

A Simple Bootloader

For 80x86 Tutorials

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1 Overview

1.1 Introduction

This project is a simple bootloader that is intended to support tutorials for [x86](#) tutorials. Basically this is a step 1 bootloader.

The bootloader loads up to 64 sectors (32 KiB) following the boot sector from a (virtual) floppy disk. The limitation to 32 KiB is intentionally as [gdb](#) can only handle 32 bit or 64 bit code and does not understand the segmentation of the processor 8086.

In the following sections the requirements to create the bootloader are shown.

1.2 NASM

This project uses [NASM](#) as assembler.

The assembly file starts with the following preamble which sets the [CPU](#) to the 8086 processor and 16 bit code which is needed for every bootloader at the [x86](#) architecture.

```
⟨preamble 5⟩≡ (9a 14d)
bits 16
cpu 8086

⟨license 42⟩
```


2 Design

2.1 Introduction

In this chapter we will do a little bit of theory to design our (stage 1) bootloader.

2.2 Memory Layout

After the bootloader executed we want to have the following memory layout. We only show the relevant parts for our bootloader.

start	end	size	meaning
0x08000	0x08000	1	number of sectors to read after the first sector loaded
0x08001	0x0ffff	32 KiB - 1	loaded code
0x10000	0x1ffff	64 KiB	stack for loaded code

2.3 Loaded Code Layout

When the code is loaded the following contents is in the registers.

register	content	meaning
AX	xxxx	content unknown
BX	xxxx	content unknown
CX	xxxx	content unknown
DX	xxxx	content unknown
SI	xxxx	content unknown
DI	xxxx	content unknown
BP	xxxx	content unknown
SP	0xffffe	TOS
IP	0x8001	first byte of the executable code loaded
CS	0x0000	code segment base
SS	0x2000	stack segment base
DS	xxxx	unknown content
ES	xxxx	unknown content

3 Code of the Bootloader

3.1 Basics

The bootloader is in the first sector of the floppy disk and its maximum size is 510 bytes (512 bytes minus 2 bytes for the magic bytes).

So start with the preamble of our program.

```
<bootloader.asm 9a>≡ 9b>
    <preamble 5>
    section .text
    org 0x7c00
```

First we ensure that our registers `CS` and `IP` have the intended values (`CS = 0x0000` and `IP = 0x7c05`) by doing a far jump. The address (`0x0000:0x7c05`) is the byte directly after this jump. The value `0x0000` in `CS` is needed because `gdb` does not understand 8086 segments.

```
<bootloader.asm 9a>+≡ <9a 9c>
    jmp     0x0000:0x7c05
```

Now we setup a few things so that we can work without disturbance. We start with setting up a data area below our program code for saving some values.

The layout of our data area will be

address	adr. rel. to SI	size	content
0x0500	0x00	1	boot device
0x0501	0x01	1	max sector # (max 63)
0x0502	0x02	2	max cylinder # (max 1023)
0x0504	0x04	1	max head # (max 255)
0x0505	0x05	1	number of sectors to read
0x0506	0x06	1	last sector (absolute) read
0x0507	0x07	1	last sector (in cylinder) read
0x0508	0x08	2	last cylinder read
0x050a	0x0a	2	address where the next sector is read in
0x050c	0x0c	1	last head read

```
<bootloader.asm 9a>+≡ <9b 10a>
    push    CS
    pop     DS
    mov     SI,0x0500
    mov     [SI],DL
```

3 Code of the Bootloader

Next we determine the amount of lower memory we have which should be at least 128 KiB. Else we jump to an error handler with AL set to 1 (as error code).

```
<bootloader.asm 9a>+≡<9c 10b>
    int     0x12
    cmp     AX,128
    ja      enoughMem
    mov     AL,0x01
    jmp     error
enoughMem:
```

Next we will setup the stack that we can use also during the load process.

```
<bootloader.asm 9a>+≡<10a 10c>
    mov     AX,0x2000
    mov     SS,AX
    mov     SP,0xfffe
```

Now we determine the geometry of the floppy drive and save the values to the data segment. If this fails we set the error code (in AL) for our error routine to 2. So the value in AH, which is the error code from `int 0x13`, remains available for the error routine.

```
<bootloader.asm 9a>+≡<10b 11a>
    push    CS
    pop     ES
    mov     DI,0x0000
    mov     AH,0x08
    mov     DL,[SI]
    int     0x13
    jnc     geometryread
    mov     AL,0x02
    jmp     error
geometryread:
    mov     [SI+0x04],DH
    mov     AL,CL
    and     AL,0x3f
    mov     [SI+0x01],AL
    mov     AL,CH
    mov     AH,CL
    mov     CL,6
    shr     AH,CL
    mov     [SI+0x02],AX
```

Next we read in the first sector after the boot sector from the first floppy disk. This sector is located at 0/0/2 (C/H/S). The registers contain the following values for the call of `int 0x13`. The final value of the cylinders is first placed into CX and then moved to CH. This only works if we assume that the cylinder number is not above 255.

