Introduction to U-Boot bootloader

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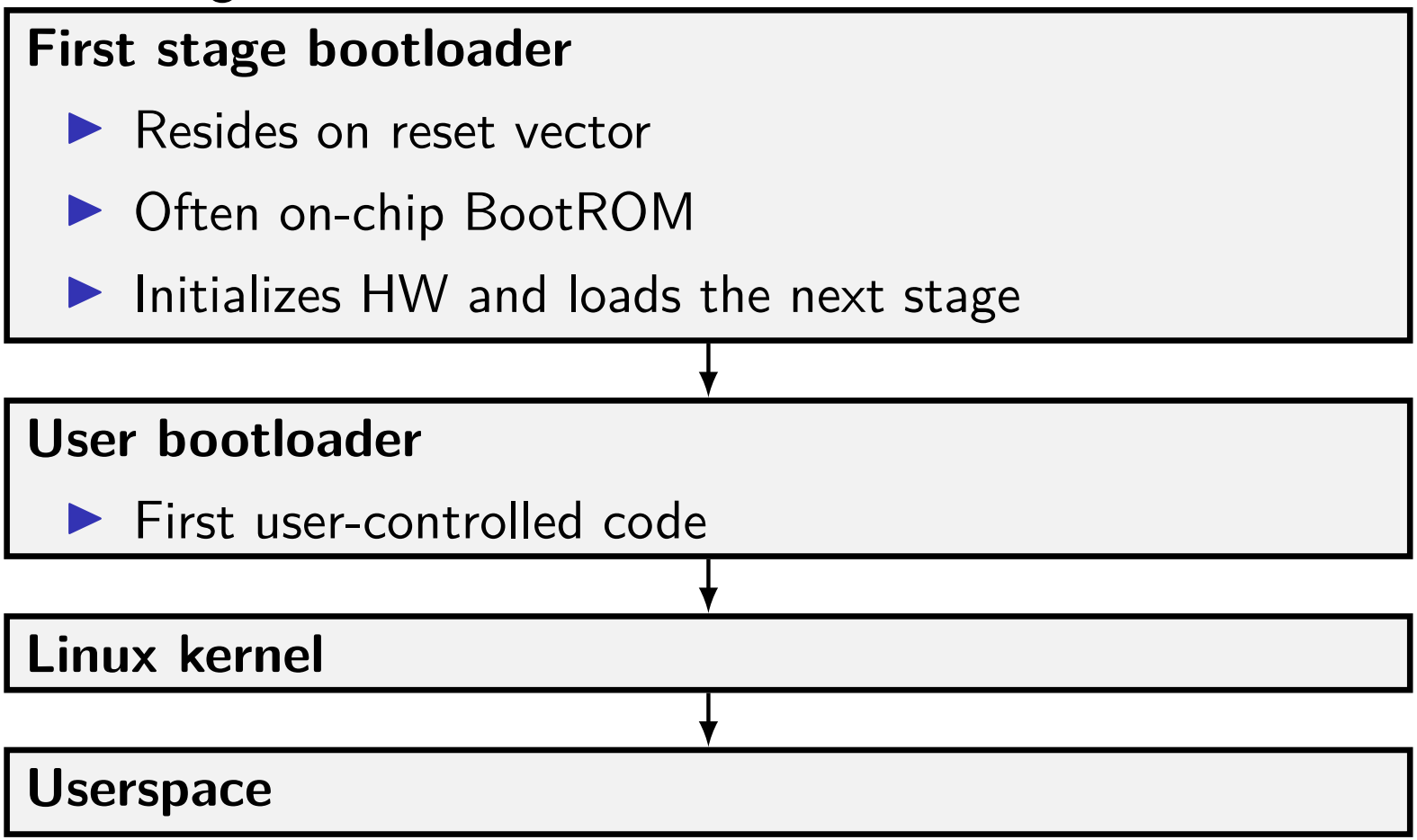
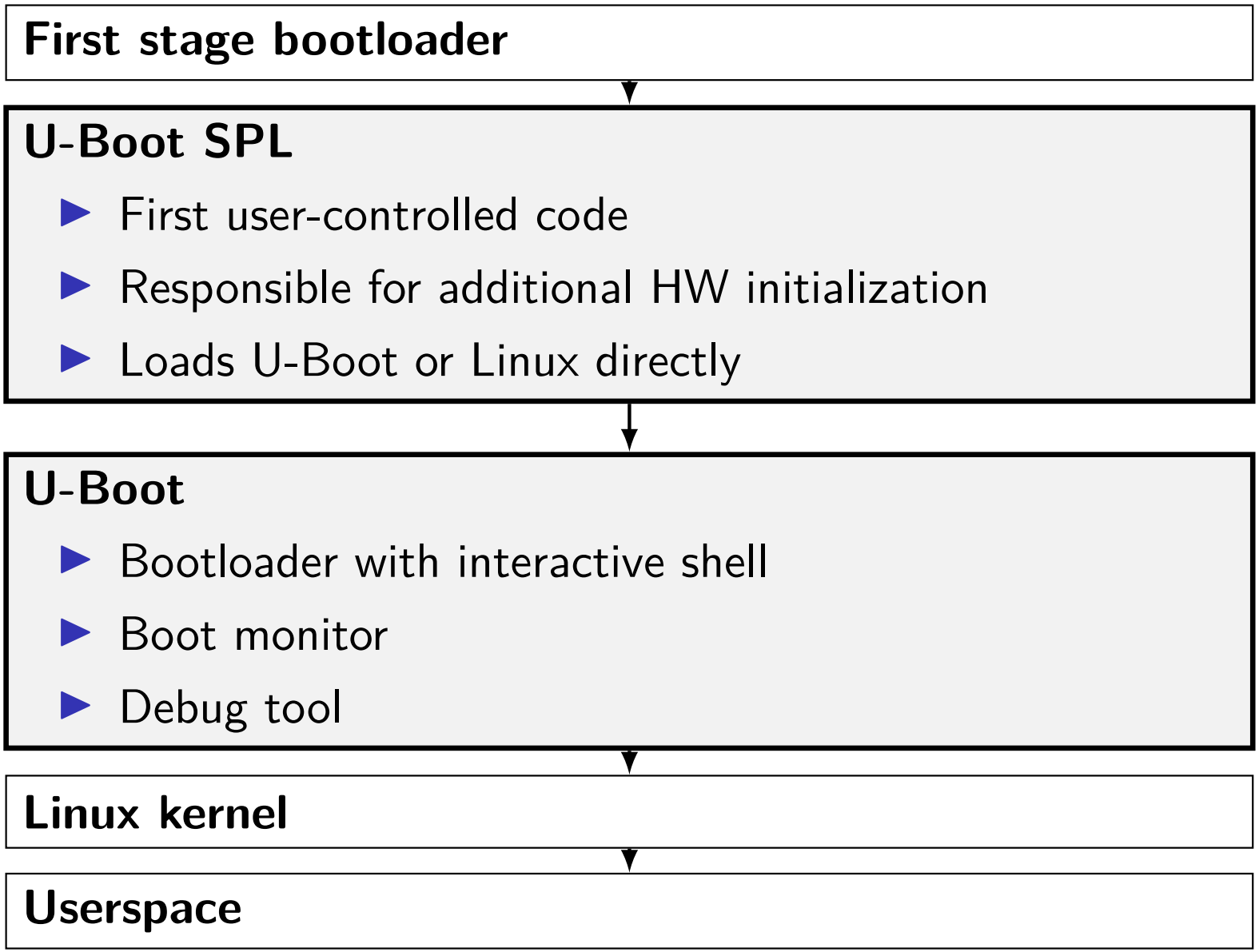
Booting a computer

