U-Boot overview

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Contents

1 Das U-Boot

Das U-Boot ("the Universal Boot Loader" or U-Boot) is an open-source bootloader that can be used on ST boards to initialize the platform and load the Linux® kernel.

- Official website: https://www.denx.de/wiki/U-Boot
- Official manual: project documentation and https://www.denx.de/wiki/DULG/Manual
- Official **source code** is available under git repository at [1]

```
PC $> git clone https://gitlab.denx.de/u-boot/u-boot.git
```

Read the README file before starting using U-Boot. It covers the following topics:

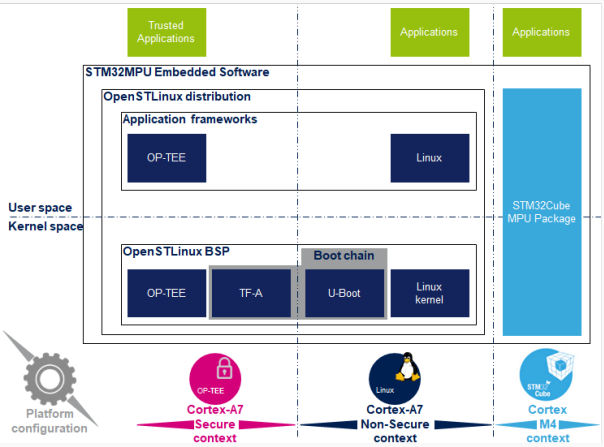
- source file tree structure
- description of CONFIG defines
- instructions for building U-Boot
- brief description of the Hush shell

- list of common environment variables

2 U-Boot overview

The same U-Boot source can generate two pieces of firmware used in SPL and U-Boot STM32 MPU boot chain:

- Trusted boot chain: TF-A as FSBL and U-Boot as SSBL
- Basic boot chain: SPL as FSBL and U-Boot as SSBL



Zoom out to STM32MPU Embedded Software

The basic boot chain cannot be used for product development (see Boot chains overview for details).

It is provided only as an example of the simplest SSBL and to support upstream U-Boot development. However, several known limitations have been identified when SPL is used in conjunction with the minimal secure monitor provided within U-Boot for basic boot chain. They apply to:

- power
- secure access to registers
- limited features (STM32CubeProgrammer / boot from NAND Flash memory).

No fix is planned for these limitations.

2.1 SPL: FSBL for basic boot

The **U-Boot SPL** or **SPL** is the first stage bootloader (FSBL) for the basic boot chain.
It is a small binary (bootstrap utility) generated from the U-Boot source and stored in the internal limited-size embedded RAM. SPL main features are the following:

- It is loaded by the ROM code.
- It performs the initial CPU and board configuration (clocks and DDR memory).
- It loads the SSBL (U-Boot) into the DDR memory.

2.2 U-Boot: SSBL

U-Boot is the default second-stage bootloader (SSBL) for STM32 MPU platforms. It is used both for trusted and basic boot chains. SSBL main features are the following:

- It is configurable and expendable.
- It features a simple command line interface (CLI), allowing users to interact over a serial port console.
- It provides scripting capabilities
- It loads the kernel into RAM and gives control to the kernel
- It manages several internal and external devices such as NAND and NOR Flash memories, Ethernet and USB.
- It supports the following features and commands:
  - File systems: FAT, UBI/UBIFS, JFFS
  - IP stack: FTP
  - Display: LCD, HDMI, BMP for splashcreen
  - USB: host (mass storage) or device (DFU stack)

2.3 SPL phases

SPL executes the following main phases in SYSRAM:

- **board_init_f()**: driver initialization including DDR initialization (mininimal stack and heap: CONFIG_SPL_STACK_R_MALLOC_SIMPLE_LEN)
- configuration of heap in DDR memory (CONFIG_SPL_SYS_MALLOC_F_LEN)
- **board_init_r()**: initialization of the other drivers activated in the SPL device tree
- loading and execution of U-Boot (or Kernel in Falcon mode[1]: README.falcon).

