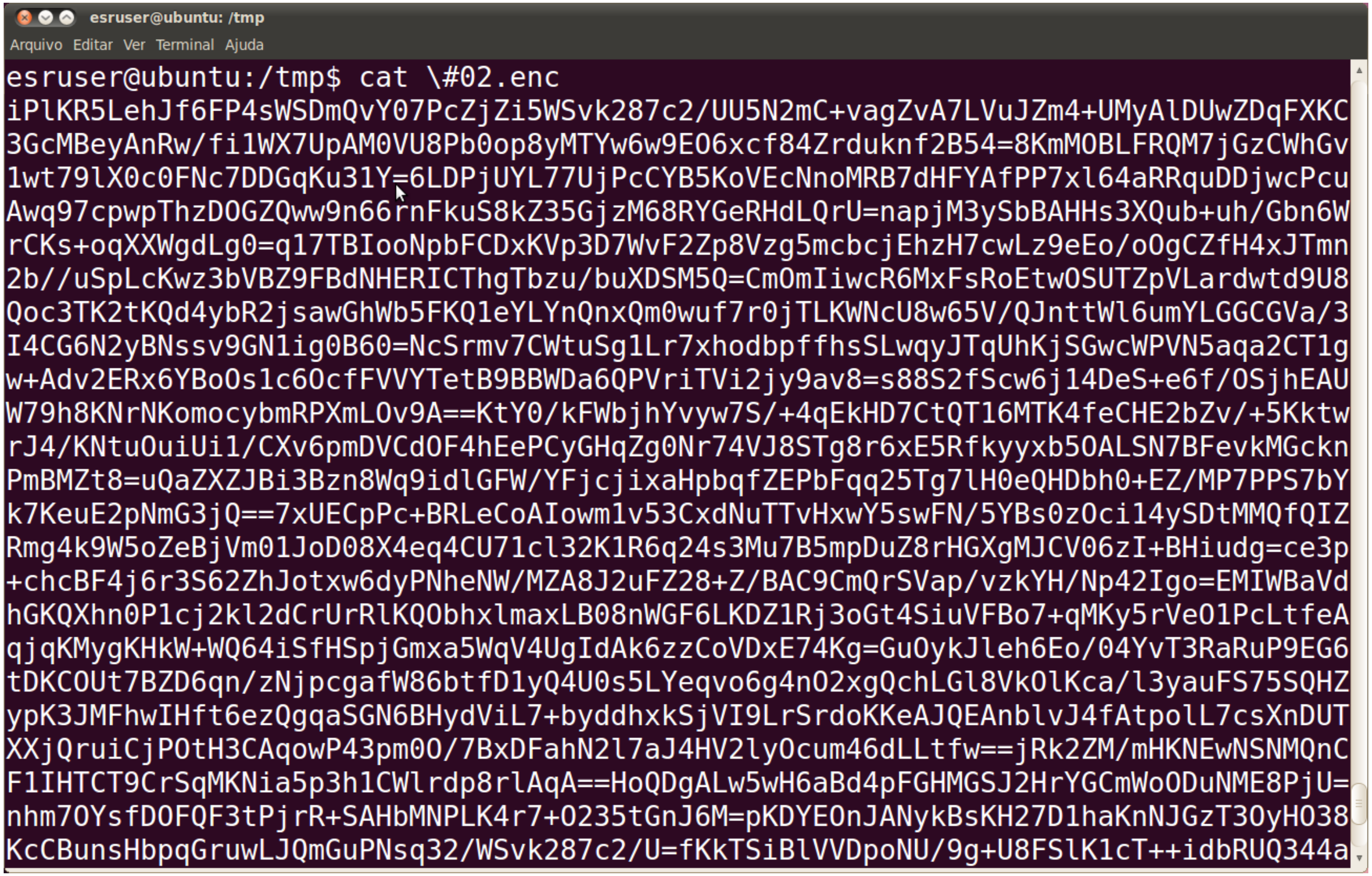
Deslocamento: 0

File #1 – Description of cipher

- **Alphabet of definition:** $\mathcal{A} = \{0, 1, 2, 3, \ldots, 255\}$
- **Plain text:** $M = m_0 m_1 m_2 \ldots m_{t-1}$, $m_i \in \mathcal{A}$
- **Cipher text:** $C = c_0 c_1 c_2 \ldots c_{t-1}$, $c_i \in \mathcal{A}$
- **Key:** $K = k_0 k_1 k_2 k_3 k_4 k_5 k_6 k_7 k_8$

  = 0x52 4f 42 49 4e 20 48 4f 4f
- **Encryption function:** $c_i = m_i + k_{(i \bmod 9)} \bmod 256$
- **Decryption function:** $m_i = c_i - k_{(i \bmod 9)} \bmod 256$

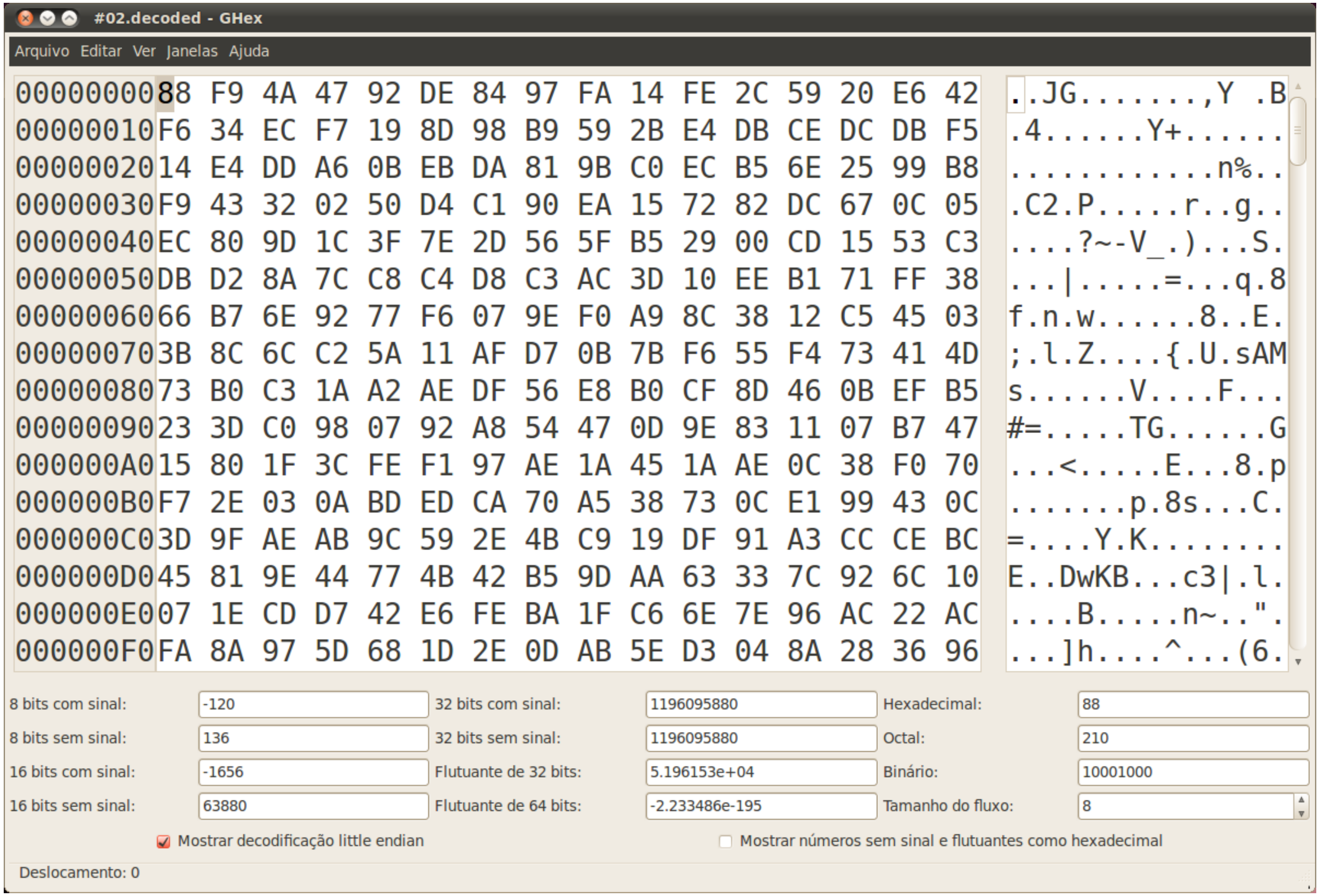
File #2 – Sample



```
esruser@ubuntu:/tmp$ cat \#02.enc
```

```
iPlKR5LehJf6FP4sWSDmQvY07PcZjZi5WSvk287c2/UU5N2mC+vagZvA7LVuJZm4+UMyAlDUwZDqFXKC
3GcMBeyAnRw/fi1WX7UpAM0VU8Pb0op8yMTYw6w9EO6xcf84Zrduknf2B54=8KmMOBLFRQM7jGzCWhGv
1wt79lX0c0FNc7DDGqKu31Y=6LDPjUYL77UjPcCYB5KoVEcNnoMRB7dHFYAfPP7xl64aRRquDDjwcPcu
Awq97cpwpThzDOGZQww9n66rnFkuS8kZ35GjzM68RYGeRHdLQrU=napjM3ySbBAHHs3XQub+uh/Gbn6W
rCKs+oqXXWgdLg0=q17TBIooNpbFCDxKVp3D7WvF2Zp8Vzg5mcbcjEhzH7cwLz9eEo/oOgCZfH4xJTmn
2b//uSpLcKwz3bVBZ9FBdNHERICThgTbzu/buXDSM5Q=CmOmIiwcR6MxFsRoEtwOSUTZpVLardwtd9U8
Qoc3TK2tKQd4ybR2jsawGhWb5FKQ1eYLYnQnxQm0wuf7r0jTLKWNcU8w65V/QJnttWl6umYLGGCGVa/3
I4CG6N2yBNssv9GN1ig0B60=NcSrmv7CWtuSg1Lr7xhodbpffhsSLwqyJTqUhKjSGwcWPVN5aqa2CT1g
w+Adv2ERx6YBoOs1c6OcfFVVYTetB9BBWDa6QPVriTVi2jy9av8=s88S2fScw6j14DeS+e6f/OSjhEAU
W79h8KNrNKomocybmRPXmLOv9A==KtY0/kFWbjhYvyw7S/+4qEkHD7CtQT16MTK4feCHE2bZv/+5Kktw
rJ4/KNtuOuiUi1/CXv6pmDVCdOF4hEePCyGHqZg0Nr74VJ8STg8r6xE5Rfkyyxb5OALSN7BFevkMGckn
PmBMZt8=uQaZXZJBi3Bzn8Wq9idlGFW/YFjcjixaHpbqfZEPbFqq25Tg7lH0eQHDbh0+EZ/MP7PPS7bY
k7KeuE2pNmG3jQ==7xUECpPc+BRLeCoAIowm1v53CxdNuTTvHxwY5swFN/5YBs0zOci14ySDtMMQfQIZ
Rmg4k9W5oZeBjVm01JoD08X4eq4CU71cl32K1R6q24s3Mu7B5mpDuZ8rHGXgMJCV06zI+BHiudg=ce3p
+chcBF4j6r3S62ZhJotxw6dyPNheNW/MZA8J2uFZ28+Z/BAC9CmQrSVap/vzkYH/Np42Igo=EMIWBaVd
hGKQXhn0P1cj2kl2dCrUrRlKQObhxlmaxLB08nWGF6LKDZ1Rj3oGt4SiuVFBo7+qMKy5rVeO1PcLtfeA
qjqKMygKHkW+WQ64iSfHSpjGmxa5WqV4UgIdAk6zzCoVDxE74Kg=GuOykJleh6Eo/04YvT3RaRuP9EG6
tDKCOUt7BZD6qn/zNjpcgafW86btfD1yQ4U0s5LYeqvo6g4nO2xgQchLGl8VkOlKca/l3yauFS75SQHZ
ypK3JMFhwIHft6ezQgqaSGN6BHydViL7+byddhxkSjVI9LrSrdoKKeAJQEAnblvJ4fAtpolL7csXnDUT
XXjQruiCjPOtH3CAqowP43pm0O/7BxDFahN2l7aJ4HV2lyOcum46dLLtfw==jRk2ZM/mHKNEwNSNMQnC
F1IHTCT9CrSqMKNia5p3h1CWlrdp8rlAqA==HoQDgALw5wH6aBd4pFGHMGSJ2HrYGCmWoODuNME8PjU=
nhm7OYsfDOFQF3tPjrR+SAHbMNPLK4r7+O235tGnJ6M=pKDYEOnJANykBsKH27D1haKnNJGzT3OyHO38
KcCBunsHbpqGruwLJQmGuPNsq32/WSvk287c2/U=fKkTSiBlVVDpoNU/9g+U8FSlK1cT++idbRUQ344a
```