Multi-stage bootloader



U-Boot bootloader



U-Boot example

```
U-Boot SPL 2018.01-00002-g9aa111a004 (Jan 20 2018 - 12:45:29)
Trying to boot from MMC1


U-Boot 2018.01-00002-g9aa111a004 (Jan 20 2018 - 12:45:29 -0600)

CPU  : AM335X-GP rev 2.1
I2C:   ready
DRAM:  512 MiB
Reset Source: Global warm SW reset has occurred.
Reset Source: Power-on reset has occurred.
MMC:   OMAP SD/MMC: 0, OMAP SD/MMC: 1

Model: BeagleBoard.org PocketBeagle
Net:   usb_ether
Press SPACE to abort autoboot in 2 seconds
=>
```

U-Boot SPL vs U-Boot

SPL – Secondary Program Loader

- Built from the same source as U-Boot
- Significantly reduced size and feature set
- Used to init system and start U-Boot or Linux

TPL – Tertiary program loader

- Built from the same source as U-Boot
- Even smaller than SPL
- Almost never used
- Used on severely limited system (ie. OneNAND)

Basic U-Boot commands

U-Boot shell

- There are two shell choices
  1. original old shell (which has no name)
  2. HUSH shell (which has more features)
- For most situations HUSH is the better choice
- Similar to bourne shell
- Persistent environment support
- Scripting support

The 'help' command

- Provides detailed built-in help text
- Can provide further details on specific command

```
=> help
?       - alias for 'help'
bdinfo  - print Board Info structure
bootm   - boot application image from memory
cmp     - memory compare
coninfo - print console devices and information
crc32   - checksum calculation
dhcp    - boot image via network using DHCP/TFTP protocol
echo    - echo args to console
go      - start application at address 'addr'
help    - print command description/usage
i2c     - I2C sub-system
load    - load binary file from a filesystem
usb     - USB sub-system
```

