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i.MX 8M Plus Nominal Drive Mode

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Application note
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Document information

Information	Content
Keywords	i.MX 8M Plus Nominal Drive mode (NDM), power optimization
Abstract	This document describes how to enable Nominal Drive Mode (NDM) on i.MX 8M Plus EVK platform in NXP Linux Release and the measured power impact versus the default Overdrive Mode (ODM) kernel configuration.

1 Introduction

This document is for the i.MX 8M Plus application processor and describes a power-saving configuration called Nominal Drive Mode (NDM). The configuration settings for NDM are now included in NXP Linux BSP releases starting with version 5.10.52_2.1.0. This document provides an introduction and instructions for enabling NDM in the core domain, as well as an example of the measured impact on i.MX 8M Plus power compared to the default Overdrive Mode (ODM) kernel configuration.

Linux BSP: version 5.10.52_2.1.0 or later.

Hardware platform: i.MX 8M Plus PEVK

2 Nominal Drive Mode introduction

The default configuration of the NXP Linux BSP sets the i.MX 8M Plus voltage and clock parameters to operate the i.MX 8M Plus in the Overdrive Mode. Overdrive mode can support the full range of operating frequencies. Nominal drive mode (NDM) specifically refers to a set of parameters set in the SOC to enable stable operation at a lower voltage and frequency to reduce power consumption. The nominal voltage setting restricts maximum operation to the nominal frequency specified in the i.MX 8M Plus datasheet.

The digital logic inside i.MX 8M Plus SOC is powered by multiple supply rails (see Table 1):

- VDD_ARM is for the Cortex-A53 platform.
- VDD_SOC for the internal SoC core logic
- VDD_xxx_0P8 rails: Multiple separate 0P8 power rails, supplying the digital logic of the Phys and PLLs

VDD_ARM can be Nominal, Overdrive or Super-Overdrive voltage, and supports DVFS for systems that choose to enable it (it is enabled by default since cpufreq is enabled by default on NXP Linux kernel releases). VDD_SOC and other digital supply rails can be Nominal or Overdrive voltage. VDD_SOC does not support fast on-the-fly DVFS but can support mode-based dynamic voltage for systems that choose to enable it.

Table 1 shows all supply domains which support Nominal Drive Mode on the i.MX 8M Plus processor.

Table 1. Power supply support for Nominal Drive Mode

Supply domain	Nominal Drive Mode			Overdrive mode			Description
	Min(V)	Typ(V)	Max(V)	Min(V)	Typ(V)	Max(V)	
VDD_ARM	0.805	0.850	0.950	0.900	0.950	1.000	Power supply for Quad-A53
VDD_SOC	0.805	0.850	0.900	0.900	0.950	1.000	Power supply for SoC logic
VDD_ANA1_0P8	0.805	0.850	0.900	0.900	0.950	1.000	Power supply for ANAMIX PLL
VDD_USB_0P8	0.805	0.850	0.900	0.900	0.950	1.000	Digital supply for USB PHY
VDD_PCI_0P8	0.805	0.850	0.900	0.900	0.950	1.000	Digital supply for PCIe PHY
VDD_HDMI_0P8	0.805	0.850	0.900	0.900	0.950	1.000	Digital supply for HDMI PHY
VDD_MIPI_0P8	0.805	0.850	0.900	0.900	0.950	1.000	Digital supply for MIPI PHY
VDD_ARM_PLL_0P8	0.805	0.850	0.900	0.900	0.950	1.000	Power supply for Arm PLL
VDD_DRAM_PLL_0P8	0.805	0.850	0.900	0.900	0.950	1.000	Power supply for DRAM PLL
VDD_SAI_PLL_0P8	0.805	0.850	0.900	0.900	0.950	1.000	Power supply for SAI PLL

Table 2 lists different maximum frequency of modules between nominal and overdrive mode on the i.MX 8M Plus processor and clock root register offsets from CCM base address: 0x30380000.