File #2 – Base64 decoded



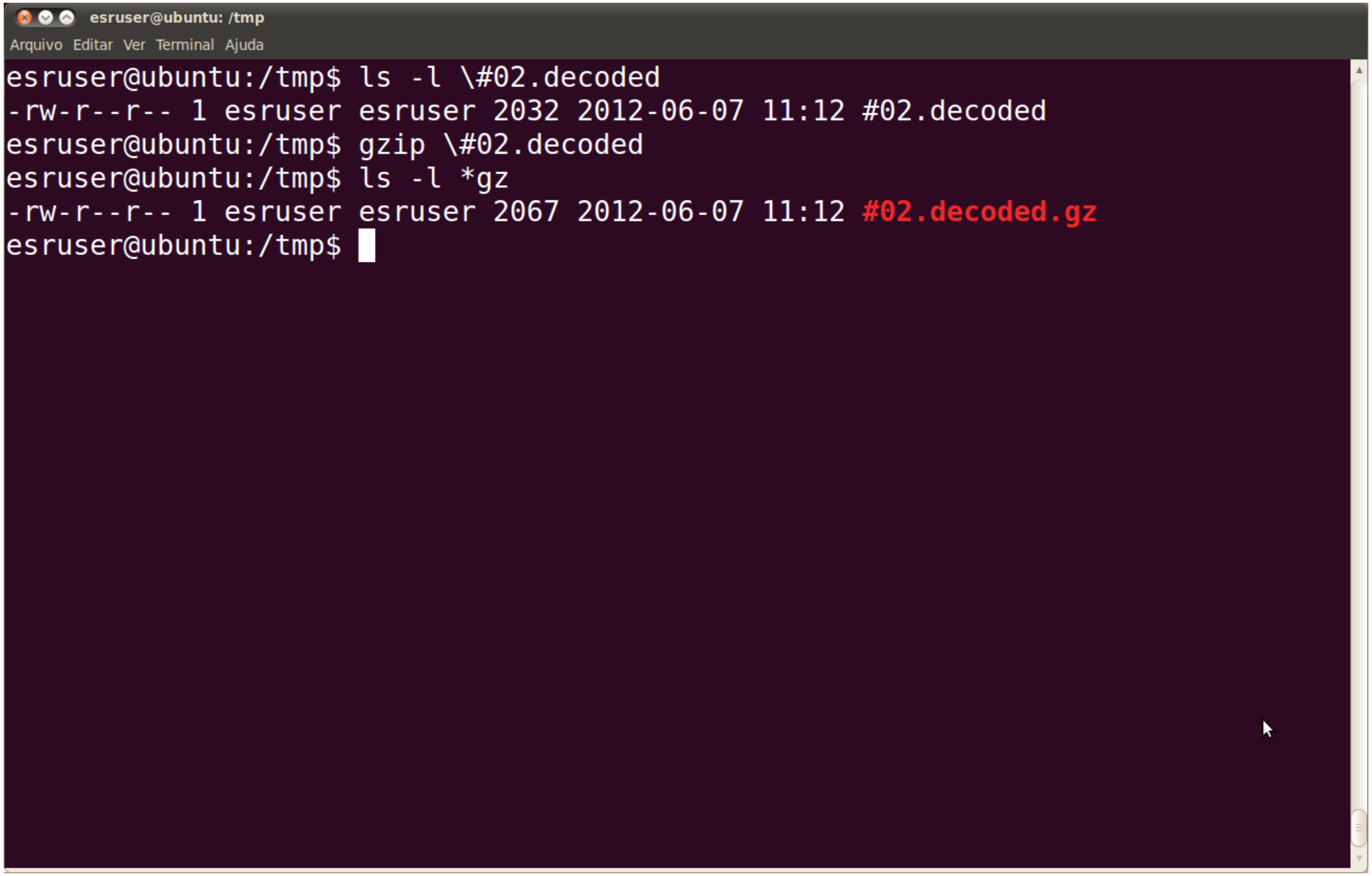
```
0000000088 F9 4A 47 92 DE 84 97 FA 14 FE 2C 59 20 E6 42  ..JG.......,Y .B
00000010F6 34 EC F7 19 8D 98 B9 59 2B E4 DB CE DC DB F5  .4......Y+......
0000002014 E4 DD A6 0B EB DA 81 9B C0 EC B5 6E 25 99 B8  ............n%..
00000030F9 43 32 02 50 D4 C1 90 EA 15 72 82 DC 67 0C 05  .C2.P.....r..g..
00000040EC 80 9D 1C 3F 7E 2D 56 5F B5 29 00 CD 15 53 C3  ....?~-V_.)...S.
00000050DB D2 8A 7C C8 C4 D8 C3 AC 3D 10 EE B1 71 FF 38  ...|.....=...q.8
0000006066 B7 6E 92 77 F6 07 9E F0 A9 8C 38 12 C5 45 03  f.n.w......8..E.
000000703B 8C 6C C2 5A 11 AF D7 0B 7B F6 55 F4 73 41 4D  ;.l.Z....{.U.sAM
0000008073 B0 C3 1A A2 AE DF 56 E8 B0 CF 8D 46 0B EF B5  s......V....F...
0000009023 3D C0 98 07 92 A8 54 47 0D 9E 83 11 07 B7 47  #=.....TG......G
000000A015 80 1F 3C FE F1 97 AE 1A 45 1A AE 0C 38 F0 70  ...<.....E...8.p
000000B0F7 2E 03 0A BD ED CA 70 A5 38 73 0C E1 99 43 0C  .......p.8s...C.
000000C03D 9F AE AB 9C 59 2E 4B C9 19 DF 91 A3 CC CE BC  =....Y.K........
000000D045 81 9E 44 77 4B 42 B5 9D AA 63 33 7C 92 6C 10  E..DwKB...c3|.l.
000000E007 1E CD D7 42 E6 FE BA 1F C6 6E 7E 96 AC 22 AC  ....B.....n~..".
000000F0FA 8A 97 5D 68 1D 2E 0D AB 5E D3 04 8A 28 36 96  ...]h....^...(6.
```

8 bits com sinal:	-120	32 bits com sinal:	1196095880	Hexadecimal:	88
8 bits sem sinal:	136	32 bits sem sinal:	1196095880	Octal:	210
16 bits com sinal:	-1656	Flutuante de 32 bits:	5.196153e+04	Binário:	10001000
16 bits sem sinal:	63880	Flutuante de 64 bits:	-2.233486e-195	Tamanho do fluxo:	8

☑ Mostrar decodificação little endian   ☐ Mostrar números sem sinal e flutuantes como hexadecimal

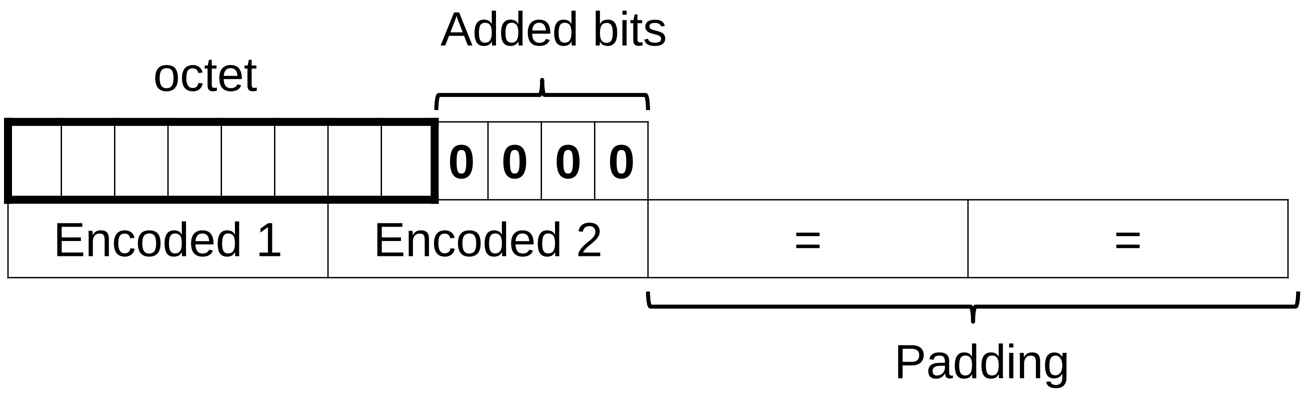
Deslocamento: 0

File #2 – Redundancy check



```
esruser@ubuntu:/tmp$ ls -l \#02.decoded
-rw-r--r-- 1 esruser esruser 2032 2012-06-07 11:12 #02.decoded
esruser@ubuntu:/tmp$ gzip \#02.decoded
esruser@ubuntu:/tmp$ ls -l *gz
-rw-r--r-- 1 esruser esruser 2067 2012-06-07 11:12 #02.decoded.gz
esruser@ubuntu:/tmp$ 
```

