

Кросс-компиляция и запуск ядра Linux armv7

```
user@debian1: ~/linux-6.17-rc4
user@debian1:~/linux-6.17-rc4$ export ARCH=arm
user@debian1:~/linux-6.17-rc4$ make help | less
user@debian1:~/linux-6.17-rc4$ apt search gcc | grep gnueabihf | less
user@debian1:~/linux-6.17-rc4$ user@debian1:~/linux-6.17-rc4$ sudo apt install gcc-arm-linux-gnueabihf
[sudo] password for user:
Installing:
gcc-arm-linux-gnueabihf

Installing dependencies:
binutils-arm-linux-gnueabihf      libasan8-armhf-cross      libgomp1-armhf-cross
cpp-14-arm-linux-gnueabihf      libatomic1-armhf-cross    libstdc++6-armhf-cross
cpp-arm-linux-gnueabihf         libcc1-armhf-cross        libubsan1-armhf-cross
gcc-14-arm-linux-gnueabihf      libcc1-dev-armhf-cross    linux-libc-dev-armhf-cross
gcc-14-arm-linux-gnueabihf-base libgcc-14-dev-armhf-cross
gcc-14-cross-base              libgcc-s1-armhf-cross

Suggested packages:
binutils-doc      cpp-14-doc      gcc-14-doc      automake      gdb-arm-linux-gnueabihf
gcc-14-locales    cpp-doc        autoconf      libtool      gcc-doc

Summary:
Upgrading: 0, Installing: 17, Removing: 0, Not Upgrading: 0
Download size: 41.5 MB
Space needed: 138 MB / 24.7 GB available

Continue? [Y/n] Y
Get:1 http://deb.debian.org/debian trixie/main amd64 binutils-arm-linux-gnueabihf amd64 2.44-3 [1,501 kB]
Get:2 http://deb.debian.org/debian trixie/main amd64 gcc-14-arm-linux-gnueabihf-base amd64 14.2.0-19cross1 [49.6 kB]
Get:3 http://deb.debian.org/debian trixie/main amd64 cpp-14-arm-linux-gnueabihf amd64 14.2.0-19cross1 [10.4 MB]
Get:4 http://deb.debian.org/debian trixie/main amd64 cpp-arm-linux-gnueabihf amd64 4:14.2.0-1 [4,856 B]
Get:5 http://deb.debian.org/debian trixie/main amd64 gcc-14-cross-base all 14.2.0-19cross1 [44.9 kB]
Get:6 http://deb.debian.org/debian trixie/main amd64 libcc1-armhf-cross all 2.41-11cross1 [922 kB]
Get:7 http://deb.debian.org/debian trixie/main amd64 libgcc-s1-armhf-cross all 14.2.0-19cross1 [36.9 kB]
Get:8 http://deb.debian.org/debian trixie/main amd64 libgomp1-armhf-cross all 14.2.0-19cross1 [109 kB]
Get:9 http://deb.debian.org/debian trixie/main amd64 libatomic1-armhf-cross all 14.2.0-19cross1 [6,936 B]
Get:10 http://deb.debian.org/debian trixie/main amd64 libasan8-armhf-cross all 14.2.0-19cross1 [2,571 kB]
Get:11 http://deb.debian.org/debian trixie/main amd64 libstdc++6-armhf-cross all 14.2.0-19cross1 [559 kB]
Get:12 http://deb.debian.org/debian trixie/main amd64 libubsan1-armhf-cross all 14.2.0-19cross1 [1,038 kB]
Get:13 http://deb.debian.org/debian trixie/main amd64 libgcc-14-dev-armhf-cross all 14.2.0-19cross1 [768 kB]
Get:14 http://deb.debian.org/debian trixie/main amd64 gcc-14-arm-linux-gnueabihf amd64 14.2.0-19cross1 [19.8 MB]
Get:15 http://deb.debian.org/debian trixie/main amd64 gcc-arm-linux-gnueabihf amd64 4:14.2.0-1 [1,452 B]
Get:16 http://deb.debian.org/debian trixie/main amd64 linux-libc-dev-armhf-cross all 6.12.38-1cross1 [2,431 kB]
Get:17 http://deb.debian.org/debian trixie/main amd64 libcc1-dev-armhf-cross all 2.41-11cross1 [1,324 kB]
Fetched 41.5 MB in 3s (13.3 MB/s)
Selecting previously unselected package binutils-arm-linux-gnueabihf.
