I.MX8MP STANDALONE APPLICATION RUNNING TIPS

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SECURE CONNECTIONS FOR A SMARTER WORLD

EXTERNAL USE

Topics

- Some customer need to run standalone application in i.MX side.
- This article describe how to run standalone application in uboot and kernel, how to improve application running performance.
- It takes i.MX8MP as example, which is also suitable for other i.MX platform.



Install Toolchain

• Produce i.MX Yocto SDK toolchain:

DISTRO=fsI-imx-xwayland MACHINE=imx8mp-lpddr4-evk source imx-setup-release.sh -b build-xwayland

bitbake imx-image-multimedia -c populate_sdk

(or use bitbake meta-toolchain for small size toolchain)

Install toolchain

cd (yocto build directory..)/build-xwayland/tmp/deploy/sdk

./fsl-imx-xwayland-glibc-x86_64-imx-image-multimedia-armv8a-imx8mp-lpddr4-evk - toolchain-6.1-mickledore.sh

Then it will install on default directory:

/opt/fsl-imx-xwayland



RUN APPLICATION IN UBOOT



Put application to Uboot standalone directory

In /uboot-imx/examples/standalone/

There is already hello_world.c here, we can put test.c application in this directory,

 Inside hello_world.c, we add new function calling test() which from test.c int hello_world(int argc, char *const argv[])

```
{.....+ test();
}
```

 Modify makefile to add new function compiling: uboot-imx/examples/standalone\$ vi Makefile

```
LIB = $(obj)/libstubs.o
LIBOBJS-$(CONFIG_PPC) += ppc_longjmp.o ppc_setjmp.o
LIBOBJS-y += stubs.o test.o
```



Increase CPU frequency

• If we want to increase application running performance in uboot, we can increase i.MX8MP CPU frequency to maximal 1.8GHz. By default, it is setting at 1.2GHz.

b/arch/arm/mach-imx/imx8m/clock_imx8mm.c

- /* Configure ARM at 1.2GHz */
- + /* Configure ARM at 1.8GHz */
- intpll_configure(ANATOP_ARM_PLL, MHZ(1200));
- + intpll_configure(ANATOP_ARM_PLL, MHZ(1800));

Then the uboot log print out 1.8G information:

```
U-Boot 2023.04-dirty (Jan 23 2024 - 18:09:51 +0800)
CPU: i.MX8MP[8] rev1.1 at 1800MHz
CPU: Commercial temperature grade (OC to 95C) at 38C
Reset cause: POR
Model: NXP i.MX8MPlus LPDDR4 EVK board
```



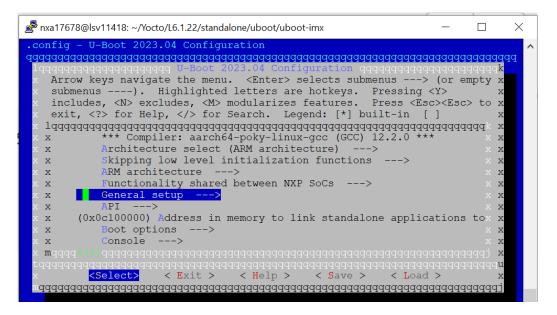
Modify uboot config file- include API examples

source /opt/fsl-imx-xwayland/6.1-mickledore/environment-setup-armv8a-poky-linux cd uboot-imx :

make imx8mp_evk_defconfig

make menuconfig

Choose "General setup"- "Compile API examples"



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x Arrow keys navigate the menu. <enter> selects submenus> (o</enter>	
x submenus). Highlighted letters are hotkeys. Pressing <y></y>	
, , , , , , , , , , , , , , , , , , , ,	
x includes, <n> excludes, <m> modularizes features. Press <esc><</esc></m></n>	(ESC> to x
x exit, for Help, for Search. Legend: [*] built-in []	X
$ imes \ 1$ dddd $\ (-)$ dddddddddddddddddddddddddddddddddddd	ddddddk x
x x [*] Recreate an ELF image from raw U-Boot binary	X X
x x () Build target special images	x x
x x [] Define a maximum size for the U-Boot image	x x
x x [] Use a custom location for the U-Boot linker script	x x
x x (0x40400000) Address in memory to use by default	хх
x x (0x1000000) Define max stack size that can be used by U-Boo	ot x x
x x (0x0) Exclude some memory from U-Boot / OS information	x x
x x (524288) Maximum size in bytes reserved for U-Boot in memor	
x x [] Support for multiprocessor	
x x [[*]] Compile API examples	
x [M] compile AFI examples	X X
. w aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa	adddddd] x
raaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa	qqqqqqqq u
x < <u><select></select></u> < Exit > < Help > < Save > < Load >	X
<u> </u>	<u>adddddddj</u>



