Introduction to 8086 Assembly

Lecture 20

x86 floating point

Floating point operations

- Floating point libraries
- Math coprocessor (floating point coprocessor, floating point unit FPU)
  - add-on
  - Integrated

Intel 8087 coprocessor

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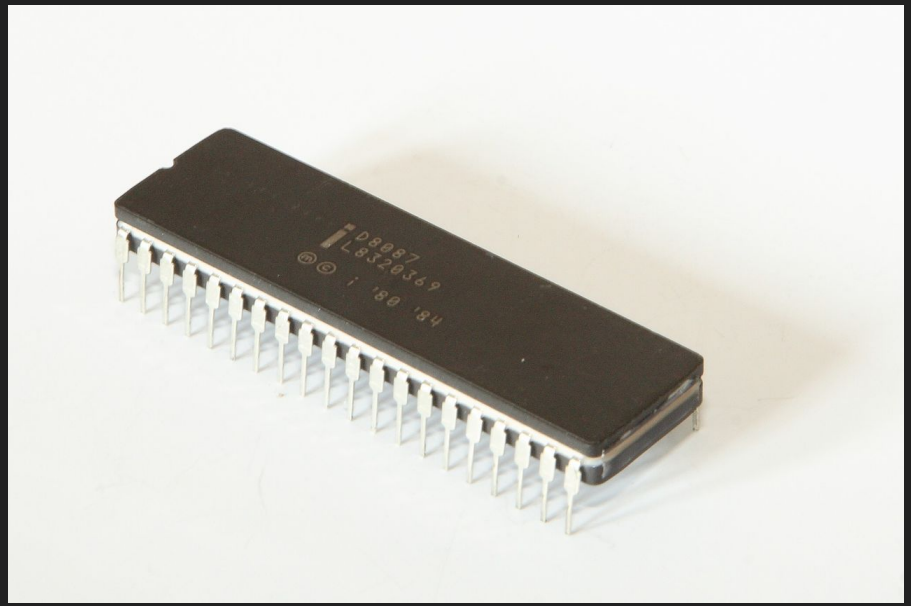