(Reading database ... 40160 files and directories currently installed.)
Preparing to unpack .../00-binutils-arm-linux-gnueabihf_2.44-3_amd64.deb ...
Unpacking binutils-arm-linux-gnueabihf (2.44-3) ...
Selecting previously unselected package gcc-14-arm-linux-gnueabihf-base:amd64.
Preparing to unpack .../01-gcc-14-arm-linux-gnueabihf-base_14.2.0-19cross1_amd64.deb ...
Unpacking gcc-14-arm-linux-gnueabihf-base:amd64 (14.2.0-19cross1) ...
Selecting previously unselected package cpp-14-arm-linux-gnueabihf.
Preparing to unpack .../02-cpp-14-arm-linux-gnueabihf_14.2.0-19cross1_amd64.deb ...
Unpacking cpp-14-arm-linux-gnueabihf (14.2.0-19cross1) ...
Selecting previously unselected package cpp-arm-linux-gnueabihf.
Preparing to unpack .../03-cpp-arm-linux-gnueabihf_4%3a14.2.0-1_amd64.deb ...
Unpacking cpp-arm-linux-gnueabihf (4:14.2.0-1) ...
Selecting previously unselected package gcc-14-cross-base.
Preparing to unpack .../04-gcc-14-cross-base_14.2.0-19cross1_all.deb ...
Unpacking gcc-14-cross-base (14.2.0-19cross1) ...
Selecting previously unselected package libcc1-armhf-cross.
Preparing to unpack .../05-libcc1-armhf-cross_2.41-11cross1_all.deb ...
Unpacking libcc1-armhf-cross (2.41-11cross1) ...
```

Устанавливаем кросс-компилятор.

```
user@debian1: ~/linux-6.17-rc4
user@debian1:~/linux-6.17-rc4$ make multi_v7_defconfig
HOSTCC scripts/basic/fixdep
HOSTCC scripts/kconfig/conf.o
HOSTCC scripts/kconfig/confdata.o
HOSTCC scripts/kconfig/expr.o
LEX scripts/kconfig/lexer.lex.c
YACC scripts/kconfig/parser.tab.[ch]
HOSTCC scripts/kconfig/lexer.lex.o
HOSTCC scripts/kconfig/menu.o
HOSTCC scripts/kconfig/parser.tab.o
HOSTCC scripts/kconfig/preprocess.o
HOSTCC scripts/kconfig/symbol.o
HOSTCC scripts/kconfig/util.o
HOSTLD scripts/kconfig/conf
#
# configuration written to .config
#
user@debian1:~/linux-6.17-rc4$ export CROSS_COMPILE=arm-linux-gnueabihf
user@debian1:~/linux-6.17-rc4$ export CROSS_COMPILE=arm-linux-gnueabihf-
user@debian1:~/linux-6.17-rc4$ make -j4 zImage
```

Компиляция с default конфигом

```
user@debian1: ~/linux-6.17-rc4/arch/arm/boot
virt-2.11      QEMU 2.11 ARM Virtual Machine (deprecated)
virt-2.12      QEMU 2.12 ARM Virtual Machine (deprecated)
virt-2.6       QEMU 2.6 ARM Virtual Machine (deprecated)
virt-2.7       QEMU 2.7 ARM Virtual Machine (deprecated)
virt-2.8       QEMU 2.8 ARM Virtual Machine (deprecated)
virt-2.9       QEMU 2.9 ARM Virtual Machine (deprecated)
virt-3.0       QEMU 3.0 ARM Virtual Machine (deprecated)