Modify uboot config file – increase optimization level

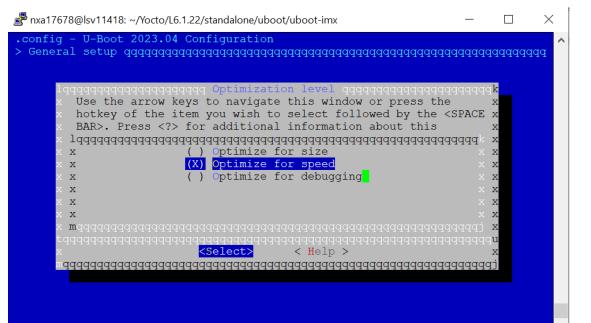
Choose "General setup"-"Optimization level"-"Optimize for speed"

Default setting is "Optimize for size". If customer have higher performance requirement, we can change this config.

run "CONFIG_STANDALONE_LOAD_ADDR=0x43000000 make" to compile

(CONFIG_STANDALONE_LOAD_ADDR=0x43000000 is parameter pass to uboot)

🖻 nxa17678@lsv11418: ~/Yocto/L6.1.22/standalone/uboot/uboot-imx – 🗌	\times
.config - U-Boot 2023.04 Configuration	^
Several setup dddddddddddddddddddddddddddddddddddd	1
lqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqq	
x Arrow keys navigate the menu. <enter> selects submenus> (or empty x</enter>	
x submenus). Highlighted letters are hotkeys. Pressing <y> x</y>	
x includes, <n> excludes, <m> modularizes features. Press <esc><esc> to x</esc></esc></m></n>	
x exit, for Help, for Search. Legend: [*] built-in [] x	
x x () Local version - append to U-Boot release x x	
x x [*] Automatically append version information to the version strinx x	
x x Optimization level (Optimize for speed)> x x	
x x [] Allow compiler to uninline functions marked 'inline' in full x x	
x x [] Allow compiler to uninline functions marked 'inline' in SPL x x	
x x [] Select U-Boot be run as a bootloader for XEN Virtual Machine x x	
x x -*- Add arch, board, vendor and soc variables to default environmx x	
x x (3) Number of DRAM banks x x	
x x [] Enable kernel command line setup x x	
\mathbf{x} \mathbf{w} dada Δ (+) adadadadadadadadadadadadadadadadadadad	
taaaaaaaaaa	
x < <u>Select></u> < Exit > < Help > < Save > < Load > x	
ad	



Check compile output file

Check compile output file to confirm it make effect:

 Config file: uboot-imx/.config: CONFIG_EXAMPLES=y CONFIG_CC_OPTIMIZE_FOR_SPEED=y

 Compile command parameter:uboot-imx/examples/standalone/.hello_world.o.cmd: cmd_examples/standalone/hello_world.o := aarch64-poky-linux-gcc -Wp,-MD,examples/standalone/.hello_world.o.d -fno-PIE -Ofast

GCC compile optimization level(low to high, -Ofast is highest level):
 -O/-O1 -O2 -Os -O3 -Ofast



Produce uboot and application binary

- After change config file and compile uboot, it produce new u-boot.bin, combine uboot/ATF/firmware to flash.bin, then burn flash.bin to the board.
- It also produce hello_world.bin under /uboot-imx/examples/standalone at the same time. We need to send hello_world.bin to board and run it.
- When customer modify their application in hello_world.c/test.c (In help_world.c, it call functions from test.c), hello_world.bin will be updated, they can download hello_world.bin to the board next time. No need to update flash.bin every time.
- It need to make sure uboot inside flash.bin and hello_world.bin are in same uboot environment.