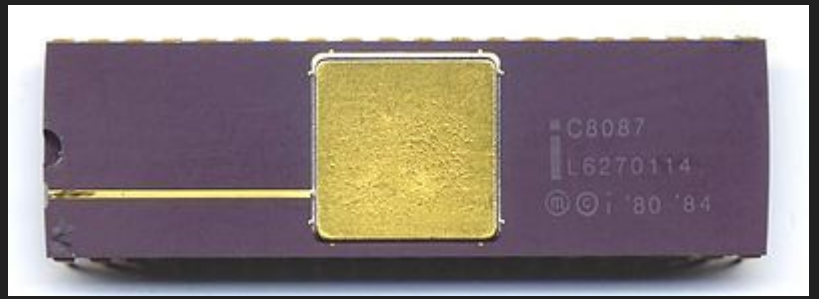

https://en.wikipedia.org/wiki/Intel_8087

Intel 8087 coprocessor

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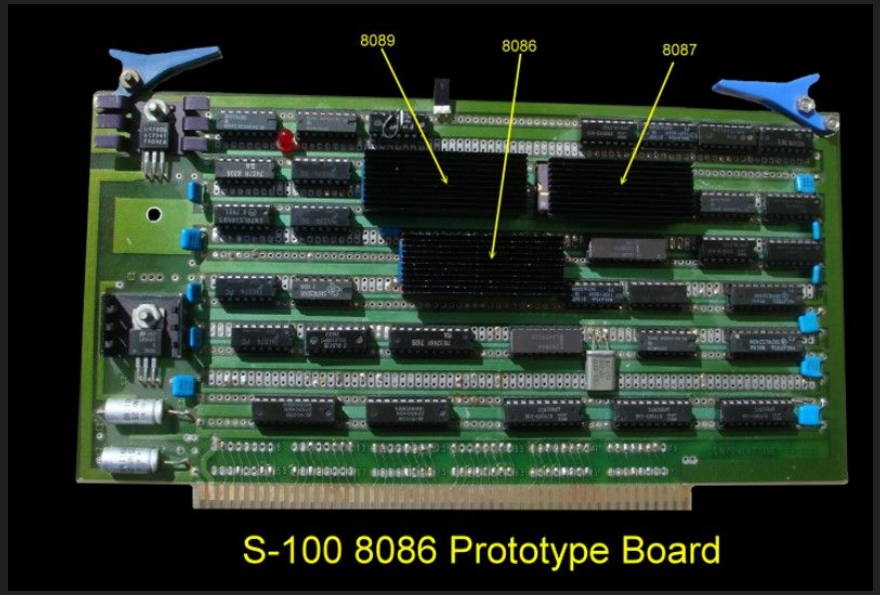
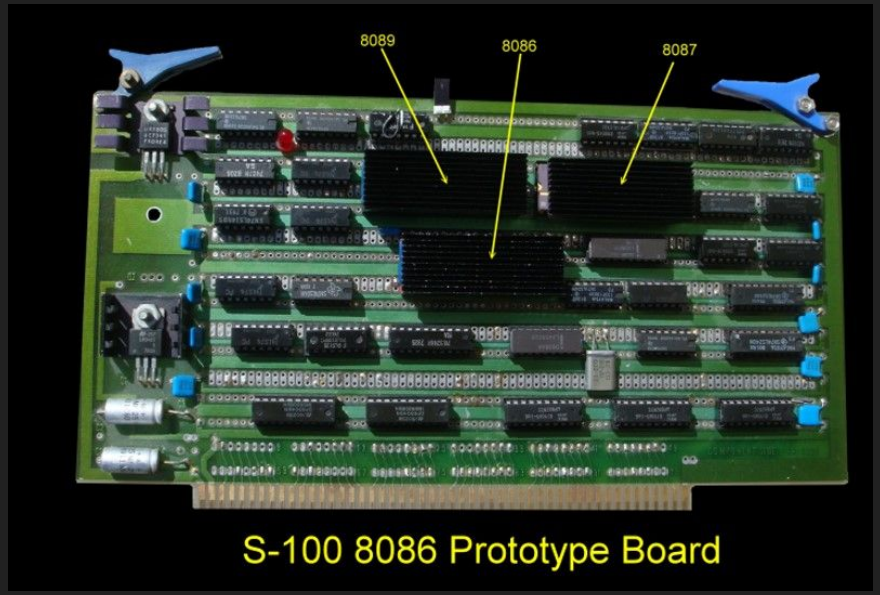


http://www.s100computers.com/My%20System%20Pages/8086%20Board/8086%20CPU%20Board.htm

Intel 8087 coprocessor



http://www.s100computers.com/My%20System%20Pages/8086%20Board/8086%20CPU%20Board.htm

http://7review.com/remembering-maths-coprocessor/

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Intel x87 extended precision

