U-Boot overview

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Contents

1 Das U-Boot

Das U-Boot ("the Universal Boot Loader" or just U-Boot) is an open-source boot loader, which 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
- The official **source code** is available with git repository at git.denx.de

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

Reading the README file is recommended. It covers the following topics:

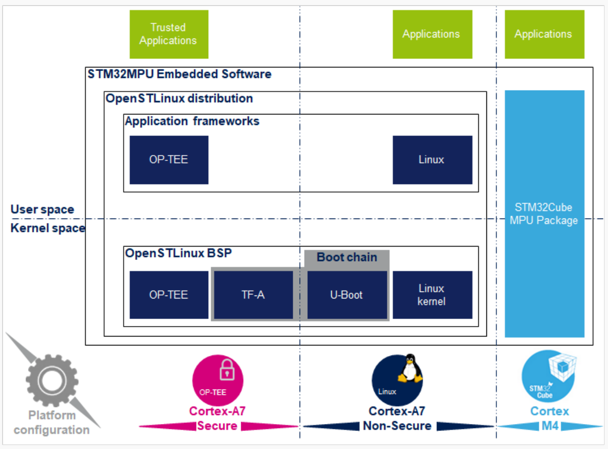
- the source file tree structure

- the meaning of the CONFIG defines
- instructions for building U-Boot
- a brief description of the Hush shell
- a list of common environment variables

2 U-Boot overview

The same U-Boot source can generate 2 pieces of firmware used in the STM32 MPU boot chain: SPL and U-Boot

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



Zoom out to STM32MPU Embedded Software

2.1 SPL: FSBL for basic boot

The **U-Boot SPL** or just **SPL** is the first stage boot loader (FSBL) for the basic boot chain.
It is a small binary (bootstrap utility), generated from the U-Boot source, which fits in the internal and limited embedded RAM:

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

2.2 U-Boot: SSBL

U-Boot is the default second stage boot loader (SSBL) for the STM32 MPU platforms for the 2 boot chains, trusted and basic:

- it is configurable and expendable
- it has a simple command line interface (CLI), usually over a serial console port for interaction with the user
- it provides scripting capabilities
- it loads the kernel into RAM and passes control to the kernel
- it manages many internal and external devices like NAND, NOR, Ethernet, USB
- it has many supported features and commands for
  - file systems: FAT, UBI/UBIFS, JFFS
  - IP stack: FTP
  - display: LCD, HDMI, BMP for splashcreen
  - USB: host profile (mass storage) or device profile (DFU stack)

2.3 SPL phases

The **SPL** runs through the main following phases in SYSRAM:

- **board_init_f()**: init drivers up to DDR initialisation (mininimal stack and heap: CONFIG_SPL _STACK_R_MALLOC_SIMPLE_LEN)
- configure heap in DDR (CONFIG_SPL_SYS_MALLOC_F_LEN)
- **board_init_r()**: init other drivers activated in the SPL device tree
- load U-Boot (or Kernel in Falcon mode[1]: README.falcon) and execute it

2.4 U-Boot phases

U-Boot runs through the following main phases in DDR:

- **Pre-relocation** initialization (common/board_f.c): minimal init (cpu, clock, reset, ddr, console,...) running at the load address CONFIG_SYS_TEXT_BASE
- **Relocation**: copy the code to the end of DDR
- **Post-relocation initialization**:(common/board_r.c): init all the drivers
- **Execution of commands**: through autoboot (CONFIG_AUTOBOOT) or console shell
  - execute the boot command (bootcmd=CONFIG_BOOTCOMMAND by default):
    for example, execute the command 'bootm' to:
    - load and check images (kernel, device tree, ramdisk....)
    - fixup kernel device tree
    - install secure monitor (optional)
    - pass control to the Linux kernel (or other 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** defines in include/configs/stm32mp*.h
  the file name is configured by CONFIG_SYS_CONFIG_NAME
  (these flags are progressively migrating to Kconfig)
  for stm32mp157: we use include/configs/stm32mp1.h file

- **DeviceTree** = U-Boot and SPL binaries include a device tree blob which is parsed at run time

All the configuration flags (CONFIG_) are described in the source code: the README file or documentation directory
example: CONFIG_SPL => activate the SPL compilation.
Hence to compile U-Boot, you need to select the <target> and the device tree for the board to select a predefined configuration.
See #U-Boot_build for examples.