2.4 U-Boot phases

U-Boot executes the following main phases in DDR memory:

- **Pre-relocation** initialization (common/board_f.c): minimal initialization (such as CPU, clock, reset, DDR and console) running at the CONFIG_SYS_TEXT_BASE load address.
- **Relocation**: copy of the code to the end of DDR memory.
- **Post-relocation initialization**:(common/board_r.c): initialization of all the drivers.
- **Command execution** through autoboot (CONFIG_AUTOBOOT) or console shell
  - Execution of the boot command (by default bootcmd=CONFIG_BOOTCOMMAND): for example, execution of the command `bootm` to:
    - load and check images (such as kernel, device tree and ramdisk)
    - fixup the kernel device tree
    - install the secure monitor (optional) or
    - pass the control to the Linux kernel (or to another target application)

3 U-Boot configuration

The U-Boot binary configuration is based on

- **Kbuild infrastructure** (as in Linux Kernel, you can use `make menuconfig` in U-Boot)
  The configurations are based on:
  - options defined in Kconfig files (CONFIG_ compilation flags)
  - the selected configuration file: configs/stm32mp*_defconfig
- **other compilation flags** defined in include/configs/stm32mp*.h (these flags are progressively migrated to Kconfig)
  The file name is configured through CONFIG_SYS_CONFIG_NAME.
  For STM32MP15x lines ⓘ, the include/configs/stm32mp1.h file is used.
- DeviceTree: U-Boot and SPL binaries include a device tree blob that is parsed at runtime

All the configuration flags (prefixed by CONFIG_) are described in the source code, either in the README file or in the documentation directory .
For example, CONFIG_SPL activates the SPL compilation.
Hence to compile U-Boot, select the <target> and the device tree for the board in order to choose a predefined configuration.
Refer to #U-Boot_build for examples.

3.1 Kbuild

Like the kernel, the U-Boot build system is based on configuration symbols (defined in Kconfig files). The selected values are stored in a **.config** file in the build directory, with the same makefile target. .
Proceed as follows:

- Select a pre-defined configuration (defconfig file in configs directory) and generate the first **.config**:

```
PC $> make <config>_defconfig.
```

- Change the U-Boot compile configuration (modify .config) by using one of the following five `make` commands:

```
PC $> make menuconfig --> menu based program
PC $> make config  --> line-oriented configuration
PC $> make xconfig --> QT program[2]
PC $> make gconfig --> GTK program
PC $> make nconfig --> ncurse menu based program
```

You can then compile U-Boot with the updated .config.

Warning: the modification is performed locally in the build directory. It will be lost after a `make distclean`.

Save your configuration to be able to use it as a defconfig file:

```
PC $> make savedefconfig
```

This target saves the current config as a defconfig file in the build directory. It can then be compared with the predefined configuration (configs/stm32mp*defconfig).

The other makefile targets are the following:

```
 PC $> make help
....
Configuration targets:
  config          - Update current config utilising a line-oriented program
  nconfig         - Update current config utilising a ncurses menu based
                    program
  menuconfig          - Update current config utilising a menu based program
  xconfig          - Update current config utilising a Qt based front-end
  gconfig          - Update current config utilising a GTK+ based front-end
  oldconfig           - Update current config utilising a provided .config as base
  localmodconfig  - Update current config disabling modules not loaded
  localyesconfig  - Update current config converting local mods to core
  defconfig           - New config with default from ARCH supplied defconfig
  savedefconfig   - Save current config as ./defconfig (minimal config)
  allnoconfig           - New config where all options are answered with no
  allyesconfig           - New config where all options are accepted with yes
  allmodconfig           - New config selecting modules when possible
  alldefconfig    - New config with all symbols set to default
  randconfig          - New config with random answer to all options
  listnewconfig   - List new options
  olddefconfig           - Same as oldconfig but sets new symbols to their
                   default value without prompting
```

3.2 Device tree

Refer to doc/README.fdt-control for details.

The board device tree has the same binding as the kernel. It is integrated within the SPL and U-Boot binaries:

- By default, it is appended at the end of the code (CONFIG_OF_SEPARATE).
- It is embedded in the U-Boot binary (CONFIG_OF_EMBED). This is useful for debugging since it enables easy .elf file loading.

A default device tree is available in the defconfig file (by setting CONFIG_DEFAULT_DEVICE_TREE).

You can either select another supported device tree using the DEVICE_TREE make flag. For stm32mp boards, the corresponding file is: arch/arm/dts/stm32mp*.dts .

```
PC $> make DEVICE_TREE=<dts-file-name>
```

or provide a precompiled device tree blob (using EXT_DTB option):

```
PC $> make EXT_DTB=boot/<dts-file-name>.dtb
```

The SPL device tree is also generated from this device tree. However to reduce its size, the U-Boot makefile uses the fdtgrep tool to parse the full U-Boot DTB and identify all the drivers required by SPL.