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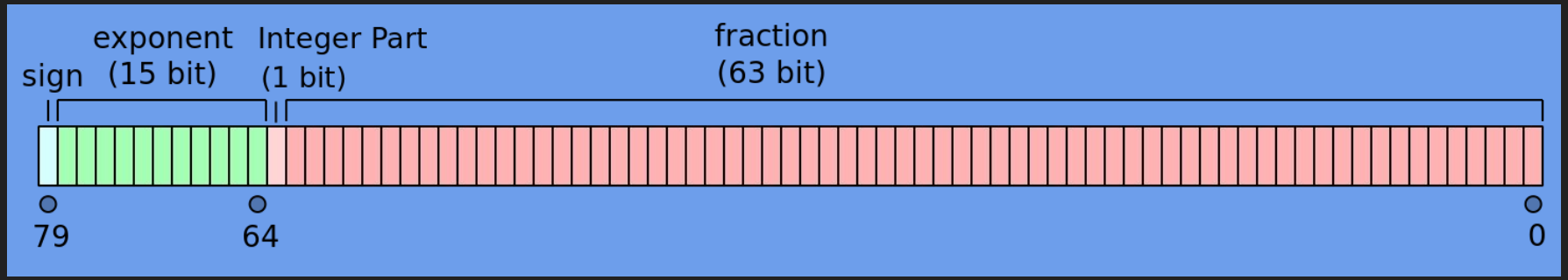
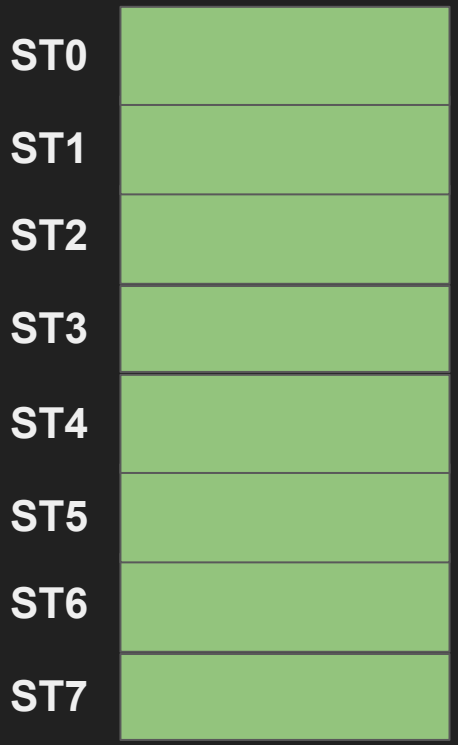