3.1 Kbuild

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

- select pre-defined configuration (defconfig file, in configs directory) and generate the first **.config**

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

- change U-Boot compile configuration (modify .config) using one of the 5 make command

```
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: modification is only done locally in the build directory, it is lost after a "make distclean"

So if you want to use your configuration as defconfig:

```
 PC $> make savedefconfig
```

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

The other makefile targets are :

```
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

See doc/README.fdt-control

The board device tree, with the same binding as the kernel, is integrated with the SPL and U-Boot binaries:

- appended at the end of the code by default (CONFIG_OF_SEPARATE)
- embedded in binary (CONFIG_OF_EMBED): useful for debug, allows easy elf file loading

A default device tree is defined in the defconfig file (with CONFIG_DEFAULT_DEVICE_TREE).

You can also select another supported device tree with the make flag DEVICE_TREE
for stm32mp32 boards the file are: arch/arm/dts/stm32mp*.dts

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

or you can provide a precompiled device tree blob (with EXT_DTB option)

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

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

To do this, U-Boot uses some specific device-tree flags to specify 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-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 but also for each used handle (clock, reset, pincontrol).

4 U-Boot command line interface (CLI)

see U-Boot Command Line Interface

If CONFIG_AUTOBOOT is activated, to enter in this console, you have CONFIG_BOOTDELAY seconds (2s by default) before bootcmd execution (CONFIG_BOOTCOMMAND) by pressing any key when the line below is displayed.

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

4.1 Commands

The commands are defined cmd/*.c , they are activated under associated configuration flag **CONFIG_CMD_***.

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

List of commands extracted from U-Boot Manual (**not-exhaustive**):

- Information Commands
  - bdinfo - print Board Info structure
  - coninfo - print console devices and informations
  - flinfo - print FLASH memory information
  - iminfo - print header information for application image
  - help - print online help
- Memory Commands
  - base - print or set 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 - print FLASH memory information
  - erase - erase FLASH memory
  - protect - enable or disable FLASH write protection
  - mtdparts - define a Linux compatible MTD partition scheme
- Execution Control Commands
  - source - run script from memory
  - bootm - boot application image from memory
  - go - start application at address 'addr'
- Download Commands
  - bootp - boot image via network using BOOTP/TFTP protocol
  - dhcp - invoke DHCP client to obtain IP/boot params
  - loadb - load binary file over serial line (kermit mode)
  - loads - load S-Record file over serial line
  - rarpboot- boot image via network using RARP/TFTP protocol
  - tftpboot- boot image via network using TFTP protocol
- Environment Variables Commands
  - printenv- print environment variables
  - saveenv - save environment variables to persistent storage
  - setenv - set environment variables
  - run - run commands in an environment variable
  - bootd - boot default, i.e., run 'bootcmd'
- Flattened Device Tree support
  - fdt addr - select FDT to work on
  - fdt list - print one level
  - fdt print - recursive print

    - fdt mknode - create new nodes
    - fdt set - set node properties
    - fdt rm - remove nodes or properties
    - fdt move - move FDT blob to new address
    - fdt chosen - fixup dynamic info
- Special Commands
    - i2c - I2C sub-system
- Storage devices
- Miscellaneous Commands
    - echo - echo args to console
    - reset - Perform RESET of the CPU
    - sleep - delay execution for some time
    - version - print monitor version

To add a new command, see doc/README.commands

4.2 U-Boot environment variables

The U-Boot behavior is configured with environment variables.

see Manual and README / Environment Variables

By default the env is NOT saved (CONFIG_ENV_IS_NOWHERE), only the default environment is used (saveenv command is not working)

You can modify this default environment by changing the content of CONFIG_EXTRA_ENV_SETTINGS in your configuration file (for example ./include/configs/stm32mp1.h) (see README / - Default Environment).

You can also choose one location with configuration flags:

- CONFIG_ENV_IS_IN_MMC
- CONFIG_ENV_IS_IN_FLASH
- CONFIG_ENV_IS_IN_SPI
- CONFIG_ENV_IS_IN_FAT
- CONFIG_ ENV_IS_IN_NAND
- CONFIG_ENV_IS_IN_UBI
- CONFIG_ENV_IS_IN_EEPROM

4.2.1 bootcmd

Autoboot command: defines the command executed when U-Boot starts (CONFIG_BOOTCOMMAND).

But you can change this variable in CONFIG_EXTRA_ENV_SETTINGS (after BOOTENV macro needed for #Generic Distro configuration).

```
#define CONFIG_EXTRA_ENV_SETTINGS \
        "stdin=serial\0" \
        "stdout=serial\0" \
        "stderr=serial\0" \
        "kernel_addr_r=0xc2000000\0" \
        "fdt_addr_r=0xc4000000\0" \
        "scriptaddr=0xc4100000\0" \
        "pxefile_addr_r=0xc4200000\0" \
        "splashimage=0xc4300000\0"  \
        "ramdisk_addr_r=0xc4400000\0" \
        "fdt_high=0xffffffff\0" \
        "initrd_high=0xffffffff\0" \
        BOOTENV \
        "bootcmd=run bootcmd_mmc0\0"
```

4.3 Generic Distro configuration

see doc/README.distro

This feature is activated for 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

With DISTRO the default command executed: include/config_distro_bootcmd.h

```
bootcmd=run distro_bootcmd
```

This script will try any device found in the variable 'boot_targets' and execute the associated bootcmd.