Running 'help' on a command

- Just run help on any command for more information

```
=> help echo
echo - echo args to console

Usage:
echo [args..]
    - echo args to console; \c suppresses newline

=> help bdinfo
bdinfo - print Board Info structure

Usage:
bdinfo
```

help on sub-commands

```
=> help usb
usb - USB sub-system

Usage:
usb start - start (scan) USB controller
usb reset - reset (rescan) USB controller
usb stop [f] - stop USB [f]=force stop
usb tree - show USB device tree
usb info [dev] - show available USB devices
usb test [dev] [port] [mode] - set USB 2.0 test mode
    (specify port 0 to indicate the device's upstream port)
    Available modes: J, K, S[E0_NAK], P[acket], F[orce_Enable]
```

The 'echo' command

- Useful for printing text
- It does **NOT** interpret control sequences (except for \\c to suppress newline)

```
1 => echo hello world
2 hello world
3 => echo foo\\c ; echo bar
4 foobar
```

The 'bdinfo' command

- Probing system info

```
=> bdinfo
arch_number = 0x00000E05
boot_params = 0x80000100
DRAM bank   = 0x00000000
-> start    = 0x80000000
-> size     = 0x20000000
eth0name    = usb_ether
ethaddr     = 60:64:05:f4:79:7f
current eth = usb_ether
ip_addr     = 192.168.1.2
baudrate    = 115200 bps
TLB addr    = 0x9FFF0000
relocaddr   = 0x9FF44000
reloc off   = 0x1F744000
irq_sp      = 0x9DF23EC0
sp start    = 0x9DF23EB0
Early malloc usage: 2a8 / 400
```

Getting further help

- Source, documentation in doc/
  `https://git.denx.de/?p=u-boot.git;a=tree;f=doc`
- IRC: `irc.freenode.net` #u-boot
- Mailing list: `u-boot@lists.denx.de`

U-Boot memory access commands

Memory access commands, 'mw', 'md'

- Useful for reading/writing memory and registers
- Support for byte/word/long/quad register access using suffixes (.b, .w, .l, .q)
- Default access width is long, 32bit (md = md.l)
- Support for reading multiple units at a time (default 0x40)
- Default for read is updated if number of units specified
- Can read subsequent addresses if no address specified

```
1  => mw 0x81000000 0x1234abcd
2  => md.l 0x81000000 0x8
3  81000000: 1234abcd 00000000 00000000 00000000 ..4.............
4  81000010: 00000000 00000000 00000000 00000000 ................
5  => md.w 0x81000000 0x8
6  81000000: abcd 1234 0000 0000 0000 0000 0000 0000 ..4.........
7  => md.b 0x81000000 0x8
8  81000000: cd ab 34 12 00 00 00 00                ..4.....
9  =>
10 81000008: 00 00 00 00 00 00 00 00                ........
```

Memory access commands, 'mw', 'md'

- Try toggling GPIOs the hard way
- Note on used bitfields:
  |xxxx|xxx0|000x|xxxx|xxxx|xxxx|xxxx|xxxx|
- Expected result: Two Blue LEDs ON/OFF

```
1 => echo "Try toggling GPIOs the hard way"
2 => md 0x4804c130 4
3 4804c130: 00000002 ffffffff f0000300 00000000 ................
4 => mw 0x4804c134 0xfe1fffff
5 => mw 0x4804c13c 0x00a00000
6 => mw 0x4804c13c 0x01400000
7 => md 0x4804c130 4
8 4804c130: 00000002 fe1fffff f1400300 01400000 ..........@...@.
```

Memory modification commands, 'mm', 'nm'

- Useful for interactively modifying registers
- Same properties as for md/mw apply
- mm autoincrements address, nm does not
- Use 'q' to drop back to U-Boot shell
- Use '-' to return to previous address
- Press 'Enter' without value to skip current address

```
1 => mm 0x4804c134
2 4804c134: ffffffff ? fe1fffff
3 4804c138: f0002300 ?
4 4804c13c: 00000000 ? 00400000
5 4804c140: 00000000 ? q
6 =>
```

Memory access commands, 'cp', 'cmp'

- cp – copy memory
- cmp – compare memory
- Same properties as md/mw above apply

```
1 => mw 0x81000000 0x1234abcd 0x10
2 => cp 0x81000000 0x82000000 0x8
3 => cmp 0x81000000 0x82000000 0x8
4 Total of 8 word(s) were the same
5 => cmp 0x81000000 0x82000000 0x9
6 word at 0x81000020 (0x1234abcd) != word at 0x82000020 \
7     (0xea000003)
8 Total of 8 word(s) were the same
```