https://en.wikipedia.org/wiki/Extended_precision v

8087 register stack

- ST0, ST1, ST2, ST3, ST4, ST5, ST6, ST7

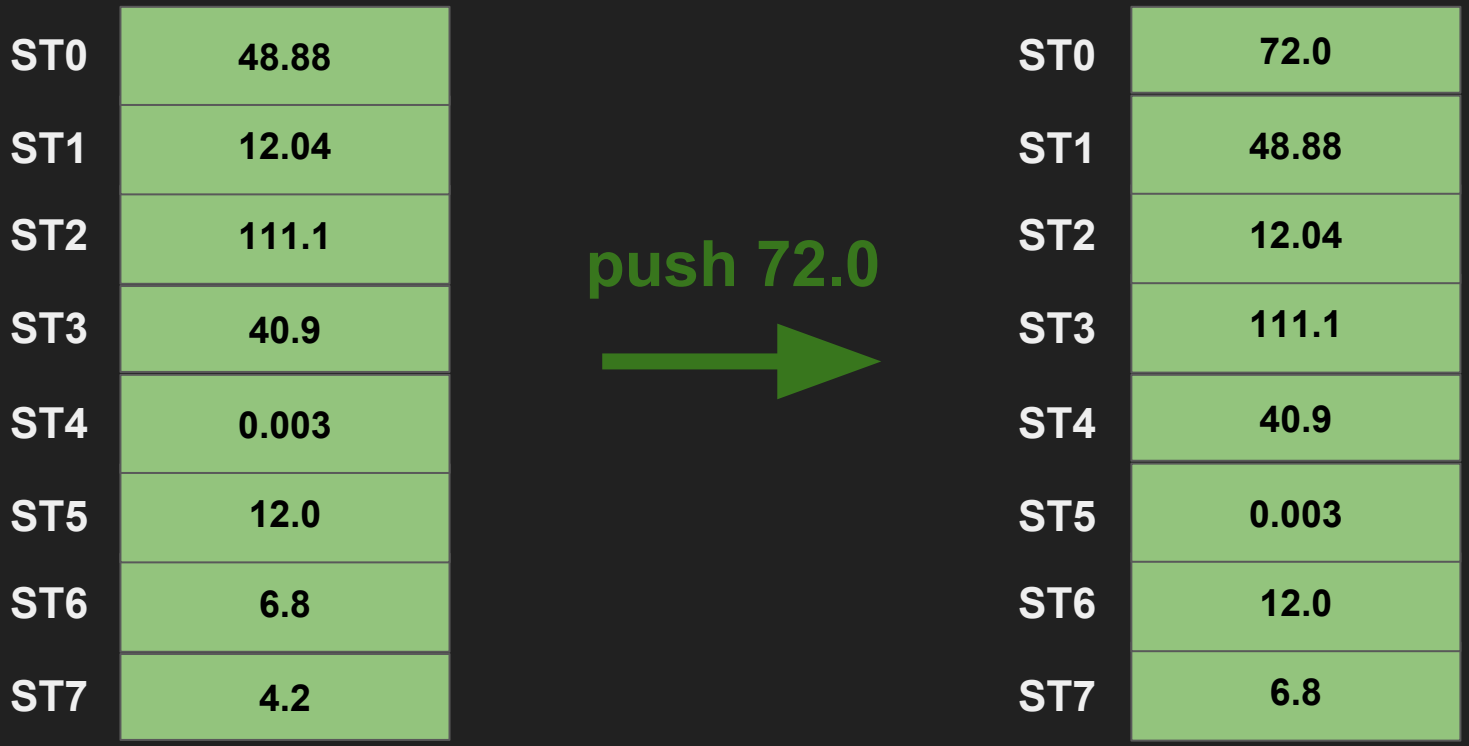
8087 register stack



8087 register stack

ST0	48.88
ST1	12.04
ST2	111.1
ST3	40.9
ST4	0.003
ST5	12.0
ST6	6.8
ST7	4.2

8087 register stack



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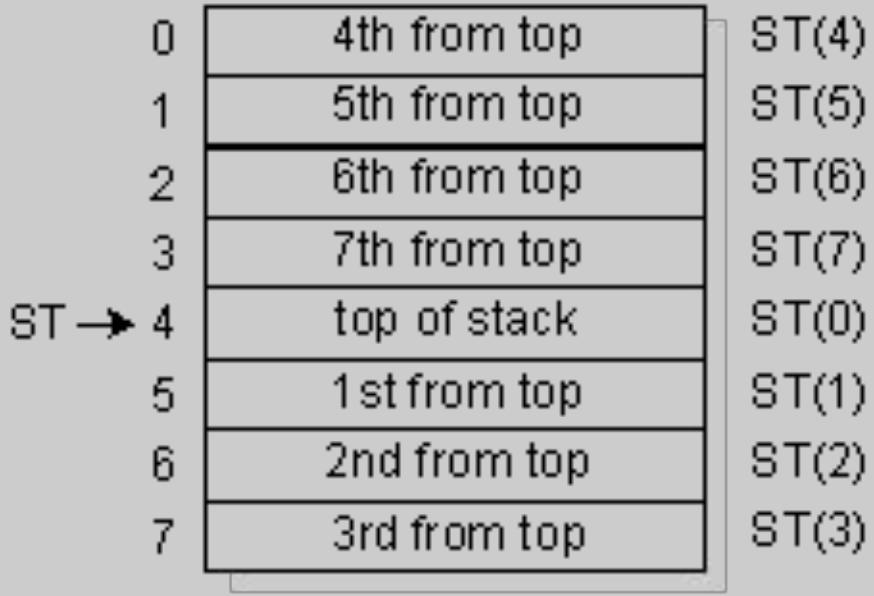
8087 register stack



https://users.pja.edu.pl/~jms/qnx/help/watcom/compiler16/pragma16.html

Floating points in memory

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single precision

```
segment .data
l1:     dd  1.0, 18.9, 0.00001, 1e-14, 12.0
l2:     dq  1.0, 18.9, 0.00001, 1e-14, 12.0
```

double precision

Floating points in memory

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32 bit integer

```
l1:     dd  1.0, 18.9, 0.00001, 1e-14, 12
l2:     dq  1.0, 18.9, 0.00001, 1e-14, 12.0
```

double precision

Example


```
segment .data

l1:     dd  1.0, 18.9, 0.00001, 1e-14, 12.0

l2:     dq  1.0, 18.9, 0.00001, 1e-14, 12.0
```

```
  fld dword [l1]          ; ST0 = [l1]
  fld dword [l1+4]        ; ST0 = [l1+4]

  fadd ST1                ; ST0 += ST1

  fist dword [l1]         ; [l1] = (int) ST0

  mov eax, [l1]
  call print_int
  call print_nl
```