File #2 – Base64 review



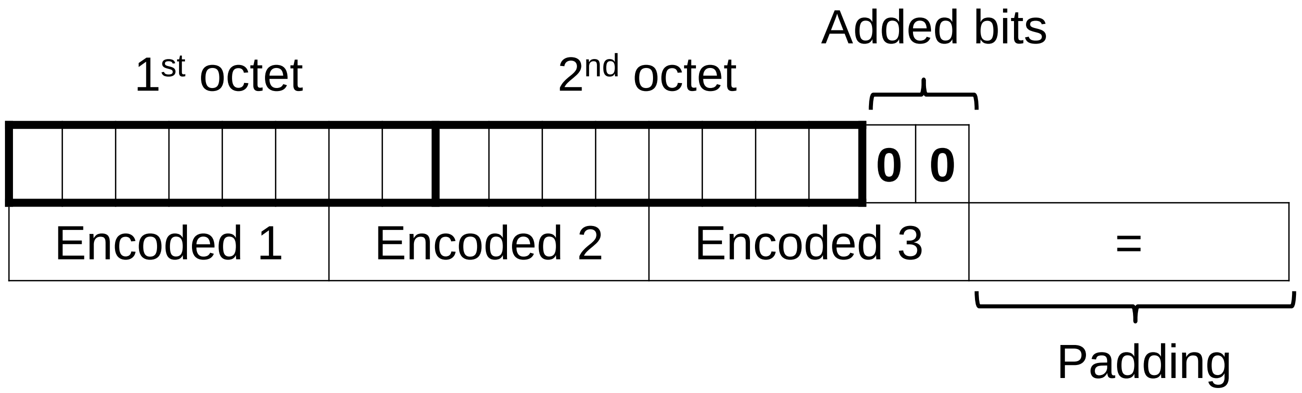
octet

Added bits

0 0 0 0

Encoded 1 | Encoded 2 | = | =

Padding



1st octet

2nd octet

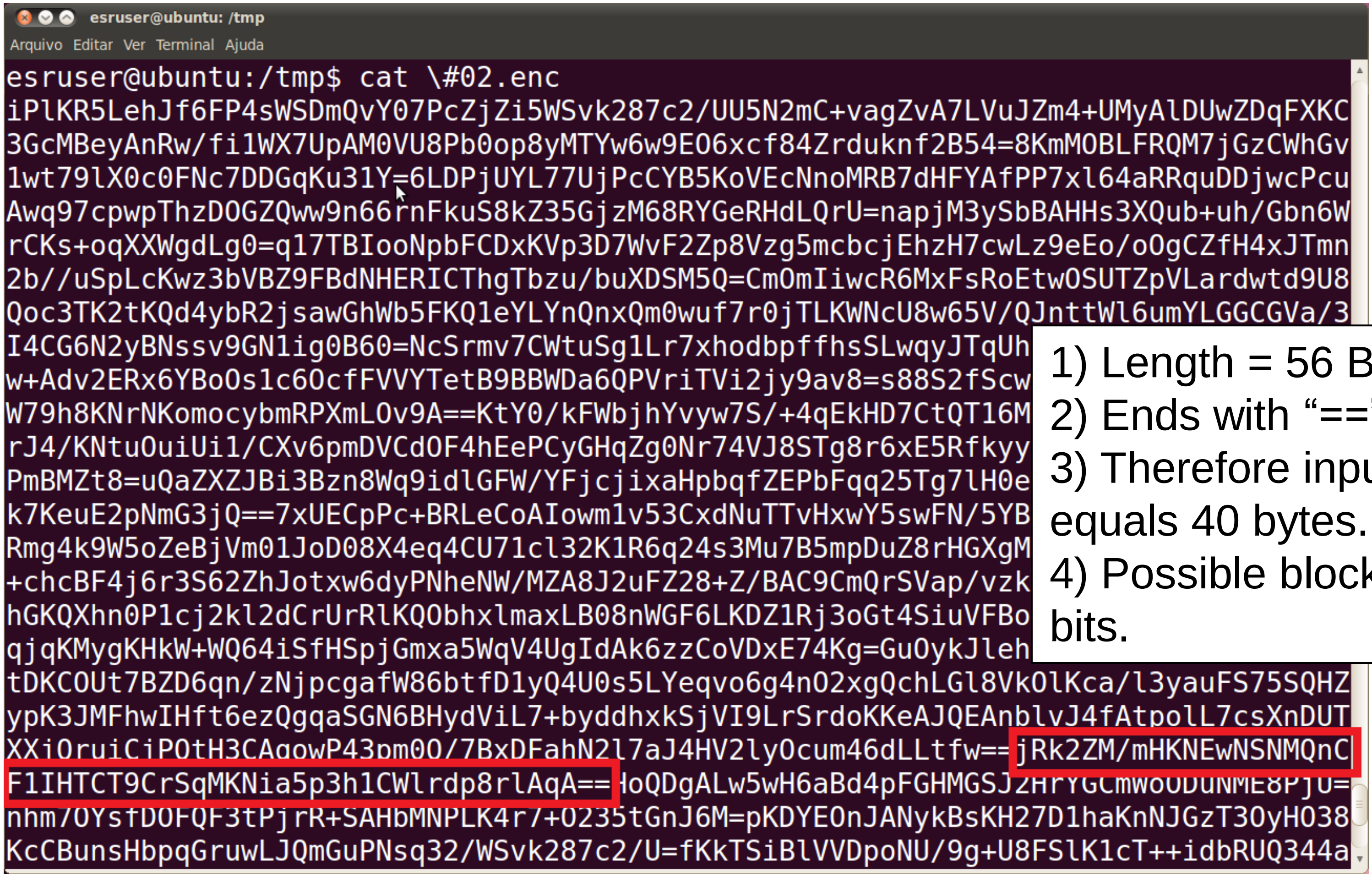
Added bits

0 0

Encoded 1 | Encoded 2 | Encoded 3 | =

Padding

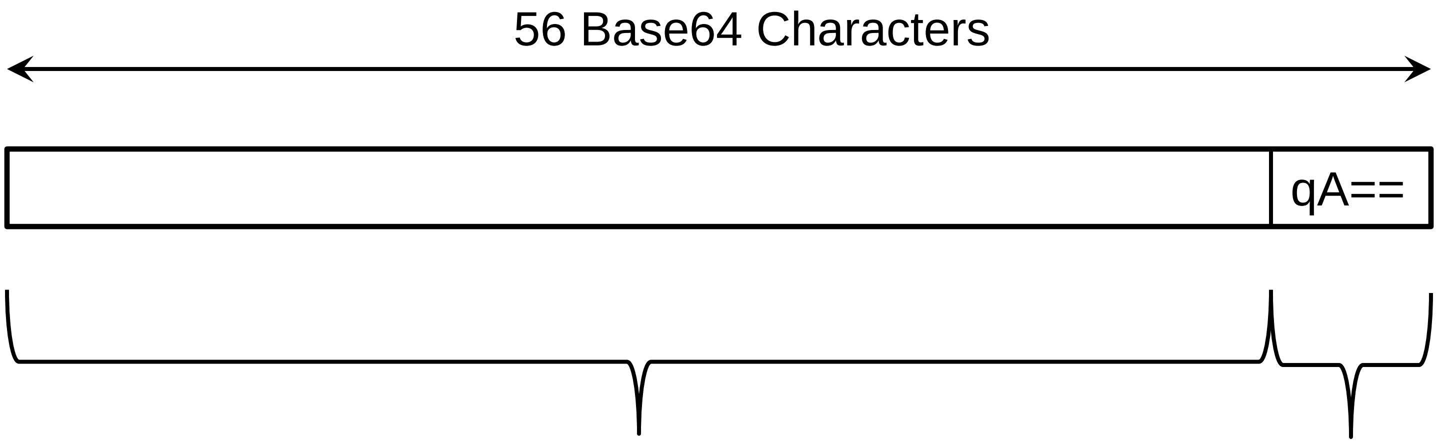
File #2 – Block size?



```
esruser@ubuntu:/tmp$ cat \#02.enc
iPlKR5LehJf6FP4sWSDmQvY07PcZjZi5WSvk287c2/UU5N2mC+vagZvA7LVuJZm4+UMyAlDUwZDqFXKC
3GcMBeyAnRw/fi1WX7UpAM0VU8Pb0op8yMTYw6w9EO6xcf84Zrduknf2B54=8KmMOBLFRQM7jGzCWhGv
1wt79lX0c0FNc7DDGqKu31Y=6LDPjUYL77UjPcCYB5KoVEcNnoMRB7dHFYAfPP7xl64aRRquDDjwcPcu
Awq97cpwpThzDOGZQww9n66rnFkuS8kZ35GjzM68RYGeRHdLQrU=napjM3ySbBAHHs3XQub+uh/Gbn6W
rCKs+oqXXWgdLg0=q17TBIooNpbFCDxKVp3D7WvF2Zp8Vzg5mcbcjEhzH7cwLz9eEo/oOgCZfH4xJTmn
2b//uSpLcKwz3bVBZ9FBdNHERICThgTbzu/buXDSM5Q=CmOmIiwcR6MxFsRoEtwOSUTZpVLardwtd9U8
Qoc3TK2tKQd4ybR2jsawGhWb5FKQ1eYLYnQnxQm0wuf7r0jTLKWNcU8w65V/QJnttWl6umYLGGCGVa/3
I4CG6N2yBNssv9GN1ig0B60=NcSrmv7CWtuSg1Lr7xhodbpffhsSLwqyJTqUh
w+Adv2ERx6YBoOs1c6OcfFVVYTetB9BBWDa6QPVriTVi2jy9av8=s88S2fScw
W79h8KNrNKomocybmRPXmLOv9A==KtY0/kFWbjhYvyw7S/+4qEkHD7CtQT16M
rJ4/KNtuOuiUi1/CXv6pmDVCdOF4hEePCyGHqZg0Nr74VJ8STg8r6xE5Rfkyy
PmBMZt8=uQaZXZJBi3Bzn8Wq9idlGFW/YFjcjixaHpbqfZEPbFqq25Tg7lH0e
k7KeuE2pNmG3jQ==7xUECpPc+BRLeCoAIowm1v53CxdNuTTvHxwY5swFN/5YB
Rmg4k9W5oZeBjVm01JoD08X4eq4CU71cl32K1R6q24s3Mu7B5mpDuZ8rHGXgM
+chcBF4j6r3S62ZhJotxw6dyPNheNW/MZA8J2uFZ28+Z/BAC9CmQrSVap/vzk
hGKQXhn0P1cj2kl2dCrUrRlKQObhxlmaxLB08nWGF6LKDZ1Rj3oGt4SiuVFBo
qjqKMygKHkW+WQ64iSfHSpjGmxa5WqV4UgIdAk6zzCoVDxE74Kg=GuOykJleh
tDKCOUt7BZD6qn/zNjpcgafW86btfD1yQ4U0s5LYeqvo6g4nO2xgQchLGl8VkOlKca/l3yauFS75SQHZ
ypK3JMFhwIHft6ezQgqaSGN6BHydViL7+byddhxkSjVI9LrSrdoKKeAJQEAnblvJ4fAtpolL7csXnDUT
XXiQruiCiPOtH3CAqowP43pm0O/7BxDFahN2l7aJ4HV2lyOcum46dLLtfw==jRk2ZM/mHKNEwNSNMQnC
F1IHTCT9CrSqMKNia5p3h1CWlrdp8rlAqA==HoQDgALw5wH6aBd4pFGHMGSJ2HrYGCmwoODUNME8PjU=
nhm7OYsfDOFQF3tPjrR+SAHbMNPLK4r7+O235tGnJ6M=pKDYEOnJANykBsKH27D1haKnNJGzT3OyHO38
KcCBunsHbpqGruwLJQmGuPNsq32/WSvk287c2/U=fKkTSiBlVVDpoNU/9g+U8FSlK1cT++idbRUQ344a
```

1) Length = 56 Base64 chars.
2) Ends with “==”.
3) Therefore input length equals 40 bytes.
4) Possible block size: 64 bits.