To do this, U-Boot uses specific device-tree flags to define if the associated driver is initialized prior to U-Boot relocation and /or if the associated node is present in SPL :

- **u-boot,dm-pre-reloc** => present in SPL, initialized before relocation in U-Boot
- **u-boot,dm-pre-proper** => initialized before relocation in U-Boot
- **u-boot,dm-spl** => present in SPL

In the device tree used by U-Boot, these flags **need to be added in each node** used in SPL or in U-Boot before relocation and for each used handle (clock, reset, pincontrol).

4 U-Boot command line interface (CLI)

Refer to U-Boot Command Line Interface.

If CONFIG_AUTOBOOT is activated, you have CONFIG_BOOTDELAY seconds (2s by default) to enter the console by pressing any key, after the line below is displayed and bootcmd is executed (CONFIG_BOOTCOMMAND):

```
Hit any key to stop autoboot:  2
```

4.1 Commands

The commands are defined in cmd/*.c . They are activated through the corresponding **CONFIG_CMD_*** configuration flag.

Use the `help` command in the U-Boot shell to list the commands available on your device:

```
Board $> help
```

Below the list of all commands extracted from U-Boot Manual (**not-exhaustive**):

- Information Commands
  - bdinfo - prints Board Info structure
  - coninfo - prints console devices and information
  - flinfo - prints Flash memory information
  - iminfo - prints header information for application image
  - help - prints online help
- Memory Commands
  - base - prints or sets the address offset
  - crc32 - checksum calculation
  - cmp - memory compare
  - cp - memory copy
  - md - memory display
  - mm - memory modify (auto-incrementing)
  - mtest - simple RAM test
  - mw - memory write (fill)
  - nm - memory modify (constant address)
  - loop - infinite loop on address range
- Flash Memory Commands
  - cp - memory copy
  - flinfo - prints Flash memory information
  - erase - erases Flash memory
  - protect - enables or disables Flash memory write protection
  - mtdparts - defines a Linux compatible MTD partition scheme

- Execution Control Commands
  - source - runs a script from memory
  - bootm - boots application image from memory
  - go - starts application at address 'addr'
- Download Commands
  - bootp - boots image via network using BOOTP/TFTP protocol
  - dhcp - invokes DHCP client to obtain IP/boot params
  - loadb - loads binary file over serial line (kermit mode)
  - loads - loads S-Record file over serial line
  - rarpboot- boots image via network using RARP/TFTP protocol
  - tftpboot- boots image via network using TFTP protocol
- Environment Variables Commands
  - printenv- prints environment variables
  - saveenv - saves environment variables to persistent storage
  - setenv - sets environment variables
  - run - runs commands in an environment variable
  - bootd - boots default, i.e., run 'bootcmd'
- Flattened Device Tree support
  - fdt addr - selects the FDT to work on
  - fdt list - prints one level
  - fdt print - recursive printing
  - fdt mknode - creates new nodes
  - fdt set - sets node properties
  - fdt rm - removes nodes or properties
  - fdt move - moves FDT blob to new address
  - fdt chosen - fixup dynamic information
- Special Commands
  - i2c - I2C sub-system
- Storage devices
- Miscellaneous Commands
  - echo - echoes args to console
  - reset - Performs a CPU reset
  - sleep - delays the execution for a predefined time
  - version - prints the monitor version

To add a new command, refer to doc/README.commands .

4.2 U-Boot environment variables

The U-Boot behavior is configured through environment variables.

Refer to Manual and README / Environment Variables.

On the first boot, U-Boot uses a default environment embedded in the U-Boot binary. You can modify it by changing the content of CONFIG_EXTRA_ENV_SETTINGS in your configuration file (for example ./include/configs/stm32mp1.h) (see README / - Default Environment).

This environment can be modified and saved in the boot device. When it is present, it is loaded during U-Boot initialization:

- for *e*â¢MMC/SD card boot (CONFIG_ENV_IS_IN_EXT4), in the bootable ext4 partition "bootfs" in in file CONFIG_ENV_EXT4_FILE="uboot.env".
- for NAND boot (CONFIG_ENV_IS_IN_UBI), in the two UBI volumes "config" (CONFIG_ENV_UBI_VOLUME) and "config_r" (CONFIG_ENV_UBI_VOLUME_REDUND).
- for NOR boot (CONFIG_ENV_IS_IN_SPI_FLASH), in the u-boot_env mtd parttion (at offset CONFIG_ENV_OFFSET).