Register	Value	Meaning
AH	2	function number to interrupt (read sectors)
AL	1	number of sectors to read
CH	0	cylinder number
CL	2	sector number
DH	0	head number
DL	[SI]	drive number (previously saved)
ES	0x0000	segment of the data buffer
BX	[SI+0x0a]	the address of the data buffer

⟨*bootloader.asm 9a*⟩+≡

◁10c 11b▷

```

push    CS
pop      ES
mov     AX,0x0201
mov     CX,0x0000
mov     [SI+0x08],CX
mov     CL,0x02
mov     [SI+0x07],CL
mov     DH,0x00
mov     [SI+0x0c],DH
mov     DL,[SI]
mov     BX,0x8000
int     0x13
jnc     firstreadsucces
mov     AL,0x03
jmp     error
firstreadsucces:
```

After we read the sector we increment the address where the next sector will be read into by 512 and store it.

⟨*bootloader.asm 9a*⟩+≡

◁11a 11c▷

```

add     BX,512
mov     [SI+0x0a],BX
```

Now we check how many sectors we still have to read (from 0x8000) and save this to 0x0505. Also we set the value of 0x0506 to 0 because that is the sector we just read.

⟨*bootloader.asm 9a*⟩+≡

◁11b 12a▷

```

mov     AL,[0x8000]
mov     [SI+0x05],AL
mov     AL,0x0000
mov     [SI+0x06],AL
```

3 Code of the Bootloader

Next we check if there are still sectors to read else we end the sector read.

```
<bootloader.asm 9a>+≡<11c 12b>
checknextsect:
    mov     AH, [SI+0x05]
    mov     AL, [SI+0x06]
    cmp     AH, AL
    ja      nextsectread
    jmp     sectreaddone
```

So here we know that we have to read (at least) one more sector. So we load all data needed into the registers as followed

Register	Meaning
BX	last cylinder read
CL	last sector (in cylinder) read
CH	last head read

```
<bootloader.asm 9a>+≡<12a 12c>
nextsectread:
    mov     BX, [SI+0x08]
    mov     CL, [SI+0x07]
    mov     CH, [SI+0x0c]
```

Now we do some calculations. We adjust the values according to the geometry of the boot drive. So first we increment the last sector read and compare the new value with the maximum number of sectors of the drive. If the maximum number of sectors is exceeded we set the sector number to 1 and increment the head number.

```
<bootloader.asm 9a>+≡<12b 13a>
    inc     CL
    mov     AL, [SI+0x01]
    cmp     AL, CL
    jb      adjusthead
    jmp     readsector
adjusthead:
    mov     CL, 0x01
    inc     CH
```

Next we check the result of the increment of the head. Here we have to check for 2 conditions because we can have a maximum head number of 255 which we check with the overflow flag. If the head number is above the maximum then we adjust the cylinder.

```

<bootloader.asm 9a>+≡
    jo      adjustcyl
    mov     AL,[SI+0x04]
    cmp     AL,CH
    jb      adjustcyl
    jmp     readsector
adjustcyl:
    mov     CH,0x00
    inc     BX

```

<12c 13b>

At last we check the number of cylinders. If now (after an increment) the cylinder number is above the maximum cylinder number then we will jump to the error routine.

```

<bootloader.asm 9a>+≡
    mov     AX,[SI+0x02]
    cmp     AX,BX
    jb      cyloverflow
    jmp     readsector
cyloverflow:
    mov     AL,0x04
    jmp     error

```

<13a 13c>

Now that we have calculated the next sector to read we will read it from the floppy disk.

```

<bootloader.asm 9a>+≡
readsector:
    mov     DL,CL
    mov     AX,CX
    xchg    AH,AL
    mov     CL,6
    shl     AL,CL
    mov     CX,AX
    or      CL,DL
    mov     DH,CH
    mov     AX,0x0201
    mov     DL,[SI]
    mov     BX,[SI+0x0a]
    int     0x13
    jnc     readsuccess
    mov     AL,0x04
    jmp     error
readsuccess:

```

<13b 14a>

3 Code of the Bootloader

Last we add 512 to the address for the next sector and save it. Then we test for the next sector to load.

```
<bootloader.asm 9a>+≡<13c 14b>
    add     BX,512
    mov     [SI+0x0a],BX
    jmp     checknextsect
```

Now we add an error handling which simply halts at the moment.

```
<bootloader.asm 9a>+≡<14a 14c>
    error:
        hlt
```

Now we add the jump to the loaded code and the magic bytes and the bootloader is done.

```
<bootloader.asm 9a>+≡<14b>
    sectreaddone:
        jmp     0x8001
        times 510-($-$$) nop
        db 0x55,0xaa
```

3.2 Dummy Payload

To have a sector to load we create a small program that is loaded by the bootloader. This is afterwards connected with the bootloader to form a floppy disk image.

```
<dummyspayload.asm 14d>≡
<preamble 5>
    section .text
    org 0x8000
        db             0x00
        cli
        hlt
```

A Glossary

C/H/S Short for Cylinder/Head/Sector, used for addressing sectors at floppy disks or hard disks [10](#)

CPU Central Processing Unit [5](#)

gdb The GNU Debugger [5](#), [9](#)

NASM The Netwide Assembler found at <https://www.nasm.us/> [5](#)

x86 A microprocessor architecture based on the 8086/8088 [5](#)

B Code Chunks

⟨bootloader.asm 9a⟩

⟨dummpayload.asm 14d⟩

⟨license 42⟩

⟨preamble 5⟩

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