virt-3.1       QEMU 3.1 ARM Virtual Machine (deprecated)
virt-4.0       QEMU 4.0 ARM Virtual Machine (deprecated)
virt-4.1       QEMU 4.1 ARM Virtual Machine (deprecated)
virt-4.2       QEMU 4.2 ARM Virtual Machine (deprecated)
virt-5.0       QEMU 5.0 ARM Virtual Machine (deprecated)
virt-5.1       QEMU 5.1 ARM Virtual Machine (deprecated)
virt-5.2       QEMU 5.2 ARM Virtual Machine (deprecated)
virt-6.0       QEMU 6.0 ARM Virtual Machine (deprecated)
virt-6.1       QEMU 6.1 ARM Virtual Machine (deprecated)
virt-6.2       QEMU 6.2 ARM Virtual Machine (deprecated)
virt-7.0       QEMU 7.0 ARM Virtual Machine (deprecated)
virt-7.1       QEMU 7.1 ARM Virtual Machine
virt-7.2       QEMU 7.2 ARM Virtual Machine
virt-8.0       QEMU 8.0 ARM Virtual Machine
virt-8.1       QEMU 8.1 ARM Virtual Machine
virt-8.2       QEMU 8.2 ARM Virtual Machine
virt-9.0       QEMU 9.0 ARM Virtual Machine
virt-9.1       QEMU 9.1 ARM Virtual Machine
virt-9.2       QEMU 9.2 ARM Virtual Machine
witherspoon-bmc OpenPOWER Witherspoon BMC (ARM1176)
xilinx-zynq-a9  Xilinx Zynq 7000 Platform Baseboard for Cortex-A9
yosemitev2-bmc Facebook YosemiteV2 BMC (ARM1176)
user@debian1:~/linux-6.17-rc4/arch/arm/boot/dts/arm$ qemu-system-armhf -M help | less
user@debian1:~/linux-6.17-rc4/arch/arm/boot/dts/arm$

user@debian1:~/linux-6.17-rc4/arch/arm/boot$ cd ~
user@debian1:~$ mkdir linux_arm
user@debian1:~$ cd linux
-bash: cd: linux: No such file or directory
user@debian1:~$ cd linux_arm/
user@debian1:~/linux_arm$ ls
user@debian1:~/linux_arm$ ls
zImage
user@debian1:~/linux_arm$ ls
vexpress-v2p-ca9.dtb  zImage
user@debian1:~/linux_arm$ export AQMU_AUDIO_DRV=none
user@debian1:~/linux_arm$ qemu-system-armhf -M vexpress-a9 -kernel zImage -dtb vexpress-v2p-ca9.dtb -append "console=ttyAMA0" -nographic
```

Запуск собранного ядра в QEMU

user@debian1: ~/linux_arm

```
[E][09:32:25.785296] pw.conf | [ conf.c: 1215 pw_conf_load_conf_for_context()] can't load config client.co
nf: No such file or directory
[ 0.000000] Booting Linux on physical CPU 0x0
[ 0.000000] Linux version 6.17.0-rc4 (user@debian1) (arm-linux-gnueabi-hf-gcc (Debian 14.2.0-19) 14.2.0, GNU ld (GNU B
inutils for Debian) 2.44) #1 SMP Sun Sep 7 08:57:49 EDT 2025
[ 0.000000] CPU: ARMv7 Processor [410fc090] revision 0 (ARMv7), cr=10c5387d
[ 0.000000] CPU: PIPT / VIPT nonaliasing data cache, VIPT nonaliasing instruction cache
[ 0.000000] OF: fdt: Machine model: V2P-CA9
[ 0.000000] Memory policy: Data cache writeback
[ 0.000000] efi: UEFI not found.