Example


```
segment .data

l1:     dd  1.0, 18.9, 0.00001, 1e-14, 12.0

l2:     dq  1.0, 18.9, 0.00001, 1e-14, 12.0
```

```
  fld dword [l1]          ; ST0 = [l1]
  fld dword [l1+4]        ; ST0 = [l1+4]

  fadd ST1                ; ST0 += ST1

  fist dword [l1]         ; [l1] = (int) ST0

  mov eax, [l1]
  call print_int
  call print_nl
```

```
b.nasihatkon@kntu:lecture20$ ./run.sh float1
20
```

Loading (pushing)

`FLD mem32 (/mem64/mem80)`	`push ST0 <- mem32 (so on)`
`FLD STi`	`push ST0 <- STi` `STi: ST0, ST1, … or ST7`
`FILD mem16 (/mem32/mem64)`	`push ST0 <- int2float(mem32)`

Example:

```
FLD dword [l1]
FLD qword [l2]
```

Loading (pushing) constants

FLD1	push ST0 <- 1.0
FLDZ	push ST0 <- +0.0
FLDPI	push ST0 <- π (the pi number)
FLDL2T/FLDL2E FLDLG2/FLDLN2	

Storing

`FST mem32/mem64`	`mem32 <- ST0`
`FST STi`	`STi <- ST0  (i=0,1,...,7)`
`FIST mem16/mem32/mem64`	`mem32 <- float2int(ST0)`
`FSTP dest` `FISTP dest`	similar to FSTP and FISTP but also pops top of stack

Example:

```
FST dword [l1]
FST qword [l2]
```

Exchange

`FXCH  STi`	`ST0 <-> STi  (i=0,1,...,7)`

Math operations

`FADD src`	`ST0 += src`
`FSUB src`	`ST0 -= src`
`FMUL src`	`ST0 *= src`
`FDIV src`	`ST0 /= src`
	`src: STi/mem32/mem64`

Math operations

`FADD src`	`ST0 += src`
`FSUB src`	`ST0 -= src`
`FMUL src`	`ST0 *= src`
`FDIV src`	`ST0 /= src`
`FSUBR src`	`ST0 = src - ST0`
`FDIVR src`	`ST0 = src / ST0`
	`src: STi/mem32/mem64`

Math operations

FADDP STi	STi += ST0
FSUBP STi	STi -= ST0
FMULP STi	STi *= ST0
FDIVP STi	STi /= ST0
FSUBRP STi	STi = ST0 - STi
FDIVRP STi	STi = ST0 / STi
	And pop top of stack STi: ST0, ST1, … or ST7

Math operations

`FADDP STi` `FADDP STi, ST0`	`STi += ST0`
`FSUBP STi` `FSUBP STi, ST0`	`STi -= ST0`
`FMULP STi` `FMULP STi, ST0`	`STi *= ST0`
`FDIVP STi` `FDIVP STi, ST0`	`STi /= ST0`
`FSUBRP STi` `FSUBRP STi, ST0`	`STi = ST0 - STi`
`FDIVRP STi` `FDIVRP STi, ST0`	`STi = ST0 / STi`
	And pop top of stack

Math operations

`FADD STi, ST0`	`STi += ST0`
`FSUB STi, ST0`	`STi -= ST0`
`FMUL STi, ST0`	`STi *= ST0`
`FDIV STi, ST0`	`STi /= ST0`
`FSUBR STi, ST0`	`STi = ST0 - STi`
`FDIVR STi, ST0`	`STi = ST0 / STi`
	`STi: ST0, ST1, … or ST7`