U-Boot environment and scripting commands

U-Boot environment

- The environment uses key-value storage
- Can contain values or scripts
- Default env built into U-Boot binary
- Optional custom env loaded from storage
- Live copy in RAM
- Can be accessed as variables
- Can be modified
- Can be made persistent

The 'printenv' command

- For printing the environment
- Legacy alias for 'env print'

```
1  => env print
2  arch=arm
3  ...
4  Environment size: 26907/131068 bytes
5  =>
6  => env print arch
7  arch=arm
8  => printenv arch
9  arch=arm
10 => echo "$arch"
11 arm
```

The 'setenv'/'askenv'/'editenv' command

- For modifying the environment
- Legacy alias for 'env set'/'env ask'/'env edit'

```
1  => env set foo bar
2  => env print foo
3  foo=bar
4
5  => env ask quux "Set quux to ?"
6  Set quux to ? 1234
7  => env print quux
8  quux=1234
9
10 => env edit  quux
11 edit: 24
12 => env print quux
13 quux=24
```

Removing variables

- Set variables to empty to remove them from the environment

```
1 => env print foo
2 ## Error: "foo" not defined
3 => env set foo bar
4 => env print foo
5 foo=bar
6 => env set foo
7 => env print foo
8 ## Error: "foo" not defined
```

The 'saveenv' command

- For environment persistency
- Environment is not persistent across reboots by default
- Any changes to environment are done to the live copy

```
1  => env set foo bar
2  => env print foo
3  foo=bar
4  => reset
5  => env print foo
6  ## Error: "foo" not defined
7
8  => env set foo bar
9  => saveenv
10 => reset
11 => env print foo
12 bar
```

The 'run' command

- For running scripts in the environment
- Chaining commands with ';' is possible
- Note that ';' ignores return value

```
1 => env set foo 'echo hello'
2 => run foo
3 hello
4
5 => env set foo 'echo hello ; echo world'
6 => run foo
7 hello
8 world
```

Variables in environment

- Proper escaping is important on U-Boot shell
- Be careful with variable expansion

```
1  => env set  foo bar
2  => env set  quux echo $foo
3  => env set  foo baz
4  => run quux
5  bar
6  => env print quux
7  quux=echo bar
8
9  => env set  quux echo \$foo
10 => env print quux
11 => env set  quux 'echo $foo'
12 => env print quux
```

Special variables

Certain variables have special meaning/function

- `ver` – U-Boot version
- `stdin`, `stdout`, `stderr` – Redirection of STDIO. Setting these has immediate impact, also see `coninfo` command.
- `loadaddr` – Default load address
- `filesize` – Size of the loaded file
- `bootargs` – Boot arguments passed to Linux command line
- `bootcmd` – Default boot command (see boot command and autoboot)
- `preboot` – Script executed before autoboot
- `ipaddr`, `netmask`, `serverip`, `gatewayip` – Network settings
- `ethaddr`, `eth1addr`, `...` – Ethernet MAC address

The 'setexpr' command

- Environment manipulation multi-tool
- Supports loading memory content into variables
- Supports arithmetic operations on both variables and memory (AND, OR, XOR, +, -, *, /, MOD)
- Supports basic regex manipulation on strings and variables

```
1  => md 0x9ff4e000 1
2  9ff4e000: ea0000b8
3  => setexpr foo *0x9ff4e000
4  => env print foo
5  foo=ea0000b8
6
7  => env set foo 1 ; env set bar 2
8  => setexpr baz $foo + $bar
9  => env print baz
10 baz=3
11
12 => setexpr foo gsub ab+ x "aabbcc"
13 foo=axcc
```

U-Boot shell conditional expressions and loops

The 'true'/'false' commands

- Return 0 (true) / non-zero (false) return values
- U-Boot supports handling return values of commands
- Automatic variables are supported too

```
1 => true
2 => echo $?
3 0
4 => false
5 => echo $?
6 1
```

Conditional expressions

- The if conditional is supported
- Shorthand || and && expressions also supported
- Warning, the "if ! foo ; then ... fi" is not supported, use ie. "if foo ; then false ; else ... fi" as a workaround

```
1 => if true ; then echo "hello" ; else echo "bye" ; fi
2 hello
3 => false || echo "false!"
4 false!
5
6 => env set foo 'true && echo "true!"'
7 => run foo
8 true!
```

The 'test' command

- Minimal test command from HUSH

```
1  => env set i 4
2  => test $i -lt 5
3  => echo $?
4  0
5  => env set i 6
6  => test $i -lt 5
7  => echo $?
8  1
9
10 => env set i 6
11 => if test $i -lt 5 ; then echo "Less then 5" ; \
12    else echo "More than 5" ; fi
13 More than 5
```