[ 0.000000] cma: Failed to reserve 64 MiB
[ 0.000000] Zone ranges:
[ 0.000000] DMA [mem 0x0000000006000000-0x0000000067ffffff]
[ 0.000000] Normal empty
[ 0.000000] HighMem empty
[ 0.000000] Movable zone start for each node
[ 0.000000] Early memory node ranges
[ 0.000000] node 0: [mem 0x0000000006000000-0x0000000067ffffff]
[ 0.000000] Initmem setup node 0 [mem 0x0000000006000000-0x0000000067ffffff]
[ 0.000000] Reserved memory: created DMA memory pool at 0x4c000000, size 8 MiB
[ 0.000000] OF: reserved mem: initialized node vram@4c000000, compatible id shared-dma-pool
[ 0.000000] OF: reserved mem: 0x4c000000..0x4c7fffff (8192 KiB) nomap non-reusable vram@4c000000
[ 0.000000] CPU: All CPU(s) started in SVC mode.
[ 0.000000] percpu: Embedded 17 pages/cpu s40204 r8192 d21236 u69632
[ 0.000000] Kernel command line: console=ttyAMA0
[ 0.000000] printk: log buffer data + meta data: 131072 + 409600 = 540672 bytes
[ 0.000000] Dentry cache hash table entries: 16384 (order: 4, 65536 bytes, linear)
[ 0.000000] Inode-cache hash table entries: 8192 (order: 3, 32768 bytes, linear)
[ 0.000000] Built 1 zonelists, mobility grouping on. Total pages: 32768
[ 0.000000] mem auto-init: stack:all(zero), heap alloc:off, heap free:off
[ 0.000000] SLUB: HWalign=64, Order=0-3, MinObjects=0, CPUs=4, Nodes=1
[ 0.000000] rcu: Hierarchical RCU implementation.
[ 0.000000] rcu: RCU event tracing is enabled.
[ 0.000000] rcu: RCU restricting CPUs from NR_CPUS=16 to nr_cpu_ids=4.
[ 0.000000] Tracing variant of Tasks RCU enabled.
[ 0.000000] rcu: RCU calculated value of scheduler-enlistment delay is 10 jiffies.
[ 0.000000] rcu: Adjusting geometry for rcu_fanout_leaf=16, nr_cpu_ids=4
[ 0.000000] RCU Tasks Trace: Setting shift to 2 and lim to 1 rcu_task_cb_adjust=1 rcu_task_cpu_ids=4.
[ 0.000000] NR_IRQS: 16, nr_irqs: 16, preallocated irq: 16
[ 0.000000] GIC CPU mask not found - kernel will fail to boot.
[ 0.000000] GIC CPU mask not found - kernel will fail to boot.
[ 0.000000] L2C: platform modifies aux control register: 0x02020000 -> 0x02420000
[ 0.000000] L2C: DT/platform modifies aux control register: 0x02020000 -> 0x02420000
[ 0.000000] L2C-310 erratum 769419 enabled
[ 0.000000] L2C-310 enabling early BRESP for Cortex-A9
[ 0.000000] L2C-310 full line of zeros enabled for Cortex-A9
[ 0.000000] L2C-310 dynamic clock gating disabled, standby mode disabled
[ 0.000000] L2C-310 cache controller enabled, 8 ways, 128 kB
[ 0.000000] L2C-310: CACHE_ID 0x410000c8, AUX_CTRL 0x46420001
[ 0.000000] rcu: srcu_init: Setting srcu_struct sizes based on contention.
[ 0.000145] sched_clock: 32 bits at 24MHz, resolution 41ns, wraps every 89478484971ns
[ 0.004092] clocksource: arm,sp804: mask: 0xffffffff max_cycles: 0xffffffff, max_idle_ns: 1911260446275 ns
[ 0.005368] smp_twd: clock not found -2
[ 0.010408] Console: colour dummy device 80x30
[ 0.011420] Calibrating local timer... 93.54MHz.