Math operations

FIADD src	ST0 += int2float(src)
FISUB src	ST0 -= int2float(src)
FIMUL src	ST0 *= int2float(src)
FIDIV src	ST0 /= int2float(src)
FISUBR src	ST0 = int2float(src) - ST0
FIDIVR src	ST0 = int2float(src) / ST0
	src: mem32/mem64

Example


```
segment .data

l1:     dd  1.0, 18.9, 0.00001, 1e-14, 12.0

l2:     dq  1.0, 18.9, 0.00001, 1e-14, 12.0
```

```
  fld dword [l1]          ; ST0 = [l1]
  fld dword [l1+4]        ; ST0 = [l1+4]

  fadd ST1                ; ST0 += ST1

  fist dword [l1]         ; [l1] = (int) ST0

  mov eax, [l1]
  call print_int
  call print_nl
```

Math operations

FCHS	ST0 = -ST0
FABS	ST0 = |ST0|
FSQRT	ST0 = sqrt(ST0)
FSCALE	ST0 *= 2^floor(ST1)
FRNDINT	ST0 = round(ST0) still floating point

Math operations

`FSIN`	`ST0 = sin(ST0)`
`FCOS`	`ST0 = cos(ST0)`
`FSINCOS`	`ST0 = cos(ST0)` **then** `ST0 <- push sin(ST0)`

x87 status register

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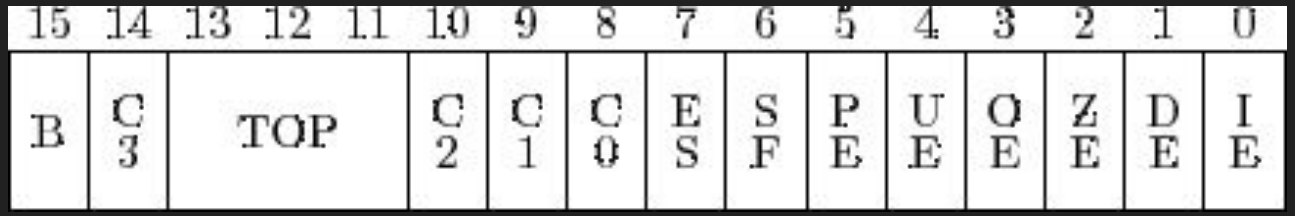

15	14	13 12 11	10	9	8	7	6	5	4	3	2	1	0
B	C3	TOP	C2	C1	C0	ES	SF	PE	UE	OE	ZE	DE	IE

http://www.russinoff.com/libman/text/node48.html

Making comparisons

FCOM src	compare ST0, src src: mem32/mem64/STi
FCOMP src	like FCOM src AND pop top of stack
FCOMPP	Compare ST0, ST1 AND pop twice
FICOM mem16/mem32	compare ST0, int2float(src) src: mem32/mem64/STi
FTST	compare ST0, 0

Making comparisons

`FSTSW mem16`	
`FSTSW AX`	
`SASF`	`FLAGS <- AX` `(not all bits)`
`LASF`	`AX <- FLAGS` `(not all bits)`

Making comparisons

FSTSW mem16	
FSTSW AX	
SASF	FLAGS <- AX (not all bits)
LASF	AX <- FLAGS (not all bits)

```
FSTSW AX
SASF
follows every comparison
```

Directly setting EFLAGS

`FCOMI STi`	`compare ST0, STi` `sets EFLAGS`
`FCOMIP STi`	`FCOMI STi` `pops top of stack`

Practice: roots of a quadric

quadroots.asm

```
extern printf
segment .data
a:      dq      1.0
b:      dq     -3.0
c:      dq      2.0
minus4: dq     -4.0
temp:   dq      0.0
format: db   "%f", 10, 0
no_roots_msg: db "No real roots",10, 0

segment .text
        :
```