nxa17678@lsv1141	8:~/Yocto/L6.1.22/	standalone/uboot/uboot-i	mx/example:	s/standalone
) ls				
atmel_df_pow2.c	hello_world.srec	ppc_setjmp.S	stubs.o	test.su
nello world	hello_world.su	README.smc91111_eeprom	stubs.su	
nello_world.bin	libstubs.o	sched.c	test_2.c	
lello_world.c	Makefile	sparc.lds	test.c	
nello_world.o	ppc_longjmp.S	stubs.c	test.o	



Download application to board

- We can use "loadb" command to download hello_world.bin to a blank address, such as 0x43000000, which can't affect uboot running.
- loadb 0x43000000

u-boot=> loadb 0x43000000 ## Ready for binary (kermit) download to 0x43000000 at 115200 bps...

• Then choose UART tools Kermit protocol to send hello_world.bin to board.

COM18:115200baud - Te Edit Setup Control	Window	KanjiCode Help				Ξ.	×
New connection Duplicate session Cygwin connection Log Comment to Log View Log Show Log dialog Send file	Alt+N Alt+D Alt+G	nings led.ret -1 ller@32e800 2e60000.vi .panel	00. deo_ 't f 503d	video bridge ind cec device id	l=0x3c		2
Transfer	>	Kermit	>	Receive			
SSH SCP		XMODEM	>	Get			
Change directory		YMODEM	>	Send			
Replay Log		ZMODEM	>	Finish			
TTY Record		8-Plus	- 21				
TTY Replay		Quick-VAN	2				
		R0he0000_e	th1:	ethernet@30bf000	O [PRIME]		



Run application from specific address

• Then run the application from the address:

go 0x43000000

It output print information from application code:

```
u-boot=> go 0x43000000
## Starting application at 0x43000000 ...
Example expects ABI version 9
Actual U-Boot ABI version 9
Hello World
argc = 1
argv[0] = "0x43000000"
argv[1] = "<NULL>"
NXP build, duration = 8000002 ticks....
NXP build, duration = 0 ticks....
NXP build2, duration = 0 ticks....
NXP build3, c = 40000, duration = 0 ticks....
Hit any key to exit ...
```



Choose suitable blank address

- We choose 0x43000000 because it is a blank address in i.MX8MP when running uboot.
- This address need to be aligned with uboot definition on:

uboot-imx/examples/standalone/Makefile: LDFLAGS_STANDALONE += -Ttext \$(CONFIG_STANDALONE_LOAD_ADDR)

While default value in include/config/auto.conf:CONFIG_STANDALONE_LOAD_ADDR=0x0c100000

This address conflict with i.MX8MP uboot running area.

• So we add following parameter when compile uboot:

make CONFIG_STANDALONE_LOAD_ADDR=0x43000000

• We can loadb hello_world.srec to the board to double check the load address and start address.

u-boot=>	loadb		
## Ready	for binary	(kermit) download to 0x40400000 at 1	15200 bps
## Total	Size	= 0x00001396 = 5014 Bytes	
## Start		= 0×40400000	
u-boot=>			



RUN APPLICATION IN KERNEL



Compile standalone application

- Setup toolchain: source /opt/fsl-imx-xwayland/6.1-mickledore/environment-setup-armv8a-poky-linux
- mkdir application/ directory, put all applications demo.c test.c... here. demo.c is main function.
 In demo.c, it call test() from test.c and calculate running time.
 void main()

```
{ t1 = get_ticks();
    test();
    t2 = get_ticks();
    printf("during ticks = %ld\n", t2 - t1);
}
```

• Compile app:

\$CC demo.c test.c -Ofast -o demo (using -Ofast to get highest optimization level) It produce demo.o finally.