The 'for' loop

- The for loop over a list of elements

```
1 => for i in a b c d ; do echo "$i" ; done
2 a
3 b
4 c
5 d
```

The 'while' loop

- The while loop with a condition
- Ctrl-c can be used to break an endless loop

```
1 => while true ; do echo hello ; done
2 hello
3 hello
4 hello
5 Ctrl-c
6 =>
```

U-Boot data loading commands

Loading from storage

- U-Boot supports loading from various storage types
  - SD/MMC – mmc command
  - USB – usb command
  - SATA – sata command
  - NAND – nand command
  - ...
- Both RAW storage and filesystems are supported
  - Universal FS access – 'ls', 'load' commands
  - ExtFS – legacy 'extls'/'extload' command
  - VFAT – legacy 'fatls'/'fatload' command
  - UBI/UBIFS – 'ubi' command
  - ...

Loading from SD card

```
=> mmc rescan
=> mmc part

Partition Map for MMC device 0  --   Partition Type: DOS

Part  Start Sector  Num Sectors   UUID           Type
  1   8192          6955008       1147c091-01    83 Boot

=> ls mmc 0:1
<DIR>       4096 .
<DIR>       4096 ..
              40 ID.txt
...
=> load mmc 0:1 $loadaddr ID.txt
=> md.b $loadaddr $filesize
82000000: 42 65 61 67 6c 65 42 6f 61 72 ... BeagleBoard.org
82000010: 44 65 62 69 61 6e 20 49 6d 61 ... Debian Image 201
82000020: 38 2d 30 31 2d 32 38 0a           8-01-28.
```

Loading from network

- U-Boot network stack is UDP-only (no TCP)
- Support for TFTP, NFS (over UDP), DHCP/BOOTP, ...
- `ping` – ICMP Echo
- `tftp` – TFTP download (`tftpput` for upload)
- `dhcp` – Obtain settings from DHCP and ev. load file

```
1 => env set ethaddr 00:aa:bb:cc:dd:ee # optional!
2 => env set ipaddr 192.168.1.300
3 => env set netmask 255.255.255.0
4 => env set serverip 192.168.1.1
5 => ping $serverip
6 => tftp $loadaddr $serverip:somefile
7 => dhcp $loadaddr $serverip:somefile
```

Loading over serial port

- When nothing else, UART is available
- U-Boot supports X/Y modem, Srecord and kermit protocol

```
U-Boot> loady
<send file over ymodem protocol, e.g. sb -T>
```

- Example with GNU screen

```
$ screen /dev/ttyUSB0 115200
  => loady
ctrl-a:exec !! sb -T yourbinary.bin

or from another shell on the same host computer:

$ screen -x -r -X exec \!\! sb -T yourbinary.bin
```

Booting the kernel

Booting the kernel

There are many image formats

- (z)Image
  - Linux binary (with decompressor)
  - No protection against bitrot
  - Just set up registers and jump to it
  - Optional separate Device Tree
- uImage
  - Legacy since forever
  - Wrapper around arbitrary binary
  - CRC32 checksum and small amount of metadata
  - Wraps single file only
  - Optional separate Device Tree
- fitImage – multi-component image
  - Based on Device Tree
  - Supports multiple files
  - Configurable checksum algorithm per entry
  - Supports digital signatures

Booting kernel image

- `bootz` – (z)Image
- `booti` – ARM64 Image
- `bootm` – fitImage, uImage
- `$bootcmd` – default boot command

```
=> help bootz
bootz - boot Linux zImage image from memory

Usage:
bootz [addr [initrd[:size]] [fdt]]
    - boot Linux zImage stored in memory
        The argument 'initrd' is optional... The optional arg
        ':size' allows specifying the size of RAW initrd.

        When booting a Linux kernel which requires a flat
        device-tree a third argument is required which is
        the address of the device-tree blob.
```

Booting kernel image

```
=> env set bootargs console=ttyO0,115200
=> load mmc 0:1 0x82000000 boot/zImage-4.9.82-ti-r102
9970640 bytes read in 673 ms (14.1 MiB/s)
=> load mmc 0:1 0x88000000 boot/dtbs/4.9.82-ti-r102/\
        am335x-pocketbeagle.dtb
132769 bytes read in 180 ms (719.7 KiB/s)
=> bootz 0x82000000 - 0x88000000
## Flattened Device Tree blob at 88000000
   Booting using the fdt blob at 0x88000000
   Loading Device Tree to 8ffdc000, end 8ffff6a0 ... OK

Starting kernel ...

[    0.000000] Booting Linux on physical CPU 0x0
[    0.000000] Linux version 4.9.82-ti-r102 \
    (root@b2-am57xx-beagle-x15-2gb) (gcc version 6.3.0 20170516
    (Debian 6.3.0-18) ) #1 SMP PREEMPT Thu Feb 22 01:16:12 UTC 2
[    0.000000] CPU: ARMv7 Processor [413fc082] revision 2 (ARMv7
```