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

```
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 searchs for a configuration file **extlinux.conf** in a bootable device, this file defines the kernel configuration to use:

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

4.4 U-Boot scripting capabilities

"Script files" are command sequences that will be executed by U-Boot's command interpreter; this feature is especially useful when you configure U-Boot to use a real shell (hush) as command interpreter.

See U-Boot script manual for example.

5 U-Boot build

5.1 Prerequisites

You need:

- a PC with Linux and tools:
  - see PC_prerequisites
  - #ARM cross compiler
- U-Boot source code
  - the latest STMicroelectonics 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 http://git.denx.de/u-boot.git
```

5.1.1 ARM cross compiler

You need to have a cross compiler [5] installed on your Host (X86_64, i686, ...) for the targeted Device architecture = ARM, the environment variables ($PATH and $CROSS_COMPILE) need to be configured in your shell.

You can use gcc for ARM, available in:

1. the SDK toolchain
   See Cross-compile with OpenSTLinux SDK, PATH and CROSS_COMPILE are automatically updated.
2. an existing package (for example, on Ubuntu/Debian: (**PC $>** sudo apt-get install gcc-arm-linux-gnueabihf)
3. an existing toolchain:
   - gcc v8 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: **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 it in $HOME,
and you need to update your environment:

```
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, you need to 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
```

KBUILD_OUTPUT can be used optionally to change the output directory if you want to compile several targets or don't compile in the source directory, for example:

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

DEVICE_TREE can be also exported to your environment when you support only one board, for example:

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

For all the stm32mp15 family, we manage 3 configurations:

- 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.

Examples from STM32MP15 U-Boot:

```
PC $> export KBUILD_OUTPUT=../build/basic
PC $> make stm32mp15_basic_defconfig
PC $> make DEVICE_TREE=stm32mp157c-<board> all
```

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

```
PC $> export KBUILD_OUTPUT=../build/trusted
PC $> export DEVICE_TREE=stm32mp157c-ev1
PC $> make stm32mp15_trusted_defconfig
PC $> make all
```

Use help to list other targets:

```
PC $> make help
```

5.3 Output files

The resulting U-Boot files are present in your build directory (U-Boot or KBUILD_OUTPUT) and SPL Images are in the spl subdirectory.

STM32 image format (*.stm32) is managed by mkimage U-Boot tools and is requested by boot ROM (for basic boot chain) or by TF-A (for trusted boot chain).

- **u-boot.stm32** : U-Boot binary with STM32 image header => SSBL for Trusted boot chain
- **u-boot.img** : U-Boot binary with uImage header => SSBL for Basic boot chain

- u-boot : elf file, used to debug with gdb
- **spl/u-boot-spl.stm32** : SPL binary with STM32 image header => FSBL for Basic boot chain
- spl/u-boot-spl : elf file, used to debug with gdb

6 References

1. ↑ https://www.denx.de/wiki/pub/U-Boot/MiniSummitELCE2013/2013-ELCE-U-Boot-Falcon-Boot.pdf
2. ↑ https://en.wikipedia.org/wiki/Xconfig
3. ↑ https://github.com/STMicroelectronics/u-boot
4. ↑ http://git.denx.de/u-boot.git or https://github.com/u-boot/u-boot
5. ↑ https://en.wikipedia.org/wiki/Cross_compiler

Secondary Program Loader, *Also known as **U-Boot SPL***

Second Stage Boot Loader

First Stage Boot Loader

Random Access Memory

Read Only Memory

Central processing unit

Doubledata rate (memory domain)

Microprocessor Unit

High-Definition Multimedia Interface (HDMI standard)

Device Firmware Upgrade

Device Tree Binary (or Blob)

Memory Technology Device

Trivial File Transfer Protocol (https://en.wikipedia.org/wiki/Trivial_File_Transfer_Protocol)

Inter-Integrated Circuit

MultimediaCard

Serial Peripheral Interface

Electrically-erasable programmable read-only memory

Initial ramdisk (https://en.wikipedia.org/wiki/Initial_ramdisk) - NEW

Software development kit

Trusted Firmware for Arm Cortex-A

Power State Coordination Interface