File #2 – Block size clarification



52 = 13 x 4

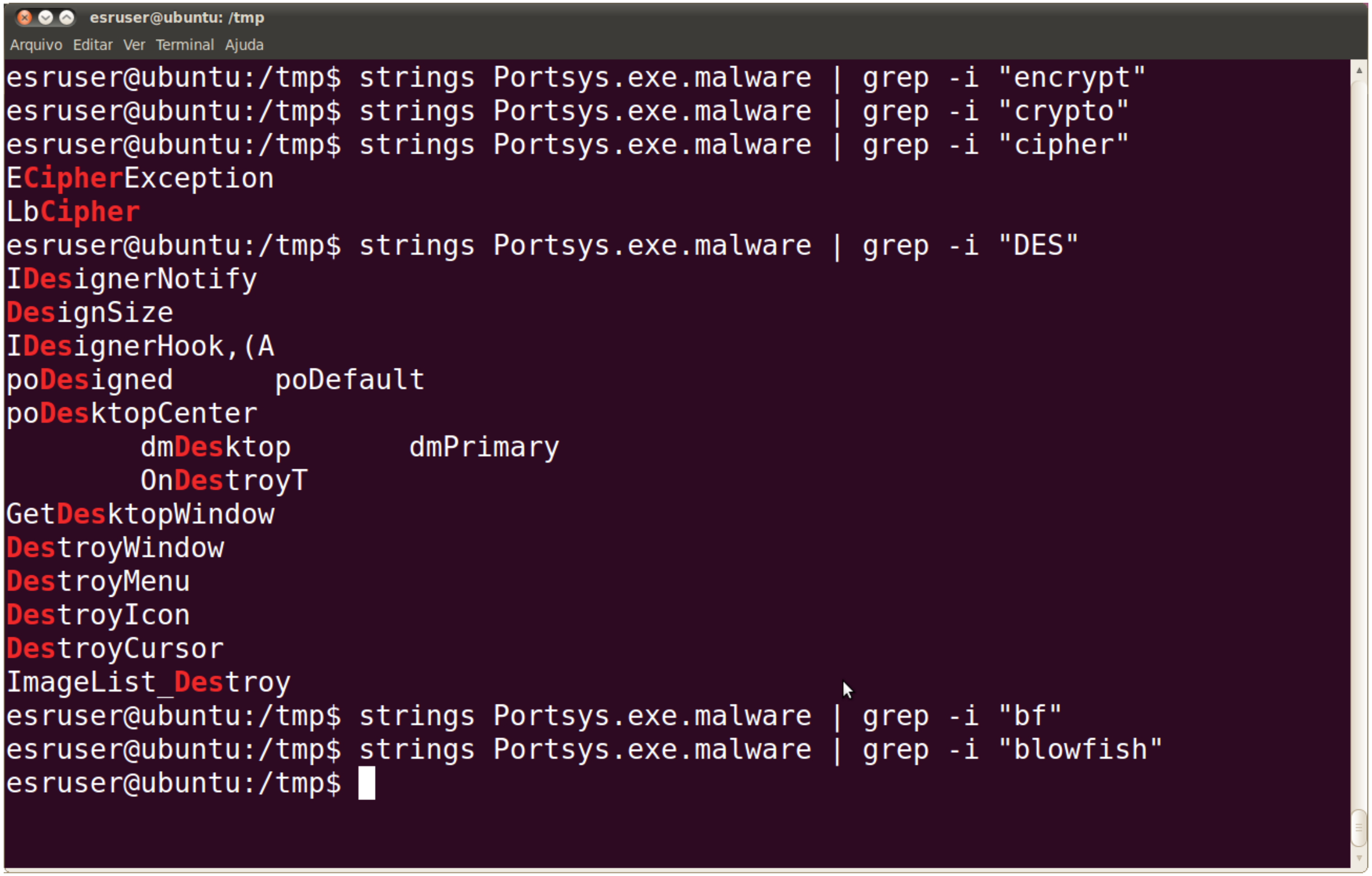
Since each group of 4 Base64 chars corresponds to 3 octets, we have 13 x 3 = **39 octets**

1 octet

File #2 – Candidate ciphers

- DES.
- 2TDES.
- 3TDES.
- FEAL.
- IDEA.
- SAFER.
- RC5.
- LOKI.
- Blowfish.

File #2 – String search



```
esruser@ubuntu:/tmp$ strings Portsys.exe.malware | grep -i "encrypt"
esruser@ubuntu:/tmp$ strings Portsys.exe.malware | grep -i "crypto"
esruser@ubuntu:/tmp$ strings Portsys.exe.malware | grep -i "cipher"
ECipherException
LbCipher
esruser@ubuntu:/tmp$ strings Portsys.exe.malware | grep -i "DES"
IDesignerNotify
DesignSize
IDesignerHook,(A
poDesigned      poDefault
poDesktopCenter
        dmDesktop       dmPrimary
        OnDestroyT
GetDesktopWindow
DestroyWindow
DestroyMenu
DestroyIcon
DestroyCursor
ImageList_Destroy
esruser@ubuntu:/tmp$ strings Portsys.exe.malware | grep -i "bf"
esruser@ubuntu:/tmp$ strings Portsys.exe.malware | grep -i "blowfish"
esruser@ubuntu:/tmp$
```

File #2 – Narrowing the options

- LbCipher is a library for Delphi.
- It implements the following algorithms from our list:
  - Blowfish (ECB, CBC).
  - DES (ECB, CBC).
  - 2TDES (ECB, CBC).
  - 3TDES (ECB, CBC).

File #2 – Starting with DES

- DES is a 64-bit block cipher.
- The cipher employs a 64-bit key of which only 56 bits are effective.
- Based on a Feistel network.
- It is possible to search the entire key space using special purpose hardware[1], which was first built in 1998.

File #2 – Inside DES (1)

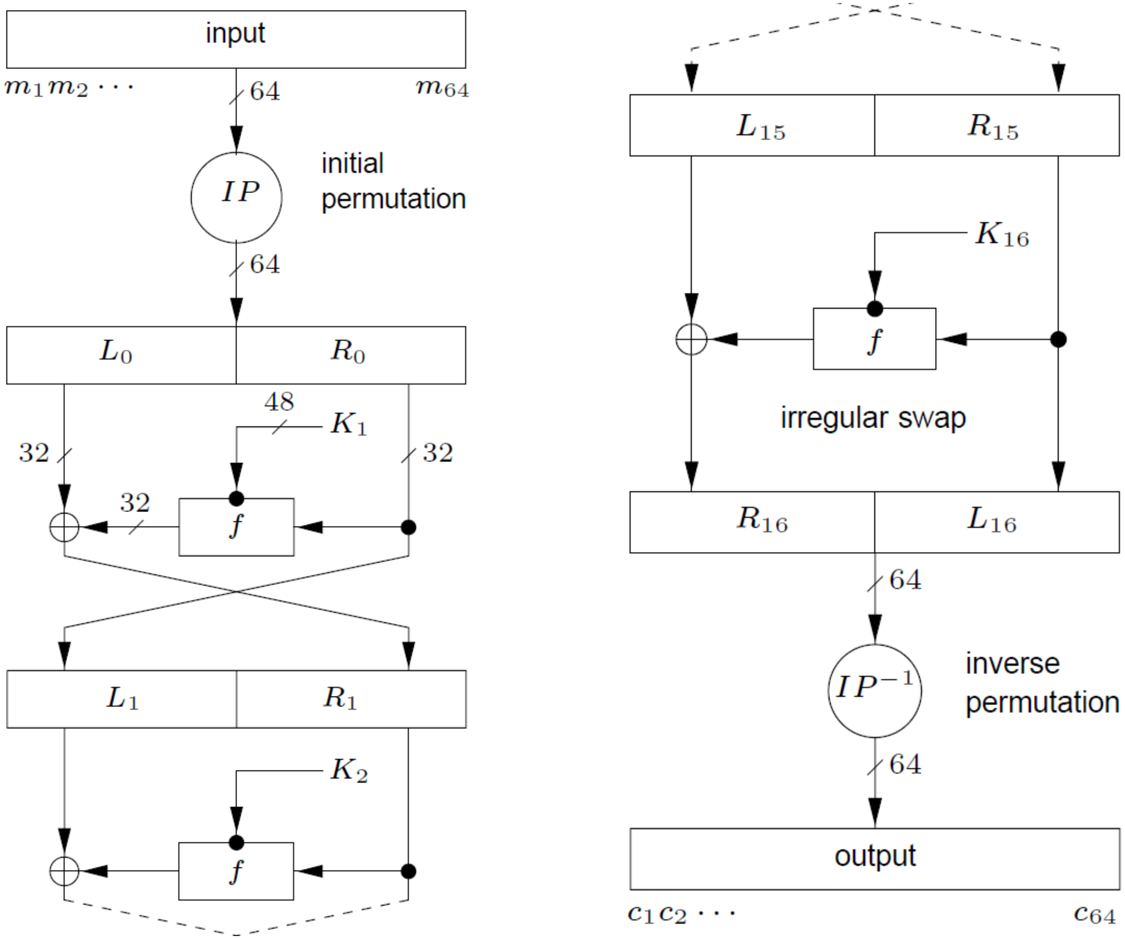
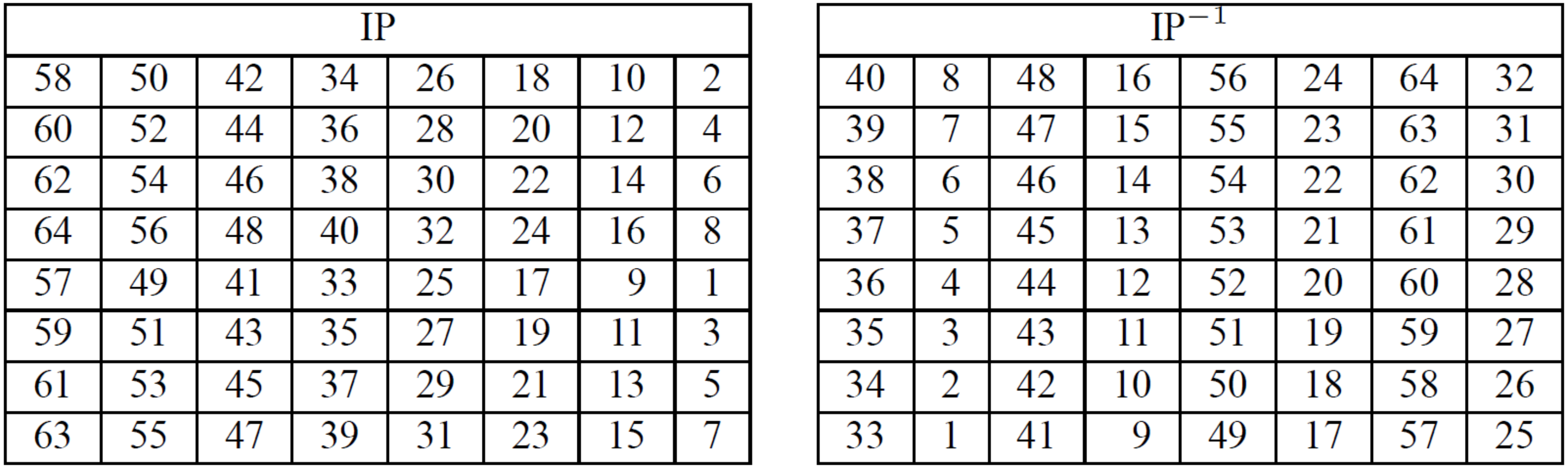


Figure: DES rounds.