Device Tree

- Data structure describing the hardware
- Usually passed to OS to provide information about HW topology where it cannot be detected or probed
- An acyclic graph, made of named nodes containing properties
  - Nodes can contain properties and child nodes
  - Properties are a name-value pairs
  - See `https://en.wikipedia.org/wiki/Device_tree`
- Device Tree properties can refer to other nodes by the used of phandles (references to other nodes)
  - phandles provide simple references to device node labels (e.g. `"<&L2>"` is reference to L2 cache node)
  - phandles can be used to reference nodes anywhere in the device tree

Device Tree example

```
/dts-v1/;
#include "arm-realview-eb-mp.dtsi"
/ {
        model = "ARM RealView EB Cortex A9 MPCore";
[...]
        cpus {
                #address-cells = <1>;
                #size-cells = <0>;
                enable-method = "arm,realview-smp";
                A9_0: cpu@0 {
                        device_type = "cpu";
                        compatible = "arm,cortex-a9";
                        reg = <0>;
                        next-level-cache = <&L2>;
                };
[...]
        pmu: pmu@0 {
        interrupt-affinity = <&A9_0>, <&A9_1>, <&A9_2>, <&A9_3>;
};          };
```

fitImage example (1)

```
/dts-v1/;

/ {
  description = "Linux kernel and FDT blob for sockit";

  images {
    kernel@1 {
      description = "Linux kernel";
      data = /incbin/("./arch/arm/boot/zImage");
      type = "kernel";
      arch = "arm";
      os = "linux";
      compression = "none";
      load = <0x00008000>;
      entry = <0x00008000>;
      hash@1 {
        algo = "crc32";
      };
    };
```

fitImage example (2)

```
1     fdt@1 {
2       description = "Flattened Device Tree blob";
3       data = /incbin/("./arch/arm/boot/dts/socfpga....dtb");
4       type = "flat_dt";
5       arch = "arm";
6       compression = "none";
7       hash@1 {
8         algo = "crc32";
9       };
10    };
11  };
```

fitImage example (3)

```
1   configurations {
2     default = "conf@1";
3     conf@1 {
4       description = "Boot Linux kernel with FDT blob";
5       kernel = "kernel@1";
6       fdt = "fdt@1";
7       hash@1 {
8         algo = "crc32";
9       };
10    };
11  };
12 };
```

Compile with

```
1 mkimage -f fit-image.its fitImage
```

fitImage commands

- `bootm $fitimageaddr` – boot fitImage/uImage
- `iminfo` – print image information
- `imxtract` – extract file from fitImage/uImage

```
=> iminfo $loadaddr

## Checking Image at 82000000 ...
   FIT image found
   FIT description: Linux kernel and FDT blob for am335x-pocketbeagle
   Created:         2018-09-03   0:46:36 UTC
    Image 0 (kernel@1)
     Description:  Linux kernel (Mon Sep  3 02:46:36 CEST 2018)
     Created:      2018-09-03   0:46:36 UTC
     Type:         Kernel Image
     Compression:  uncompressed
     Data Start:   0x82000154
     Data Size:    5665328 Bytes = 5.4 MiB
     Architecture: ARM
     OS:           Linux
     Load Address: 0x80008000
     Entry Point:  0x80008000
     Hash algo:    crc32
     Hash value:   1a1062ee
...
=> imxtract $loadaddr kernel@1 0x8a000000
## Copying 'kernel@1' subimage from FIT image at 82000000 ...
crc32+    Loading part 0 ... OK
=> md 0x8a000000
8a000000: e1a00000 e1a00000 e1a00000 e1a00000    ................
8a000010: e1a00000 e1a00000 e1a00000 e1a00000    ................
8a000020: ea000005 016f2818 00000000 00567230    .....(o.....0rV.
```

The 'fdt' command

- FDT manipulation
- `fdt addr` – Tell U-Boot where the FDT is
- `fdt resize` – Add extra space to FDT
- `fdt print` – Print DT path
- `fdt set` – Add or change DT entry

```
1  => load mmc 0:1 0x88000000 boot/dtbs/4.9.82-ti-r102/am335x-pocketbeagle.dtb
2  132769 bytes read in 180 ms (719.7 KiB/s)
3  => fdt addr 0x88000000
4  => fdt resize
5  => fdt print /chosen
6  chosen {
7          stdout-path = "/ocp/serial@44e09000";
8  };
9  => fdt set /chosen/ foo bar
10 => fdt print /chosen
11 chosen {
12         foo = "bar";
13         stdout-path = "/ocp/serial@44e09000";
14 };
15 => bootz 0x82000000 - 0x88000000
```