4.2.1 env command

The `env` command allows displaying, modifying and saving the environment in U-Boot console.

```
Board $> help env
env - environment handling commands

Usage:
env default [-f] -a - [forcibly] reset default environment
env default [-f] var [...] - [forcibly] reset variable(s) to their default values
env delete [-f] var [...] - [forcibly] delete variable(s)
env edit name - edit environment variable
env exists name - tests for existence of variable
env print [-a | name ...] - print environment
env print -e [name ...] - print UEFI environment
env run var [...] - run commands in an environment variable
env save - save environment
env set -e name [arg ...] - set UEFI variable; unset if 'arg' not specified
env set [-f] name [arg ...]
```

Example: proceed as follows to restore the default environment and save it. This is useful after a U-Boot upgrade:

```
Board $> env default -a
Board $> env save
```

4.2.2 bootcmd

"bootcmd" variable is the autoboot command. It defines the command executed when U-Boot starts (CONFIG_BOOTCOMMAND).

For stm32mp, CONFIG_BOOTCOMMAND="run bootcmd_stm32mp":

```
Board $> env print bootcmd
 bootcmd=run bootcmd_stm32mp
```

"bootcmd_stm32mp" is a script that selects the command to be executed for each boot device (see ./include/configs /stm32mp1.h), based on generic distro scripts:

- for serial/usb: execute the `stm32prog` command.
- for mmc boot (*e*â¢MMC, SD card), boot only on the same device (bootcmd_mmc...).
- for nand boot, boot with on ubifs partition on nand (bootcmd_ubi0).
- for nor boot, use the default order *e*â¢MMC (SDMMC 1)/ NAND / SD card (SDMMC 0) / SDMMC2 (the default bootcmd: distro_bootcmd).

```
Board $> env print bootcmd_stm32mp
```

You can then change this configuration:

- either permanently in your board file (default environment by CONFIG_EXTRA_ENV_SETTINGS or change CONFIG_BOOTCOMMAND value) or
- temporarily in the saved environment:

```
Board $> env set bootcmd run bootcmd_mmc0
Board $> env save
```

Note: To reset the environment to its default value:

```
Board $> env default bootcmd
Board $> env save
```

4.3 Generic Distro configuration

Refer to doc/README.distro for details.

This feature is activated by default on ST boards (CONFIG_DISTRO_DEFAULTS):

- one boot command (bootmcd_xxx) exists for each bootable device.
- U-Boot is independent of the Linux distribution used.
- bootcmd is defined in ./include/config_distro_bootcmd.h

When DISTRO is enabled, the command that is executed by default is include/config_distro_bootcmd.h :

```
bootcmd=run distro_bootcmd
```

This script tries any device found in the 'boot_targets' variable and executes the associated bootcmd.

Example for mmc0, mmc1, mmc2, pxe and ubifs devices:

```
bootcmd_mmc0=setenv devnum 0; run mmc_boot
bootcmd_mmc1=setenv devnum 1; run mmc_boot
bootcmd_mmc2=setenv devnum 2; run mmc_boot
bootcmd_pxe=run boot_net_usb_start; dhcp; if pxe get; then pxe boot; fi
bootcmd_ubifs0=setenv devnum 0; run ubifs_boot
```

U-Boot searches for a **extlinux.conf** configuration file for each bootable device. This file defines the kernel configuration to be used:

- bootargs
- kernel + device tree + ramdisk files (optional)
- FIT image

4.4 U-Boot scripting capabilities

"Script files" are command sequences that are executed by the U-Boot command interpreter. This feature is particularly useful to configure U-Boot to use a real shell (hush) as command interpreter.

See U-Boot script manual for an example.

5 U-Boot build

5.1 Prerequisites

- a PC with Linux and tools:
  - see PC_prerequisites
  - #ARM cross compiler
- U-Boot source code
  - the latest STMicroelectronics U-Boot version
    - tar.xz file from Developer Package (for example STM32MP1)
    - from GITHUB[3], with `git` command

```
PC $> git clone https://github.com/STMicroelectronics/u-boot
```

  - from the Mainline U-Boot in official GIT repository [4]

```
PC $> git clone https://gitlab.denx.de/u-boot/u-boot.git
```

5.1.1 ARM cross compiler

A cross compiler [5] must be installed on your Host (X86_64, i686, ...) for the ARM targeted Device architecture. In addition, the $PATH and $CROSS_COMPILE environment variables must be configured in your shell.