[ 0.065471] Calibrating delay loop... 1653.14 BogoMIPS (lpj=8265728)
[ 0.139742] CPU: Testing write buffer coherency: ok
[ 0.141056] CPU0: Spectre v2: using BPIALL workaround
[ 0.141186] pid_max: default: 32768 minimum: 301
[ 0.143629] Mount-cache hash table entries: 1024 (order: 0, 4096 bytes, linear)
[ 0.143666] Mountpoint-cache hash table entries: 1024 (order: 0, 4096 bytes, linear)
[ 0.162357] CPU0: thread -1, cpu 0, socket 0, mpidr 80000000
[ 0.172594] Setting up static identity map for 0x60300000 - 0x603000ac
```

```
user@debian1: ~/linux_arm
[ 1.611578] 1000b000.serial: ttyAMA2 at MMIO 0x1000b000 (irq = 39, base_baud = 0) is a PL011 rev1
[ 1.613639] 1000c000.serial: ttyAMA3 at MMIO 0x1000c000 (irq = 40, base_baud = 0) is a PL011 rev1
[ 1.964756] input: ImExPS/2 Generic Explorer Mouse as /devices/platform/bus@40000000/bus@40000000:motherboard-bus@400
00000/bus@40000000:motherboard-bus@40000000:iofpga@7,00000000/10007000.kmi/serio1/input/input2
[ 2.089296] clk: Disabling unused clocks
[ 2.097590] check access for rdinit=/init failed: -2, ignoring
[ 2.103076] /dev/root: Can't open blockdev
[ 2.103867] VFS: Cannot open root device "" or unknown-block(0,0): error -6
[ 2.103896] Please append a correct "root=" boot option; here are the available partitions:
[ 2.104203] 0100          65536 ram0
[ 2.104298] (driver?)
[ 2.104330] 0101          65536 ram1
[ 2.104340] (driver?)
[ 2.104349] 0102          65536 ram2
[ 2.104357] (driver?)
[ 2.104364] 0103          65536 ram3
[ 2.104371] (driver?)
[ 2.104379] 0104          65536 ram4
[ 2.104385] (driver?)
[ 2.104394] 0105          65536 ram5
[ 2.104401] (driver?)
[ 2.104409] 0106          65536 ram6
[ 2.104417] (driver?)
[ 2.104425] 0107          65536 ram7
[ 2.104432] (driver?)
[ 2.104439] 0108          65536 ram8
[ 2.104446] (driver?)
[ 2.104453] 0109          65536 ram9
[ 2.104473] (driver?)
[ 2.104480] 010a          65536 ram10
[ 2.104488] (driver?)
[ 2.104497] 010b          65536 ram11
[ 2.104505] (driver?)
[ 2.104513] 010c          65536 ram12
[ 2.104520] (driver?)
[ 2.104527] 010d          65536 ram13
[ 2.104534] (driver?)
[ 2.104542] 010e          65536 ram14
[ 2.104550] (driver?)
[ 2.104559] 010f          65536 ram15
[ 2.104567] (driver?)
[ 2.104588] 1f00       131072 mtdblock0
[ 2.104603] (driver?)
[ 2.104694] List of all bdev filesystems:
[ 2.104715] ext3
[ 2.104732] ext2
[ 2.104741] ext4
[ 2.104746] squashfs
[ 2.104752] vfat
[ 2.104756] msdos
[ 2.104760] ntfs
[ 2.104765] ntfs3
[ 2.104774]
[ 2.104982] Kernel panic - not syncing: VFS: Unable to mount root fs on unknown-block(0,0)
[ 2.113179] CPU: 0 UID: 0 PID: 1 Comm: swapper/0 Not tainted 6.17.0-rc4 #1 NONE
[ 2.113634] Hardware name: ARM-Versatile Express
[ 2.114108] Call trace:
[ 2.114679] unwind_backtrace from show_stack+0x10/0x14
[ 2.115749] show_stack from dump_stack_lvl+0x54/0x68
[ 2.116011] dump_stack_lvl from vpanic+0xf4/0x300
[ 2.116243] vpanic from __do_trace_suspend_resume+0x0/0x4c
[ 2.117138] ---[ end Kernel panic - not syncing: VFS: Unable to mount root fs on unknown-block(0,0) ]---
```

Успешный запуск.