Source: [2] HAC.

File #2 – Inside DES (2)



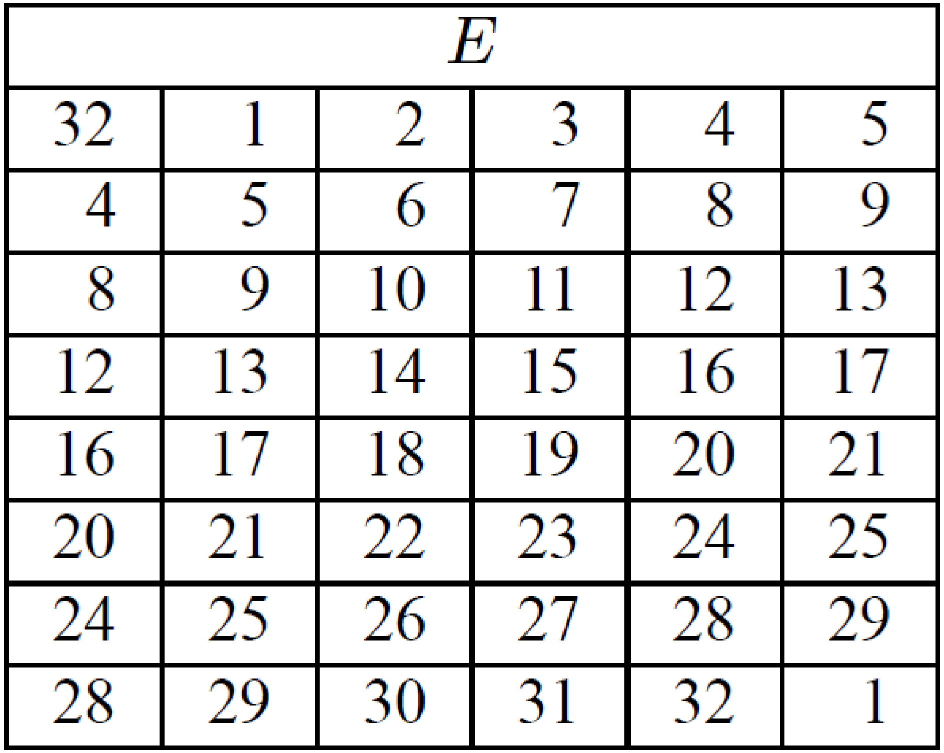
IP							
58	50	42	34	26	18	10	2
60	52	44	36	28	20	12	4
62	54	46	38	30	22	14	6
64	56	48	40	32	24	16	8
57	49	41	33	25	17	9	1
59	51	43	35	27	19	11	3
61	53	45	37	29	21	13	5
63	55	47	39	31	23	15	7

IP^{-1}							
40	8	48	16	56	24	64	32
39	7	47	15	55	23	63	31
38	6	46	14	54	22	62	30
37	5	45	13	53	21	61	29
36	4	44	12	52	20	60	28
35	3	43	11	51	19	59	27
34	2	42	10	50	18	58	26
33	1	41	9	49	17	57	25

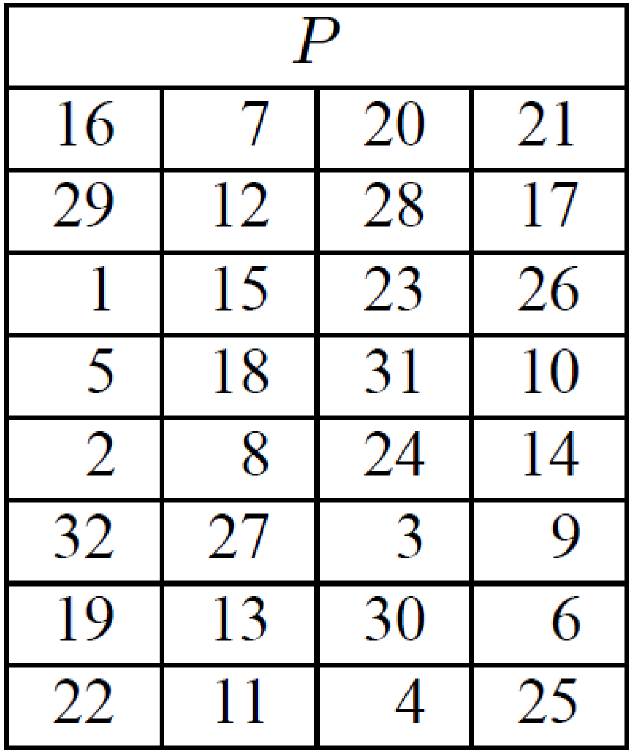
Figure: DES initial permutation and inverse.

Source: [2] HAC.

File #2 – Inside DES (3)



E					
32	1	2	3	4	5
4	5	6	7	8	9
8	9	10	11	12	13
12	13	14	15	16	17
16	17	18	19	20	21
20	21	22	23	24	25
24	25	26	27	28	29
28	29	30	31	32	1

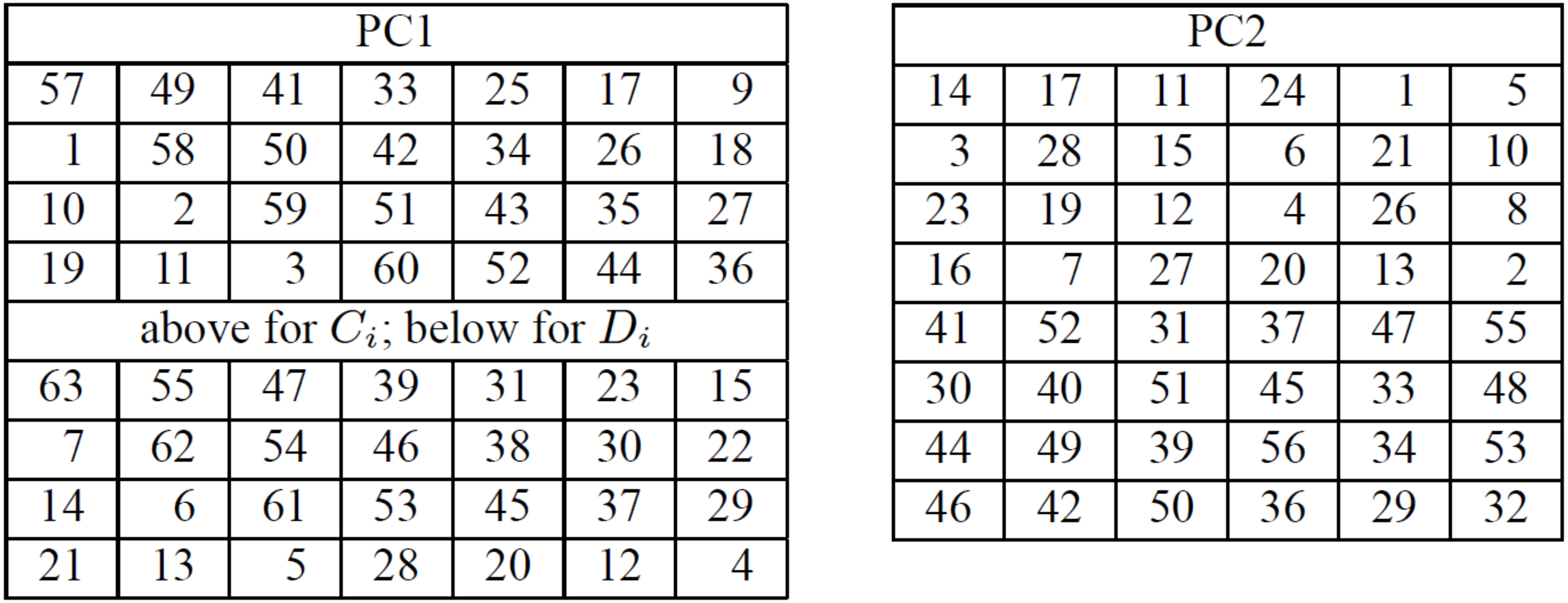


P			
16	7	20	21
29	12	28	17
1	15	23	26
5	18	31	10
2	8	24	14
32	27	3	9
19	13	30	6
22	11	4	25

Figure: DES round function expansion E and permutation P.

Source: [2] HAC.

File #2 – Inside DES (4)



PC1						
57	49	41	33	25	17	9
1	58	50	42	34	26	18
10	2	59	51	43	35	27
19	11	3	60	52	44	36
above for C_i; below for D_i						
63	55	47	39	31	23	15
7	62	54	46	38	30	22
14	6	61	53	45	37	29
21	13	5	28	20	12	4

PC2					
14	17	11	24	1	5
3	28	15	6	21	10
23	19	12	4	26	8
16	7	27	20	13	2
41	52	31	37	47	55
30	40	51	45	33	48
44	49	39	56	34	53
46	42	50	36	29	32

Figure: DES key schedule bit selections.

Source: [2] HAC.