Miscellaneous U-Boot commands

The 'gpio' command

- Useful for toggling/sampling GPIOs
- GPIO input sets return value
- gpio input - to read a gpio
- gpio set - to set a gpio
- gpio clear - to clear a gpio
- gpio toggle - to toggle a gpio

```
1 => gpio input 45
2 gpio: pin 45 (gpio 45) value is 1
3 => echo $?
4 1
5 => gpio set 53
6 gpio: pin 53 (gpio 53) value is 1
```

The 'i2c' command

- Useful for accessing I2C bus
- i2c bus – lists available I2C busses
- i2c dev – select an I2C bus
- i2c md – read registers from I2C device
- i2c mw – write registers to I2C device
- i2c probe – probe for devices on I2C
- i2c speed – set I2C bus speed

```
=> i2c dev 2
Setting bus to 2
=> i2c probe
Valid chip addresses: 1C
=> i2c md 0x1c 0x0 0x8
0000: 00 41 ac 01 fc 7f 10 00    .A......
```

Compiling U-Boot from source

U-Boot sources

- Git master at:
  `http://git.denx.de/?p=u-boot.git;a=summary`
- on Github:
  `https://github.com/u-boot/u-boot`
- Custodian subtrees at:
  `http://git.denx.de/?p=u-boot.git;a=forks`
- Available via Git and HTTP protocols

Building the sources

```
$ git clone git://git.denx.de/u-boot.git
$ cd u-boot
$ export CROSS_COMPILE=arm-linux-gnueabihf- # optional, set cross compiler
$ make am335x_evm_defconfig
$ make
```

- U-Boot sandbox target (`sandbox_defconfig`)
  U-Boot running as userspace application
- U-Boot QEMU targets, (`qemu_defconfig`)
  U-Boot running in QEMU as "BIOS"
  `qemu-system-arm -M virt -bios u-boot.bin`

Practical labs

- Examples work with a PocketBeagle and Techlab
- `https://beagleboard.org/pocket`
- `https://beagleboard.org/techlab`

Task 0

Enter U-Boot prompt

- HINT: Press SPACE to stop autoboot

Task 0

```
Model: BeagleBoard.org PocketBeagle
<ethaddr> not set. Validating first E-fuse MAC
Net:   No ethernet found.
Press SPACE to abort autoboot in 2 seconds
=>
```

Task 1

Boot kernel from SD card

- Check if SD card contains zImage and DTB.
- Load both into memory
- Set `$bootargs`
- Boot the kernel with DT
- HINT: mmc rescan, ls, load, bootz commands

Task 1

```
=> env set bootargs root=/dev/mmcblk0p1 rootfstype=ext4 rootwait \
       console=ttyO0,115200
=> mmc rescan
=> load mmc 0:1 0x82000000 boot/vmlinuz-4.14.91-ti-r90
=> load mmc 0:1 0x88000000 boot/dtbs/4.14.91-ti-r90/\
       am335x-pocketbeagle-techlab.dtb
=> bootz 0x82000000 - 0x88000000
9970640 bytes read in 6594 ms (1.4 MiB/s)
132769 bytes read in 123 ms (1 MiB/s)
## Flattened Device Tree blob at 88000000
   Booting using the fdt blob at 0x88000000
   Loading Device Tree to 8ffdc000, end 8ffff6a0 ... OK

Starting kernel ...

[    0.000000] Booting Linux on physical CPU 0x0
```

Task 2

Boot kernel from SD card with adjusted DT

- Change /model property in DT and boot kernel with it
- HINT: mmc rescan, load, fdt addr, fdt set, bootz commands
- HINT: in Linux see `cat /proc/device-tree/model`

Task 2

```
=> env set bootargs root=/dev/mmcblk0p1 rootfstype=ext4 rootwait \
        console=ttyO0,115200
=> mmc rescan
=> load mmc 0:1 0x82000000 boot/vmlinuz-4.14.91-ti-r90
=> load mmc 0:1 0x88000000 boot/dtbs/4.14.91-ti-r90/\
        am335x-pocketbeagle-techlab.dtb
=> fdt addr 0x88000000
=> fdt set / model "Something"
=> fdt list
/ {
        ...
        compatible = "ti,am335x-pocketbeagle", "ti,am335x-bone", "ti,am33xx";
        model = "Something";
        chosen {
        ...
};
=> bootz 0x82000000 - 0x88000000
...
[    0.000000] OF: fdt: Machine model: Something
...
beaglebone login:debian
debian@beaglebone:~$ dmesg | grep model
[    0.000000] OF: fdt: Machine model: Something
```