Table 2. Maximum frequency of modules for Nominal Drive Mode

Clock root	Nominal Drive Mode	Overdrive mode	Unit
ARM_M7_CLK_ROOT	600	800	MHz
ML_CLK_ROOT	800	1000	MHz
ML_AHB_CLK_ROOT	300	400	MHz
GPU3D_CORE_CLK_ROOT	800	1000	MHz
GPU3D_SHADER_CLK_ROOT	800	1000	MHz
GPU2D_CLK_ROOT	800	1000	MHz
AUDIO_AXI_CLK_ROOT	600	800	MHz
HSIO_AXI_CLK_ROOT	400	500	MHz
MEDIA_ISP_CLK_ROOT	400	500	MHz
VPU_BUS_CLK_ROOT	600	800	MHz
MEDIA_AXI_CLK_ROOT	400	500	MHz
HDMI_AXI_CLK_ROOT	400	500	MHz
GPU_AXI_CLK_ROOT	600	800	MHz
GPU_AHB_CLK_ROOT	300	400	MHz
NOC_CLK_ROOT	800	1000	MHz
NOC_IO_CLK_ROOT	600	800	MHz
GIC_CLK_ROOT	400	500	MHz
VPU_G1_CLK_ROOT	600	800	MHz
VPU_G2_CLK_ROOT	500	700	MHz
HDMI_FDCC_TST_CLK_ROOT	200	300	MHz
MEDIA_CAM1_PIX_CLK_ROOT	400	500	MHz
VPU_VC8000E_CLK_ROOT	400	500	MHz
LPDDR4-4000	3200	4000	MT/s

Note:

- *Table 1 and Table 2 are for reference only. For more detailed information about Nominal Drive Mode, see the i.MX 8M Plus datasheet at https://www.nxp.com.*
- *On the i.MX 8MP EVK and PEVK reference platforms, VDD_xxx_0p8 rails are connected directly to VDD_SOC (See chapter 3.1.3 Power architecture in i.MX 8M Plus datasheet). In the rest of the document, these rails are referenced as VDD_SOC.*
- *VDD_ARM and VDD_SOC operating modes are independent from each other. Any VDD_ARM vs VDD_SOC operating mode combination is supported.*

3 How to generate a Linux image for LPDDR4 EVK and PEVK boards

Build an NDM image support for i.MX 8M Plus SoC has been integrated into the i.MX Yocto project by creating a machine configuration since release L5.10.52_2.1.0.

DVFS on Cortex-A53 cores is enabled by default (CPUFREQ enabled in defconfig). VDD_ARM can dynamically vary between Nominal, Overdrive, and Super-Overdrive modes depending on the load requirements and there is no difference in the behavior of Cortex-A53 cores compared to the default standard Yocto ODM build image

(MACHINE=imx8mpevk). All the other supply domains are set statically for Nominal Drive mode configuration. Their frequencies are set to the maximum supported frequency in Nominal Drive mode as shown in Table 2. For example, LPDDR4-4000 runs at 3200MTS.

3.1 NDM build Instructions

Building an NDM image for i.MX 8M Plus SoC has been integrated in the i.MX Yocto project by creating a new machine configuration since release L5.10.52_2.1.0:

```
MACHINE=imx8mp-lpddr4-ndm
```

To create an NDM image, you can use the same distributions as for the standard ODM image (MACHINE=imx8mpevk), make sure you select the appropriate machine.

```
DISTRO=<distro name> MACHINE=imx8mp-lpddr4-ndm source imx-setup-release.sh -b
<build dir>
```

For example, to generate an i.MX 8M Plus Yocto configuration in NDM using XWayland backend on L5.10.52_2.1.0 release, use the following command:

```
$DISTRO=fsl-imx-xwayland MACHINE=imx8mp-lpddr4-ndm source imx-setup-release.sh -b
<build dir>
```

```
$bitbake <image_name>
```

For detailed information on i.MX Yocto project and instructions on how to generate Yocto builds, refer to the i.MX Yocto Project User's Guide (IMXLXYOCTOUG) available on www.nxp.com.

Yocto Build artifacts:

Once the build is complete, a bootloader and SD card image (.wic.bz2) that can be flashed directly in SD card or eMMC using uuu is available in `<build dir>/tmp/deploy/images`:

Artifacts:

- i.MX 8M Plus Boot image : `imx-boot-imx8mp-lpddr4-ndm-sd.bin-flash_evk`
- RootFS: `<image_name>-imx8mp-lpddr4-ndm.wic.bz2`
  For flashing instructions using uuu, refer to the i.MX Linux Users Guide (IMXLUG) available on www.nxp.com.
  For example, to flash the image in the eMMC, use the following command:
  ```
  $sudo uuu -b emmc_all imx-boot-imx8mp-lpddr4-ndm-sd.bin-flash_evk <image_name>-
  imx8mp-lpddr4-ndm.wic.bz2
  ```
- dtb: `imx8mp-evk-ndm.dtb`
  At first boot, stop in U-boot and ensure the right device tree for NDM (imx8mp-evk-ndm.dtb) is selected using following command:
  ```
  $ printenv fdtfile
  ```
  If not, update the dtb file and save the configuration. No need to repeat this operation for subsequent boots.
  ```
  $ setenv fdtfile imx8mp-evk-ndm.dtb
  $ saveenv
  $ boot
  ```

4 Example NDM power measurements vs ODM

Measurements were recorded on i.MX 8MP PEVK board to assess the impact on power in NDM compared to the default ODM configuration. The data presented in this application note is based on empirical measurements taken on a single sample, therefore the presented results are not guaranteed.