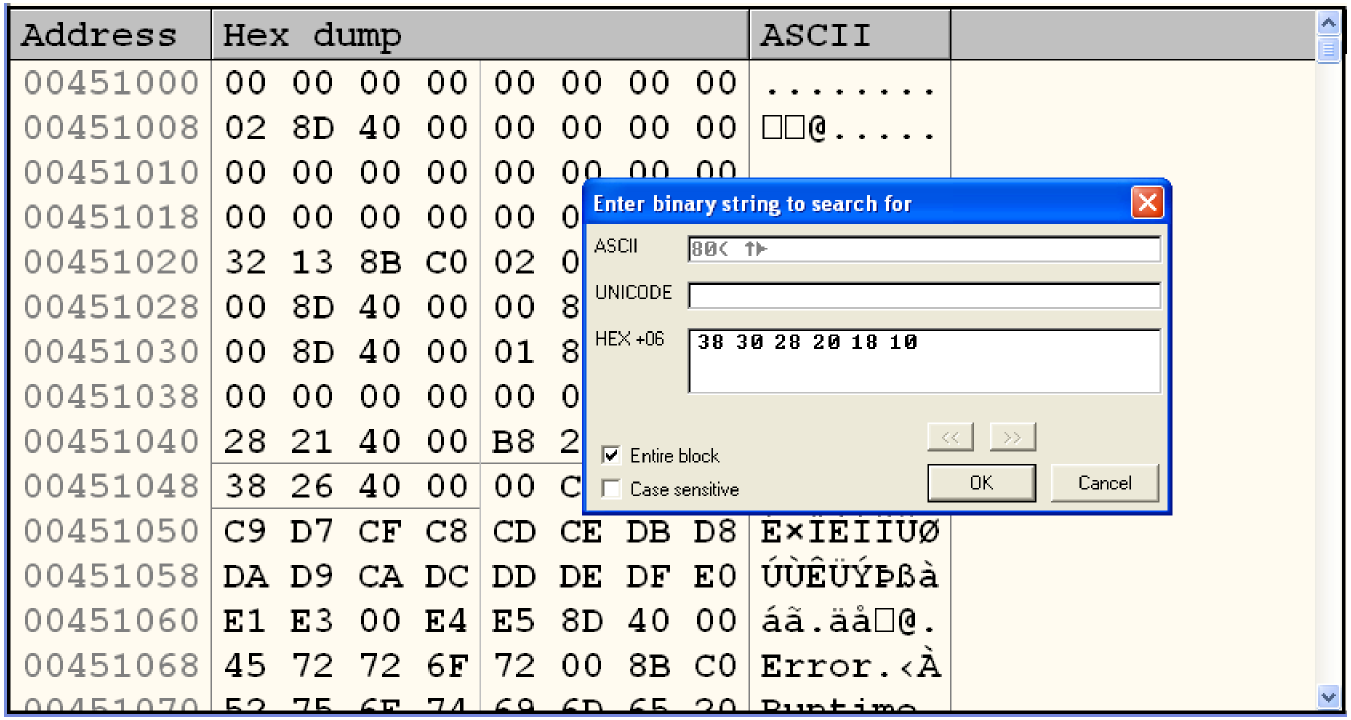
File #2 – From LbCipher

```
procedure InitEncryptDES(const Key : TKey64;
                         var Context : TDESContext;
                         Encrypt : Boolean);
const
PC1 : array [0..55] of Byte = (56, 48, 40, 32, 24,
16, 8, 0, 57, 49, 41, 33, 25, 17, 9, 1, 58, 50, 42,
34, 26, 18, 10, 2, 59, 51, 43, 35, 62, 54, 46, 38,
30, 22, 14, 6, 61, 53, 45, 37, 29, 21, 13, 5, 60,
52, 44, 36, 28, 20, 12, 4, 27, 19, 11, 3);
PC2 : array [0..47] of Byte = (13, 16, 10, 23, 0, 4,
2, 27, 14, 5, 20, 9, 22, 18, 11, 3, 25, 7, 15, 6,
26, 19, 12, 1, 40, 51, 30, 36, 46, 54, 29, 39, 50,
44, 32, 47, 43, 48, 38, 55, 33, 52, 45, 41, 49, 35,
28, 31);
```

File #2 – Next steps

- Load the malware in OllyDbg.
- Search for PC1 and use it to locate the address of InitEncryptDES, if present.
- Set a breakpoint in that address.
- Run the malware.
- Extract the key from the first parameter.

File #2 – Finding PC1 (1)



```
Address   Hex dump                  ASCII
00451000  00 00 00 00 00 00 00 00   ........
00451008  02 8D 40 00 00 00 00 00   □□@.....
00451010  00 00 00 00 00 00 00 00
00451018  00 00 00 00 00 0
00451020  32 13 8B C0 02 0
00451028  00 8D 40 00 00 8
00451030  00 8D 40 00 01 8
00451038  00 00 00 00 00 0
00451040  28 21 40 00 B8 2
00451048  38 26 40 00 00 C
00451050  C9 D7 CF C8 CD CE DB D8   E×IEIIUØ
00451058  DA D9 CA DC DD DE DF E0   ÚÙÊÜÝÞßà
00451060  E1 E3 00 E4 E5 8D 40 00   áã.äå□@.
00451068  45 72 72 6F 72 00 8B C0   Error.<À
00451070  52 75 6E 74 69 6D 65 20   Runtime
```

Enter binary string to search for

ASCII: 80< ↑▸

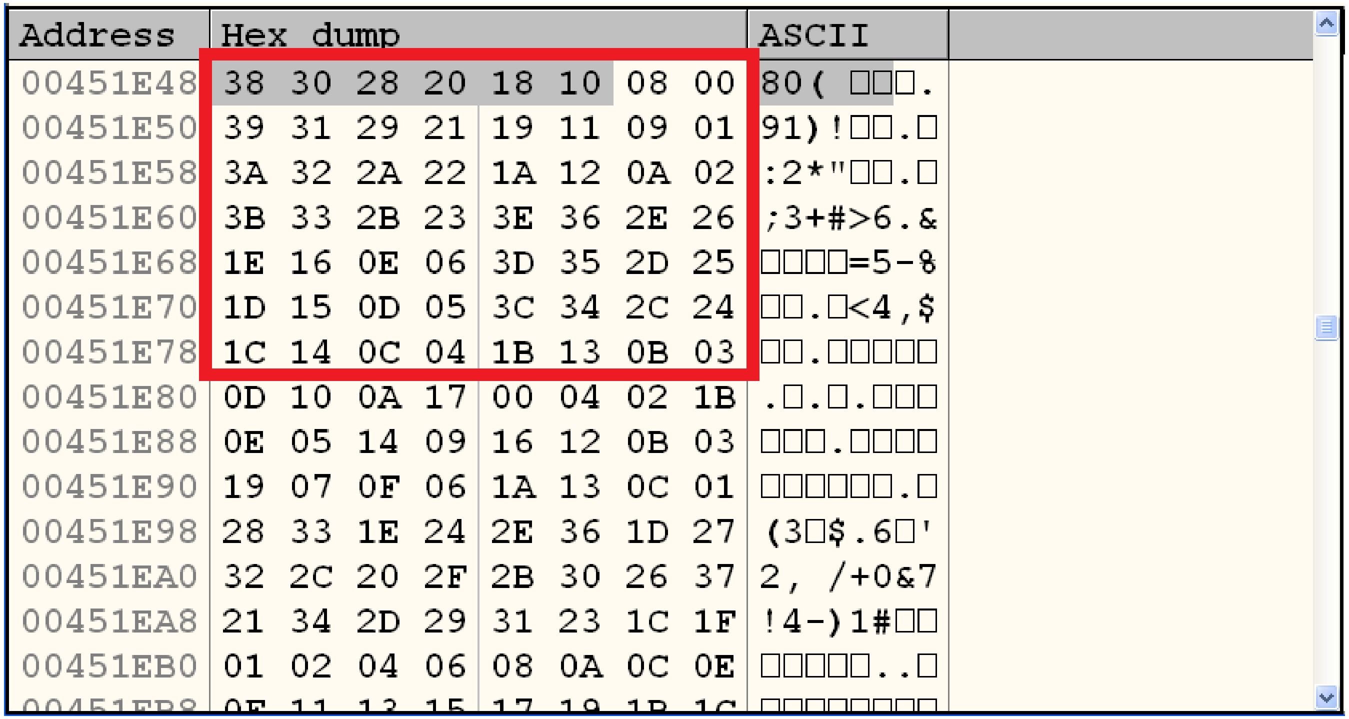
UNICODE:

HEX +06: 38 30 28 20 18 10

☑ Entire block

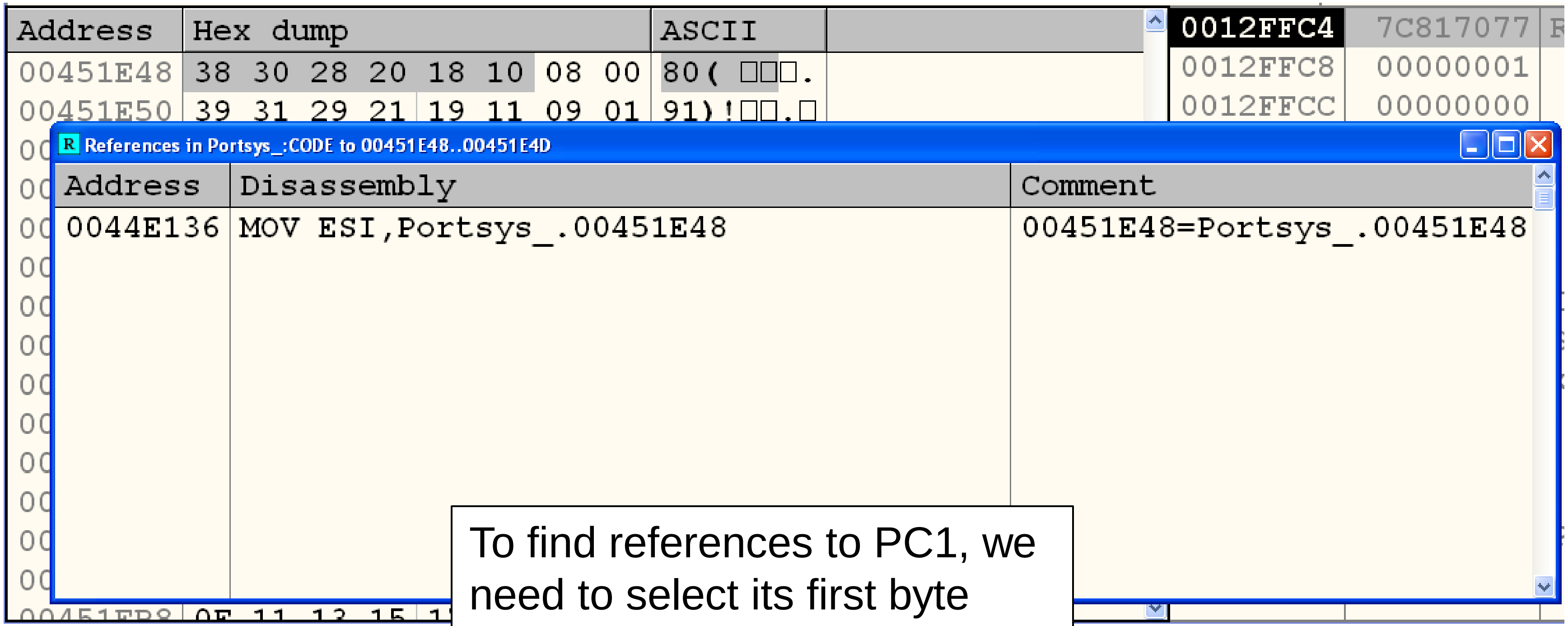
☐ Case sensitive

File #2 – Finding PC1 (2)



```
Address   Hex dump                  ASCII
00451E48  38 30 28 20 18 10 08 00  80( □□□.
00451E50  39 31 29 21 19 11 09 01  91)!□□.□
00451E58  3A 32 2A 22 1A 12 0A 02  :2*"□□.□
00451E60  3B 33 2B 23 3E 36 2E 26  ;3+#>6.&
00451E68  1E 16 0E 06 3D 35 2D 25  □□□□=5-%
00451E70  1D 15 0D 05 3C 34 2C 24  □□.□<4,$
00451E78  1C 14 0C 04 1B 13 0B 03  □□.□□□□□
00451E80  0D 10 0A 17 00 04 02 1B  .□.□.□□□
00451E88  0E 05 14 09 16 12 0B 03  □□□.□□□□
00451E90  19 07 0F 06 1A 13 0C 01  □□□□□□.□
00451E98  28 33 1E 24 2E 36 1D 27  (3□$.6□'
00451EA0  32 2C 20 2F 2B 30 26 37  2, /+0&7
00451EA8  21 34 2D 29 31 23 1C 1F  !4-)1#□□
00451EB0  01 02 04 06 08 0A 0C 0E  □□□□□..□
00451EB8  0F 11 13 15 17 19 1B 1C  □□□□□□□□
```