Isolate CPU and run application in one dedicated CPU

 In uboot command line, we can add isolcpus=1-3 to isolate three cpu cores: 1, 2, 3 (i.MX8MP have four cpu cores: 0 1 2 3)

setenv mmcargs 'setenv bootargs \${jh_clk} \${mcore_clk} console=\${console} root=\${mmcroot} isolcpus=1-3'

- Put demo.o to the board, then run: chmod 777 demo
- taskset -c 1 ./demo (taskset means to combine to one CPU to run, -c 1 means CPU1, it is aligned with isolcpus =1 in uboot command line)
- Then it output running print information as following:

root@imx8mpevk:~# taskset -c 1 ./demo hello world during ticks = 8003253 root@imx8mpevk:~#



Set to CPU performance mode

 In order to run at maximal CPU frequency, suggest to set to performance mode to run at highest CPU frequency. It is ondemand mode by default.

Take CPU1 as example:

root@imx8mpevk:~# echo performance > /sys/devices/system/cpu/cpu1/cpufreq/scaling_governor

root@imx8mpevk:~# cat /sys/devices/system/cpu/cpu1/cpufreq/scaling_governor ondemand root@imx8mpevk:~# echo performance > /sys/devices/system/cpu/cpu1/cpufreq/scali g_governor root@imx8mpevk:~# cat /sys/devices/system/cpu/cpu1/cpufreq/scaling_governor performance

Then run application again:

root@imx8mpevk:~# taskset -c 1 ./demo



Run dhrystone benchmark test

We can run dhrystone benchmark as an example:

- DMIPS (Dhrystone Million Instructions Per Second)
- dhry2 is compiled with optimization level -O3 and download from NXP web:

https://www.nxp.com/docs/en/application-note-software/AN13917SW.zip

We can use script dhrystone.sh to repeat running dhry2 on CPU 1 for stress test.
 while true; do

./dhry2

done

root@imx8mpevk:~# echo performance > /sys/devices/system/cpu/cpu1/cpufreq/scaling_governor root@imx8mpevk:~# taskset -c 1 ./dhrystone.sh



Dhrystone result in i.MX8MP

- We can get the benchmark data from the log.
- Use "top" command to check. The dhry2 application is running on CPU1. CPU1 is almost 100%, CPU0/2/3 are spare.

top - 22:29:3	33 up 15 m	nin, 3 u	users,	oad avei	rage: 1	.00, 0.8	4, 0.49	
Tasks: 147 to								
	<u>} us 03</u>	sy O	<u> 1 ni 9</u>	bi D f	<u> </u>	<u> </u>	<u>i 00 si</u>	t2 0 0
\$Cpu1 :100.0) us, 0.0	lsy, O	.0 ni, ().0 id,	<mark>0.0</mark> wa	i, <mark>0.0</mark> h	i, <mark>0.0</mark> si	, 0.0 st
%Cpu2 : 0. ()us, <mark>0.</mark> 0	lsy, O	.0 ni,100).0 id,	0.0 wa	ı, <mark>0.0</mark> h	i, 0.0 si	, 0.0 st
%Cpu3 : 0.0)us, <mark>0.0</mark>) sy, 🛛	.0 ni,100).O id,	0.0 wa	ι, <mark>0.0</mark> h	i, <mark>0.0</mark> si	, <mark>0.0</mark> st
MiB Mem : 🗧	5 <mark>643.0</mark> tot	al, <mark>5</mark>	3 <mark>31.8</mark> fre	e, <mark>2</mark> 0	6 <mark>5.5</mark> us	sed, <mark>1</mark>	55.6 buff/0	cache
MiB Swap:	0.0 tot	al,	<mark>0.0</mark> fr€	e,	0.0 us	sed. <mark>53</mark>	77.5 avail	Mem
PID USER	PR	NI V	IRT RE	ES SHF	RS %C	PU %MEM	TIME+	COMMAND
1713 root	20	0 2	996 84	10 730	6 R 99	0.7 0.0	0:05.01	dhry2
1712 root	ŹÛ	<u> </u>	212 430)4 230 0	BR Û).3 Û.Î	Û:ÛÛ.Û8	top
1 root	20	0 991	740 1039	92 7484	4S 0	0.0 0.2	0:04.27	systemd
2 root	20	0	0	0 () S – O	0.0 0.0	0:00.00	kthreadd



SOME OTHER OPTIMIZATION WAYS



Dynamic link and static link library

- Normally it is dynamic linked library by default when compiling application. Its advantage is executable file size is small. But it may affect application loading time and affect performance. If customer has strict requirement for application loading time, we may try following way:
- Using default dynamic link compile, loading linked library to cache in advance;
- Using static link compile to compile image.