4.1 Hardware and software used

The software versions used for the measurements are:

- Yocto rootfs, Linux Kernel version: L5.15.71_2.2.0 i.MX 8M Plus.
  - ODM Yocto build image: MACHINE = imx8mpevk
  - NDM Yocto build image: MACHINE = imx8mp-lpddr4-ndm
- The board used for the measurements is i.MX 8M Plus Rev.A1 LPDDR4 PWR EVK platform (8MPLUSLPD4-PEVK) populated with a device specified for consumer applications.
- Connected interfaces:
  - HDMI port (J17): 4K30p display
- The measurements were performed using the on-board measurement circuitry and BCU software tool (The BCU tool can be found at https://github.com/NXPmicro/bcu).
- These measurements have been taken at room temperature without thermal forcing equipment.

4.2 Use cases and measurements results

4.2.1 Low-power use cases

Table 3. Suspend Mode (DSM)

		Rail label	OverDrive Mode			NDM			
DSM (Suspend)			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg(mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.1	0	0.5	1.1	0	0.6	
		nvcc_snvs_1v8	1.81	0	0.2	1.81	0	0.2	
		vdd_arm	0	0	0	0	0	0	
		vdd_soc	0.85	13	11.1	0.85	12	10.2	
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			27.78			27.74	
		Total SOC:			**39.58**			**38.74**	2.1 %
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**4.01**			**3.92**	2.2 %

Note: *Total SoC consumption variation is negligeable and due to power measurements precision. DSM configuration is identical in ODM and NDM modes.*

Table 4. Idle Mode

		Rail label	OverDrive Mode			NDM			
useridle (Idle default)			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.1	69.2	76	1.1	60.1	66.1	
		nvcc_snvs_1v8	1.8	0	0.4	1.79	0	0.4	
		vdd_arm	0.85	14.4	12.9	0.85	14.5	13	
		vdd_soc	0.93	846.2	788.5	0.84	607.3	508.1	

Table 4. Idle Mode*...continued*

		Rail label	OverDrive Mode			NDM			
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			245.41			224.85	
		Total SOC:			**1123.21**			**812.45**	27.7 %
	GROUP_ DRAM	VDD1 + VDDQ + VDD2			**6.91**			**5.9**	14.6 %

4.2.2 Core benchmarks

Table 5. 4-Core Dhrystone

		Rail label	OverDrive Mode			NDM			
dhrystone			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.1	69.6	76.5	1.1	60.1	66.1	
		nvcc_snvs_1v8	1.8	0	0.4	1.79	0	0.4	
		vdd_arm	0.97	1149.5	1110.9	0.97	1153.4	1114.5	
		vdd_soc	0.93	855.5	797.5	0.84	616.5	516	
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			245.46			225	
		Total SOC:			**2230.76**			**1922**	13.8 %
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**5.47**			**6.06**	-10.8 %

Note: *GROUP_DRAM consumption variation is negligeable and due to power measurements precision.*

Table 6. 4-Core Whestone

		Rail label	OverDrive Mode			NDM			
whetstone			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.1	69.4	76.3	1.1	60.5	66.5	
		nvcc_snvs_1v8	1.8	0	0.4	1.79	0	0.4	
		vdd_arm	0.98	809.5	789.4	0.98	807.6	787.6	
		vdd_soc	0.93	854.2	796.1	0.84	615.5	515	
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			245.27			224.93	
		Total SOC:			**1907.47**			**1594.43**	16.4 %
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**7.9**			**6.17**	21.9 %

Note: *GROUP_DRAM consumption variation is negligeable and due to power measurements precision.*

Table 7. Coremark

		Rail label	OverDrive Mode			NDM			
coremark			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.1	68.9	75.7	1.1	59.9	65.9	
		nvcc_snvs_1v8	1.8	0	0.4	1.8	0	0.4	
		vdd_arm	0.97	962.3	933.9	0.97	956.8	937.3	
		vdd_soc	0.93	854.8	796.7	0.84	614.5	514.2	
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			245.37			224.75	
		Total SOC:			**2052.07**			**1742.55**	15.1 %
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**5.93**			**5.6**	5.6 %

Note: *GROUP_DRAM consumption variation is negligeable and due to power measurements precision.*

4.2.3 GPU

Table 8. GPU_MM07

		Rail label	OverDrive Mode			NDM			
GPU_MM07			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.09	207.1	225.9	1.09	195.4	213.2	
		nvcc_snvs_1v8	1.8	0	0.4	1.8	0	0.4	
		vdd_arm	1	76.3	75.7	1	71.2	70.6	
		vdd_soc	0.92	1506.6	1385.7	0.83	1082.2	896.4	
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			243.31			225.51	
		Total SOC:			**1931.01**			**1406.11**	27.2 %
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**290.48**			**257.89**	11.2 %