Practice: roots of a quadric

quadroots.asm

```
extern printf
segment .data
a:      dq      1.0
b:      dq     -3.0
c:      dq      2.0
minus4:  dq     -4.0
temp:    dq     0.0
format:  db   "%f", 10, 0
no_roots_msg: db "No real roots",10, 0

segment .text
        :
       fld  qword [b]
       fld  qword [b]
       fmulp ST1
```

Practice: roots of a quadric

quadroots.asm

```
extern printf
segment .data
a:      dq      1.0
b:      dq     -3.0
c:      dq      2.0
minus4:  dq     -4.0
temp:    dq     0.0
format:  db   "%f", 10, 0
no_roots_msg: db "No real roots",10, 0

segment .text
        :
        fld  qword [b]
        fld  qword [b]
        fmulp ST1

        fld qword [a]
        fld qword [c]
        fld qword [minus4]
        fmulp ST1
        fmulp ST1
```

quadroots.asm

```
extern printf
segment .data
a:      dq      1.0
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minus4:  dq     -4.0
temp:    dq     0.0
format:  db   "%f", 10, 0
no_roots_msg: db "No real roots",10, 0

segment .text
        :
        fld  qword [b]
        fld  qword [b]
        fmulp ST1

        fld qword [a]
        fld qword [c]
        fld qword [minus4]
        fmulp ST1
        fmulp ST1
        faddp ST1
        fldz
        fcomip ST1
        ja    no_roots
```

quadroots.asm

```
extern printf
segment .data
a:      dq      1.0
b:      dq     -3.0
c:      dq      2.0
minus4:  dq     -4.0
temp:    dq     0.0
format:  db   "%f", 10, 0
no_roots_msg: db "No real roots",10, 0
segment .text
        :
      fld  qword [b]
      fld  qword [b]
      fmulp ST1

      fld qword [a]
      fld qword [c]
      fld qword [minus4]
      fmulp ST1
      fmulp ST1
      faddp ST1

      fldz
      fcomip ST1
      ja    no_roots

      fsqrt

      fld st0
      fld qword [b]
      faddp st1
      fchs

      fld qword [a]
      fld1
      fld1
      faddp
      fmulp
      fdivp ST1             ; ST1 /= ST0

      ; print st0
      fst  qword [temp]
      push dword [temp+4]
      push dword [temp]
      push format
      call printf
      add  esp, 12

      fcomp

      fld qword [b]
      fchs
      faddp

      fld qword [a]
      fld1
      fld1
      faddp
      fmulp

      fdivp ST1             ; ST1 /= ST0

      ; print st0
      fst  qword [temp]
      push dword [temp+4]
      push dword [temp]
      push format
      call printf
      add  esp, 12

      jmp endl

no_roots:
      mov eax, no_roots_msg
      call print_string
endl:
```

quadroots.asm

```
extern printf
segment .data
a:      dq      1.0
b:      dq     -3.0
c:      dq      2.0
minus4:  dq     -4.0
temp:    dq     0.0
format:  db   "%f", 10, 0
no_roots_msg: db "No real
segment .text
        :
        fld  qword [b]
        fld  qword [b]
        fmulp ST1

        fld qword [a]
        fld qword [c]
        fld qword [minus4]
        fmulp ST1
        fmulp ST1
        faddp ST1

        fldz
        fcomip ST1
        ja     no_roots
```

```
        fsqrt

        fld st0
        fld qword [b]
        faddp st1
        fchs

        fld qword [a]
                                  [temp]
                                  [temp+4]
                                  [temp]
                                  t
        push dword [temp]
        push format
        call printf
        add  esp, 12

        fcomp
```

```
        fld qword [b]
        fchs
        faddp

        fld qword [a]
        fld1
        fld1
        faddp
        fmulp
                                  ; ST1 /= ST0

        add  esp, 12

        jmp endl

no_roots:
        mov eax, no_roots_msg
        call print_string
endl:
```

This code is inefficient!
Go through the code and make it more efficient.