File #2 – References



```
Address   Hex dump                  ASCII
00451E48  38 30 28 20 18 10 08 00   80( □□□.
00451E50  39 31 29 21 19 11 09 01   91)!□□.□
```

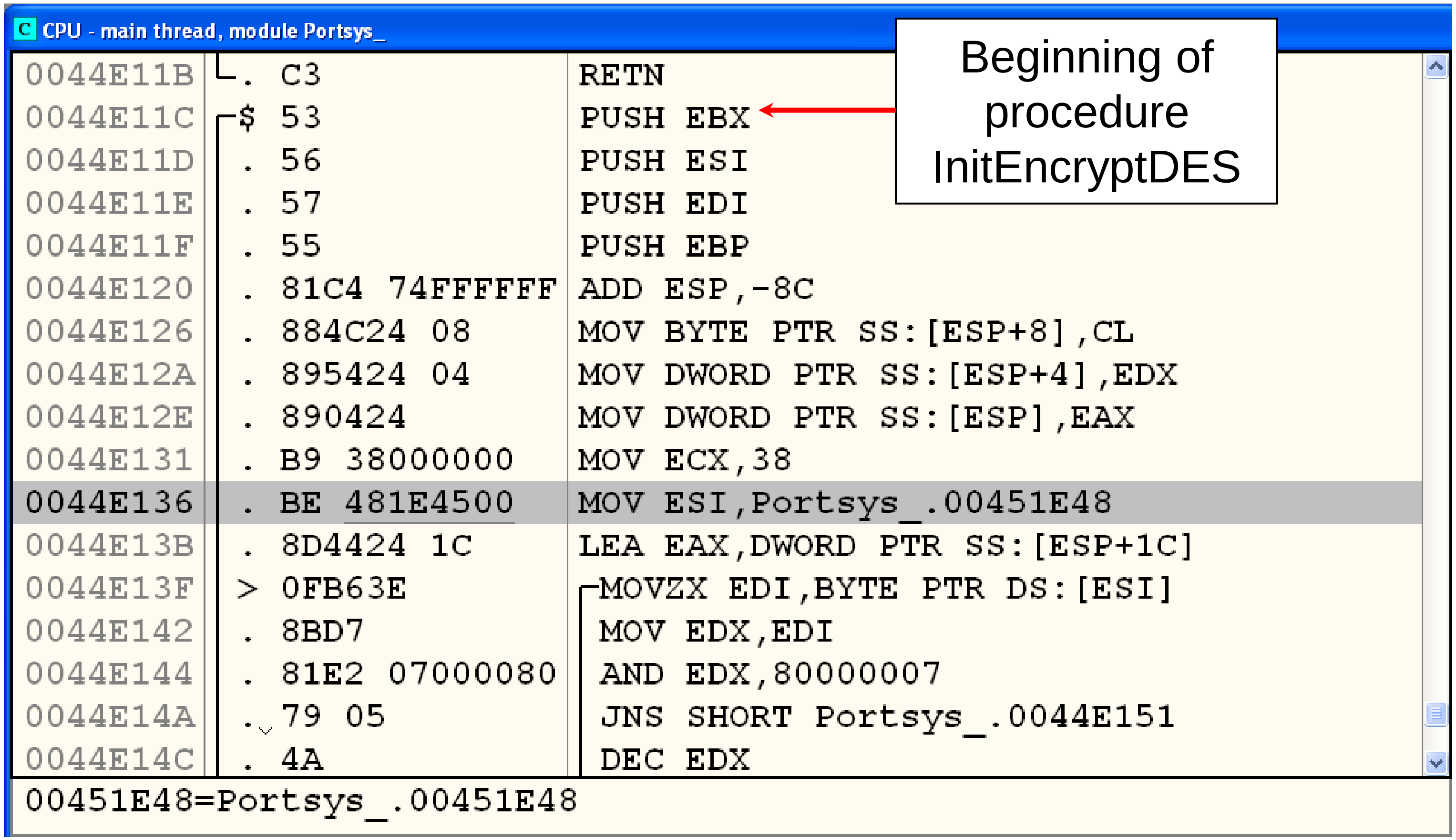
```
0012FFC4  7C817077
0012FFC8  00000001
0012FFCC  00000000
```

References in Portsys_:CODE to 00451E48..00451E4D

```
Address   Disassembly                Comment
0044E136  MOV ESI,Portsys_.00451E48  00451E48=Portsys_.00451E48
```

To find references to PC1, we need to select its first byte (0x38) and press Ctrl+R.

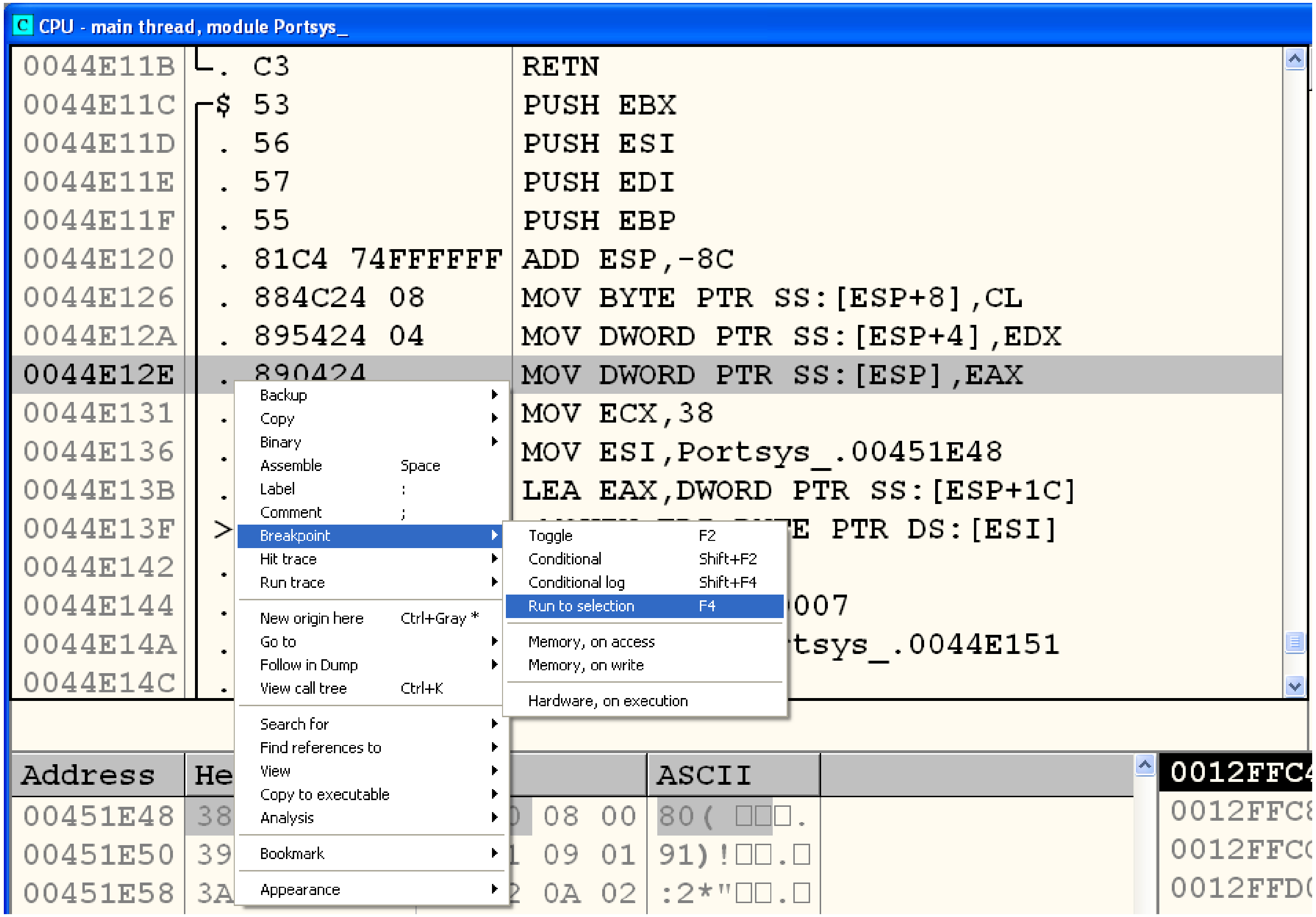
File #2 - Beginning of the function



```
0044E11B └. C3              RETN
0044E11C ┌$ 53              PUSH EBX
0044E11D │. 56              PUSH ESI
0044E11E │. 57              PUSH EDI
0044E11F │. 55              PUSH EBP
0044E120 │. 81C4 74FFFFFF   ADD ESP,-8C
0044E126 │. 884C24 08       MOV BYTE PTR SS:[ESP+8],CL
0044E12A │. 895424 04       MOV DWORD PTR SS:[ESP+4],EDX
0044E12E │. 890424          MOV DWORD PTR SS:[ESP],EAX
0044E131 │. B9 38000000     MOV ECX,38
0044E136 │. BE 481E4500     MOV ESI,Portsys_.00451E48
0044E13B │. 8D4424 1C       LEA EAX,DWORD PTR SS:[ESP+1C]
0044E13F │> 0FB63E          ┌MOVZX EDI,BYTE PTR DS:[ESI]
0044E142 │. 8BD7            │MOV EDX,EDI
0044E144 │. 81E2 07000080   │AND EDX,80000007
0044E14A │.⌄79 05           │JNS SHORT Portsys_.0044E151
0044E14C │. 4A              │DEC EDX
00451E48=Portsys_.00451E48
```

Beginning of procedure InitEncryptDES

File #2 – Running the malware



CPU - main thread, module Portsys_

```
0044E11B └.  C3            RETN
0044E11C ┌$  53            PUSH EBX
0044E11D │.  56            PUSH ESI
0044E11E │.  57            PUSH EDI
0044E11F │.  55            PUSH EBP
0044E120 │.  81C4 74FFFFFF ADD ESP,-8C
0044E126 │.  884C24 08     MOV BYTE PTR SS:[ESP+8],CL
0044E12A │.  895424 04     MOV DWORD PTR SS:[ESP+4],EDX
0044E12E │.  890424        MOV DWORD PTR SS:[ESP],EAX
0044E131 │.                MOV ECX,38
0044E136 │.                MOV ESI,Portsys_.00451E48
0044E13B │.                LEA EAX,DWORD PTR SS:[ESP+1C]
0044E13F │>                              E PTR DS:[ESI]
0044E142 │.
0044E144 │.                             007
0044E14A │.                             tsys_.0044E151
0044E14C │.
```

```
Address  He                        ASCII
00451E48 38                 08 00  80(
00451E50 39                 09 01  91)!  .
00451E58 3A                 0A 02  :2*"  .
```

```
0012FFC4
0012FFC8
0012FFCC
0012FFD0
```

File #2 – Which parameter?