Task 3

Button input

- HINT: 'gpio input' command
- HINT: 0x4804c138 is the offset of the GPIO input register
- HINT: gpio 45 is the USR button GPIO

Task 3

```
=> if gpio input 45 ; then
        echo "Button pressed" ;
   else
        echo "Button not pressed" ;
   fi
```

Task 4

Blink USR LED using direct HW IO

- HINT: for or while commands
- HINT: 0x4804c134 is the offset of the GPIO direction register
  Use the following to set the four pins as outputs
  mw 0x4804c134 0xfe1fffff
- HINT: 0x4804c13c is the offset of the GPIO value register
  Use the following to set LED 0 on
  mw 0x4804c13c 0x00200000
- HINT: sleep 1 waits 1 second
- HINT: look at 'base' command

Task 4

```
=> mw 0x4804c134 0xfe1fffff
=> while true ; do
        mw 0x4804c13c 0x00200000 ;
        sleep 1 ;
        mw 0x4804c13c 0x00000000 ;
        sleep 1 ;
   done
```

Task 5

Implement moving light using USR LEDs using GPIO command

- HINT: for or while commands
- HINT: LEDs are GPIO 53, 54, 55, 56
- HINT: sleep 1 waits 1 second
- HINT: look at 'base' command

Task 5

```
=> while true ; do
        for i in 53 54 55 56 ; do
                gpio set $i ;
                sleep 1 ;
                gpio clear $i ;
        done ;
   done
```

Task 6

Conveniently load custom environment using Ymodem

- HINT: loady and env import commands

Task 6

```
linux$ cat << EOF > /tmp/env.txt
> hello=world
> foo=bar
> EOF

=> loady
## Ready for binary (ymodem) download to 0x82000000 at 115200 bps...
ctrl-a:exec !! sb -T /tmp/env.txt
C## Total Size      = 0x00000014 = 20 Bytes
=> md.b $loadaddr $filesize
82000000: 68 65 6c 6c 6f 3d 77 6f 72 6c 64 0a 66 6f 6f 3d    hello=world.foo=
82000010: 62 61 72 0a                                        bar.
=> env import $loadaddr $filesize
## Warning: defaulting to text format
=> env print hello
hello=world
```

Task 7

Compiling U-Boot to run in sandbox mode

- Clone U-Boot sources, configure them for sandbox, compile U-Boot.
- HINT: On your host machine

```
1 $ git clone git://git.denx.de/u-boot.git
2 $ cd u-boot
3 $ make sandbox_defconfig
4 $ make -j $(nproc)
5 $ ./u-boot
```

Task 7

```
$ make sandbox_defconfig
  HOSTCC  scripts/basic/fixdep
...
#
# configuration written to .config
#

$ make -j $(nproc)
scripts/kconfig/conf  --syncconfig Kconfig
  CHK     include/config.h
  UPD     include/config.h
...
  CFGCHK  u-boot.cfg
$ ./u-boot

U-Boot 2018.11-rc1-00033-ga16accc9fb (Oct 07 2018 - 17:13:29 +0200)

Model: sandbox
DRAM:  128 MiB
...
=>
```

Task 8

Barcode reader example

- Imagine that an ethernet MAC address is entered into U-Boot from a barcode reader which is formatted incorrectly.
- Filter the MAC address out and ignore the separators
- The input should read with "env ask" and be somthing like "00xaaxbbxccxddxee"
- USe setexpr to change the input into a proper MAC address (i.e. "00:aa:bb:cc:dd:ee").
- Assume the list of separators is known and fixed as "xyz".

Task 8

```
=> env ask mac 'MAC address ?'
MAC address ? 00xaaxbbxccxddxee
=> setexpr myethaddr gsub '\\(..\\)[xyz]' '\\\\1:' $mac
myethaddr=00:aa:bb:cc:dd:ee
```

Task 9

Playing with the Techlab Accelerometer

- Read out the MMA8452Q accelerometer data
- HINT: i2c commands
- HINT: Accelerometer is on bus 2, select bus 2

```
1 => i2c dev 2
```

- HINT: Accelerometer has I2C address 0x1c, try

```
1 => i2c md 0x1c 0 0x10
```

- HINT: Accelerometer is in standby, wake it up with

```
1 => i2c mw 0x1c 0x2a 0x1
```

then try reading samples at offset 0x1..0x6 again

Task 9

```
=> i2c dev 2
=> i2c md 0x1c 0 0x10
=> i2c mw 0x1c 0x2a 0x1
=> while true ; do i2c md 0x1c 0x2a 0x3; done
```

bjs

Questions

Thank you. Questions?

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