Table 9. GPU_MM06

		Rail label	OverDrive Mode			NDM			
GPU_MM06			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.09	264.2	287.3	1.09	252.6	274.9	
		nvcc_snvs_1v8	1.8	0	0.4	1.8	0	0.4	
		vdd_arm	1	145	143.9	1	137.3	136.3	
		vdd_soc	0.92	1720.9	1576.6	0.83	1248.4	1030.3	
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			243.7			225.78	
		Total SOC:			**2251.9**			**1667.68**	25.9 %

Table 9. GPU_MM06*...continued*

		Rail label	OverDrive Mode			NDM			
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**375.1**			**351.01**	6.4 %

Table 10. GPU_Kanzi

		Rail label	OverDrive Mode			NDM			
GPU_Kanzi			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.09	202	220.1	1.09	132.5	210	
		nvcc_snvs_1v8	1.8	0	0.4	1.8	0	0.4	
		vdd_arm	0.99	188	187	0.99	168.9	167.4	
		vdd_soc	0.92	1514.7	1392.5	0.83	1095.3	906.7	
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			242.49			224.79	
		Total SOC:			**2042.49**			**1509.29**	26.1 %
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**268.6**			**239.33**	10.9 %

Table 11. GPU_GLmark

		Rail label	OverDrive Mode			NDM			
GPU_ Glmark			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.09	246.6	268.4	1.09	230.8	251.4	
		nvcc_snvs_1v8	1.8	0	0.4	1.8	0	0.4	
		vdd_arm	1.0	163.3	161.9	1.0	148.1	146.9	
		vdd_soc	0.92	1639.9	1501.9	0.83	1179.6	974.5	
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			241.7			224.4	
		Total SOC:			**2174.3**			**1597.6**	26.5 %
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**321.05**			**277.33**	13.6 %

4.2.4 Heavy load use cases

Table 12. Stream (VPU + MM07)

		Rail label	OverDrive Mode			NDM			
stream_ VPU_ MM07_			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.09	245.3	267.1	1.09	226.4	246.9	
		nvcc_snvs_1v8	1.8	0	0.4	1.8	0	0.4	
		vdd_arm	0.98	818.7	798.8	0.98	779.2	761.3	
		vdd_soc	0.92	1579.1	1450.3	0.83	1135.9	939.8	

Table 12. Stream (VPU + MM07)*...continued*

		Rail label	OverDrive Mode			NDM			
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			246.6			227.89	
		Total SOC:			**2763.2**			**2176.29**	21.2 %
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**410.84**			**360.1**	12.4 %

Table 13. Audio Playback

		Rail label	OverDrive Mode			NDM			
gplay (audio)			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.1	82.9	90.9	1.1	73.5	80.7	
		nvcc_snvs_1v8	1.8	0	0.4	1.79	0	0.4	
		vdd_arm	1.0	47.3	47.1	1.0	44.1	43.9	
		vdd_soc	0.93	912.2	848.9	0.84	661.3	552.5	
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			296.78			276.21	
		Total SOC:			**1284.08**			**953.71**	25.7 %
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**32.83**			**30.72**	6.4 %

Table 14. Video Playback

		Rail label	OverDrive Mode			NDM			
gplay (video)			V	I avg(mA)	P avg (mW)	V	I avg(mA)	P avg (mW)	NDM Power Saving
	GROUP_SOC	nvcc_dram_1v1	1.1	129	141.2	1.09	134.9	147.6	
		nvcc_snvs_1v8	1.8	0	0.4	1.79	0	0.4	
		vdd_arm	1.0	86	85.4	1.0	89.7	89.2	
		vdd_soc	0.93	1040	966.2	0.83	765.8	638.4	
		VDD_xxx_1P81 + VDD_xxx _0P82 + VDD_ USB_3P3			296.74			278.07	
		Total SOC:			**1489.94**			**1153.67**	22.6 %
	GROUP_DRAM	VDD1 + VDDQ + VDD2			**150.34**			**141.3**	6.0 %

5 Summary

As detailed above, nominal drive mode (NDM) is a set of parameters in the SOC to enable stable operation at a lower voltage, and frequency to reduce power consumption. The nominal voltage setting restricts maximum operation to the nominal frequency specified in the i.MX 8M Plus datasheet. For more information or assistance with this configuration, refer to the NXP community.

6 Revision history

Table 15. Revision history

Revision number	Date	Substantive changes
0	27 March 2023	Initial release

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