Dynamic link library

• It is dymamic linked by default when compiling application. Use file command to check:

root@imx8mpevk:~# file demo demo: ELF 64-bit LSB pie executable, ARM aarch64, version 1 (SYSV), dynamically Linked, interpreter /lib/ld-linux-aarch64.so.1, BuildID[sha1]=beb13fd62764b301af 85c33eadb17b447f9c2c7f, for GNU/Linux 3.14.0, with debug_info, not stripped root@imx8mpevk:~#

Check which dynamica library are linked.
 root@imx8mpevk:~# Idd demo

linux-vdso.so.1 (0x0000ffffaa1e8000) libc.so.6 => /lib/libc.so.6 (0x0000ffffa9fd0000) /lib/ld-li<u>n</u>ux-aarch64.so.1 (0x0000ffffaa<u>1ab000)</u>

· Using vmtouch tool to fix dynanica linked library to cache in advance.

root@imx8mpevk:~# ./vmtouch -| -d -w -t /lib/ld-linux-aarch64.so.1 LOCKED 50 pages (200K) root@imx8mpevk:~# ./vmtouch -| -d -w -t /lib/libc.so.6 LOCKED 404 pages (1M) root@imx8mpevk:~# ./vmtouch -| -d -w -t demo LOCKED 19 pages (7<u>6</u>K)

• Then run application:

root@imx8mpevk:~# taskset -c 1 ./demo

add mlockall() function

- Try to add mlockall() before calling timer start and customer function.
- It locks all pages mapped into the address space of the calling process. It can help to reduce the page fault latency and avoid potential page reclaim.
 - + #include <sys/mman.h>

void main()

```
{
```

```
+ mlockall(MCL_CURRENT);
```

```
t1 = get_ticks();
```

test();

```
t2 = get_ticks();
printf("during ticks = %ld\n", t2 - t1)
```

```
NP
```

Use linaro toolchain to realize static link compile

i.MX Yocto default toolchain don't support static link compile. We can also use another toolchain to have a test.

• Download linaro toolchain which support static link compile:

https://releases.linaro.org/components/toolchain/binaries/latest-7/aarch64-linux-gnu/ download gcc-linaro-7.5.0-2019.12-x86_64_aarch64-linux-gnu.tar.xz

tar -xvf gcc-linaro-7.5.0-2019.12-x86_64_aarch64-linux-gnu.tar.xz

Install toolchain and add to PATH

export PATH=~/Yocto/tool/gcc-linaro-7.5.0-2019.12-x86_64_aarch64-linux-gnu/bin:\$PATH

Compile application using static link

aarch64-linux-gnu-gcc demo.c test.c -Ofast -static -o demo_static

Use "strip" command to reduce demo_static.o file size:

aarch64-linux-gnu-strip demo_static



Run static linked compiled file

Check demo_static file status on board using "file" command

root@imx8mpevk:~# file demo_static demo_static: ELF 64-bit LSB executable, ARM aarch64, version 1 (SYSV), staticall y linked, for GNU/Linux 3.7.0, BuildID[sha1]=f189f617b6f2a8828c74f8fa94a3bad008d 2048a, stripped

• Run application on board:

```
root@imx8mpevk:~# echo performance > /sys/devices/system/cpu/cpu1/cpufreq/scalin
g_governor
root@imx8mpevk:~# taskset -c 1 ./demo_static
hello world
during ticks = 8003040
```



Conclusion

- It describe how to run standalone application in i.MX8MP board, including in uboot & kernel.
- If customer want to get better performance, they can consider following way:
 - >Check application compile parameters, including optimization level;
 - >Set board status to run at maximal CPU frequency and DDR frequency;
 - Check dynamic link library status.
 - >Check application memory allocation status.

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