You can use gcc for ARM, available in:

- the SDK toolchain (see Cross-compile with OpenSTLinux SDK)
  PATH and CROSS_COMPILE are automatically updated.
- an existing package
  For example, install gcc-arm-linux-gnueabihf on Ubuntu/Debian: (**PC $>** sudo apt-get.
- an existing toolchain:
  - latest gcc toolchain provided by arm (https://developer.arm.com/open-source/gnu-toolchain/gnu-a/downloads/)
  - gcc v7 toolchain provided by linaro: (https://www.linaro.org/downloads/)

For example, to use *gcc-arm-9.2-2019.12-x86_64-arm-none-linux-gnueabihf.tar.xz* from arm, extract the toolchain in $HOME and update your environment with:

```
PC $> export PATH=$HOME/gcc-arm-9.2-2019.12-x86_64-arm-none-linux-gnueabihf/bin:$PATH
PC $> export CROSS_COMPILE=arm-none-linux-gnueabihf-
```

For example, to use **gcc-linaro-7.2.1-2017.11-x86_64_arm-linux-gnueabi.tar.xz**
from https://releases.linaro.org/components/toolchain/binaries/7.2-2017.11/arm-linux-gnueabi/
Unzip the toolchain in $HOME and update your environment with:

```
PC $> export PATH=$HOME/gcc-linaro-7.2.1-2017.11-x86_64_arm-linux-gnueabi/bin:$PATH
PC $> export CROSS_COMPILE=arm-linux-gnueabi-
```

5.2 Compilation

In the U-Boot source directory, select the <target> and the <device tree> for your configuration and then execute the `make all` command:

```
PC $> make <target>_defconfig
PC $> make DEVICE_TREE=<device-tree> all
```

Optionally **KBUILD_OUTPUT** can be used to change the output directory to compile several targets or not to compile in the source directory. For example:

```
PC $> export KBUILD_OUTPUT=../build/basic
```

DEVICE_TREE can also be exported to your environment when only one board is supported. For example:

```
PC $> export DEVICE_TREE=stm32mp157c-ev1
```

Examples from STM32MP15 U-Boot:

Three configurations are supported for STM32MP15x lines :

- **stm32mp15_trusted_defconfig**: trusted boot chain, U-Boot (without SPL) is unsecure and uses Secure monitor from TF-A
- **stm32mp15_optee_defconfig**: trusted boot chain, U-Boot (without SPL) is unsecure and uses Secure monitor from SecureOS = OP-TEE
- stm32mp15_basic_defconfig: basic boot chain, with an SPL as FSBL, U-BOOT is secure and installs monitor with PSCI

The board diversity is only managed with the device tree.

```
PC $> export KBUILD_OUTPUT=../build/trusted
PC $> make stm32mp15_trusted_defconfig
PC $> make DEVICE_TREE=stm32mp157c-<board> all
```

```
PC $> export KBUILD_OUTPUT=../build/optee
PC $> export DEVICE_TREE=stm32mp157c-<board>
PC $> make stm32mp15_optee_defconfig
PC $> make all
```

```
PC $> make stm32mp15_basic_defconfig
PC $> make DEVICE_TREE=stm32mp157c-<board>  all
```

Use help to list other targets:

```
PC $> make help
```

5.3 Output files

The resulting U-Boot files are located in your build directory (U-Boot or KBUILD_OUTPUT).

Two binary formats are used for stm32mp devices:

- STM32 image format (*.stm32), managed by mkimage U-Boot tools and Signing_tool. It is requested by ROM code and TF-A (see STM32 header for binary files for details).
- uImage (*.img) format, file including a U-Boot header, managed by SPL and U-Boot (for kernel load)

The U-Boot generated files are the following

- For Trusted boot chain (TF-A is used as FSBL, with or without OP-TEE)
  - u-boot.stm32 : U-Boot binary with STM32 image header, loaded by TF-A
- For Basic boot chain (SPL is used as FSBL)
  - u-boot-spl.stm32 : SPL binary with STM32 image header, loaded by ROM code
  - u-boot.img : U-Boot binary with uImage header, loaded by SPL

The files used to debug with gdb are

- u-boot : elf file for U-Boot
- spl/u-boot-spl : elf file for SPL

6 References

- â https://www.denx.de/wiki/pub/U-Boot/MiniSummitELCE2013/2013-ELCE-U-Boot-Falcon-Boot.pdf
- â https://en.wikipedia.org/wiki/Xconfig
- â https://github.com/STMicroelectronics/u-boot
- â https://gitlab.denx.de/u-boot/u-boot.git or https://github.com/u-boot/u-boot
- â https://en.wikipedia.org/wiki/Cross_compiler