- Remember the procedure signature is as follows:

```
procedure InitEncryptDES(
    const Key : TKey64;
    var Context : TDESContext;
    Encrypt : Boolean);
```

- `TKey64` definition:

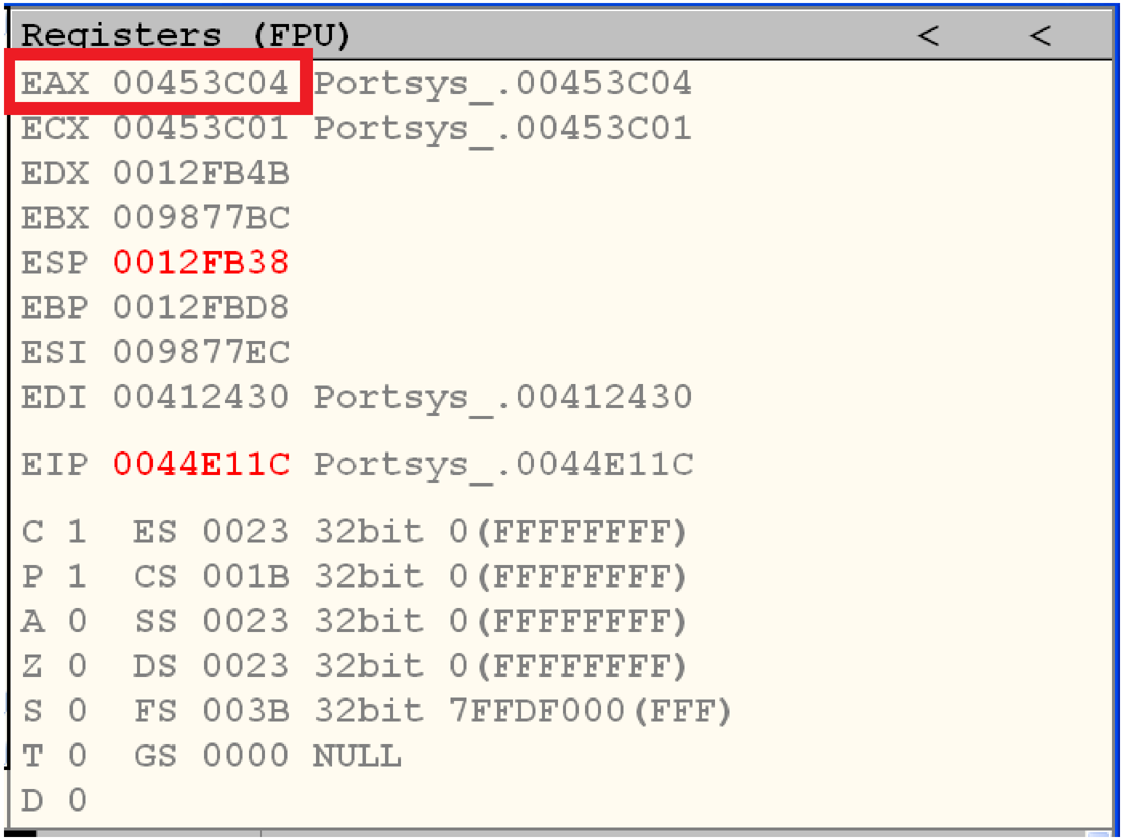
```
TKey64  = array [0..7] of Byte;
```

- A `TKey64` value can not be stored by a single register in a 32-bit architecture.

File #2 – Calling convention

- Delphi’s calling convention (left-to-right):
  - 1st parameter: EAX.
  - 2nd parameter: EDX.
  - 3rd parameter: ECX.
  - Remaining parameters: stack.

File #2 – Key address

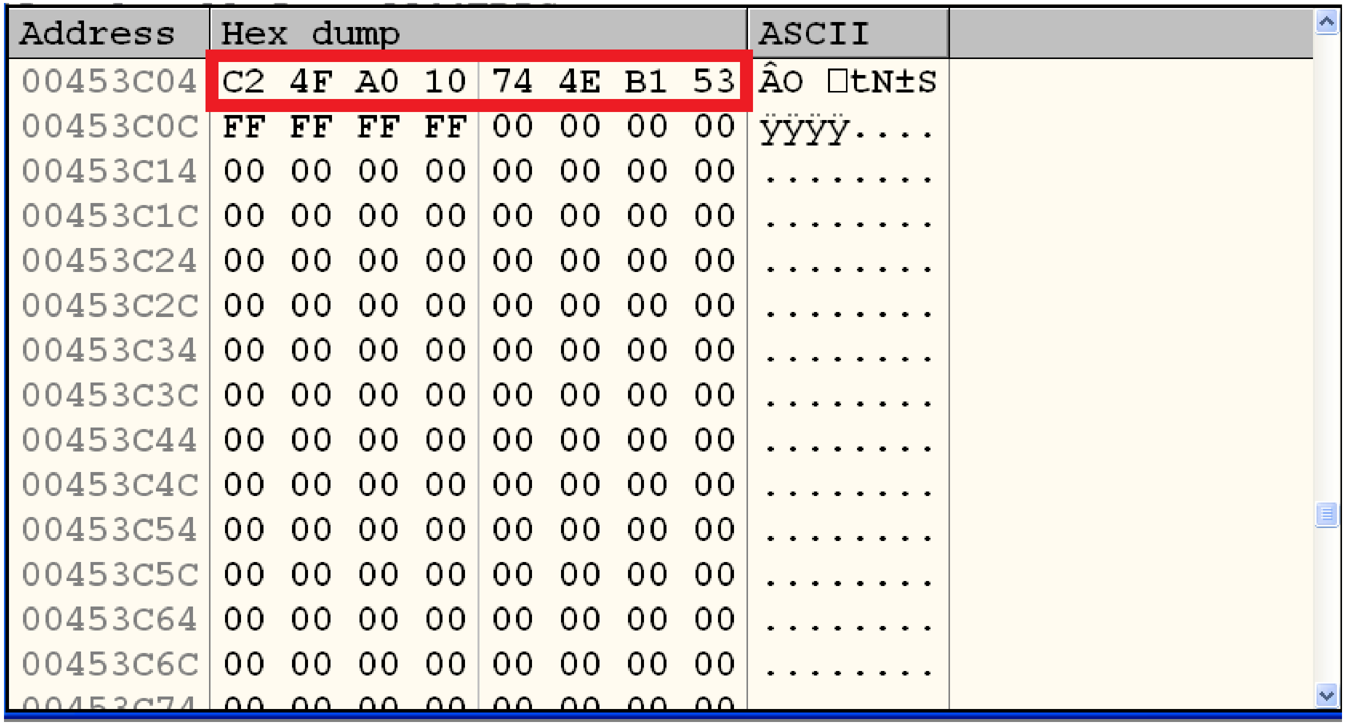


```
Registers (FPU)                                 <    <
EAX 00453C04 Portsys_.00453C04
ECX 00453C01 Portsys_.00453C01
EDX 0012FB4B
EBX 009877BC
ESP 0012FB38
EBP 0012FBD8
ESI 009877EC
EDI 00412430 Portsys_.00412430

EIP 0044E11C Portsys_.0044E11C

C 1  ES 0023 32bit 0(FFFFFFFF)
P 1  CS 001B 32bit 0(FFFFFFFF)
A 0  SS 0023 32bit 0(FFFFFFFF)
Z 0  DS 0023 32bit 0(FFFFFFFF)
S 0  FS 003B 32bit 7FFDF000(FFF)
T 0  GS 0000 NULL
D 0
```

File #2 – Key value



```
Address   Hex dump                 ASCII
00453C04  C2 4F A0 10 74 4E B1 53  ÂO □tN±S
00453C0C  FF FF FF FF 00 00 00 00  ÿÿÿÿ....
00453C14  00 00 00 00 00 00 00 00  ........
00453C1C  00 00 00 00 00 00 00 00  ........
00453C24  00 00 00 00 00 00 00 00  ........
00453C2C  00 00 00 00 00 00 00 00  ........
00453C34  00 00 00 00 00 00 00 00  ........
00453C3C  00 00 00 00 00 00 00 00  ........
00453C44  00 00 00 00 00 00 00 00  ........
00453C4C  00 00 00 00 00 00 00 00  ........
00453C54  00 00 00 00 00 00 00 00  ........
00453C5C  00 00 00 00 00 00 00 00  ........
00453C64  00 00 00 00 00 00 00 00  ........
00453C6C  00 00 00 00 00 00 00 00  ........
00453C74  00 00 00 00 00 00 00 00
```

File #2 – Description of cipher

- **Encryption algorithm:** DES.
- **Mode of operation:** ECB.
- **Key:** K = 0xc24fa010744eb153

Alternative for finding keys

- A properly generated key is entropic.
- Information, on the other hand, is structured.
- Based on those facts, in 1999, Shamir and Someren[3] proposed a way of finding stored keys.
- The basic idea is to traverse memory and identify the region with more entropy.
- One way of doing that is to set a window size and count the number of different elements on each window.

File #3 – Sample

```
50E96823#0851CDA207333E24 1.0.6 St - P: 6 R: 11
CFT:1.0.2
PA: 3
C3@158BF7627CD2750FF53D7288C863F7C7041221CD8E77B6A7F7833815075091A
23EB3ADA2352ADFE9514952DE6DF8B619D41E51DFB7C0196A104F994920E243471
6699DEF0DA48E624CEC0953F7BE159E0B43F3862C4A8D8FE1476F7939F72F99A04
9CAC2DC1DE0E6BB91066FF3E920283A373E8B94DF3D39F06FCB6A29B9E5DCF20A
0D02DE8F288F5C2737D1D64E1E25AA51A42C0AAE3ABFE354EBCE781342A6D8441
3391F4038EDB213AA87870D25FC06DD05DBF3EEB684665A7E20C080F196BA42D96
CFE0FA08FF64FF9B3C08CA3765768EDCBEDF620562ADB442C6A1191A1A137E50C
7F75C629AEB702F09F81107
PF: 3
50E96832#K@881A6DC9E4470F
50E96837#K@06BB
50E9683C#K@3FE759EE
```

References

- [1] Electronic Frontier Foundation, *Cracking Des: Secrets of Encryption Research, Wiretap Politics & Chip Design*, O'Reilly Media, 1998.
- [2] Menezes, A., van Oorschot, P, and Vanstone, S., *Handbook of Applied Cryptography*, CRC Press, 2001.
- [3] Shamir, A. and van Someren,N., *Playing "Hide and Seek" with Stored Keys*, in FC'99 Proc. of the 3rd Intl. Conference on Financial Cryptography, 1999.

Thank you for listening!

Questions?

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