

AN13917

i.MX 93 Power Consumption Measurement

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Application note

Document information

Information	Content
Keywords	AN13917, i.MX 93, MCIMX93-EVK, power consumption, i.MX 93 power domains
Abstract	This application note describes how to measure the current drain of the i.MX 93 application processor on an NXP MCIMX93-EVK board, through different use cases.



1 Introduction

This application note is intended to help system designers to create power-optimized systems. It describes how to measure the current drain of the i.MX 93 application processor on an NXP MCIMX93-EVK board through different use cases.

Note:

*Some use case binaries can be found in [AN13917SW](#). Copy the binaries (Linux app) to the board, then use "chmod +x *" to grant the execution permissions.*

Users can choose the appropriate power supply domains for the i.MX 93 processor and become familiar with the expected processor power consumption in various scenarios.

Note: *The reported results are not guaranteed because the data presented in this application note is based on empirical measurements performed on a small sample size.*

2 Acronyms

[Table 1](#) lists the acronyms used in this document.

Table 1. Acronyms

Acronym	Meaning
CA55	Arm Cortex-A55 processor
CM33	Arm Cortex-M33 processor
ADC	Analog-to-digital converter
AHB	Arm AMBA high-performance bus
APLL	Auxiliary phase-locked loop clock generator
Arm	Advanced RISC machine processor architecture
AXI	Arm Advanced eXtensible Interface
BSP	Board support package
BBNSM	Battery-backed non-secure module
BBSM	Battery-backed security module
CCM	Clock controller module
DAC	Digital-to-analog converter
DDR	Dual data rate DRAM
DMA	i.MX 93 direct memory access controller
DRAM	Dynamic random-access memory
EVK	Evaluation kit
FIRC	FAST internal reference clock
GND	Ground
GPIO	General-purpose input/output
High-Z	High-impedance
I/Os	Inputs/Outputs
IOMUX	Chip-level I/O multiplexing
IOMUXC	i.MX 93 input/output multiplexing controller
LDO	Low drop-out regulator
LPAV	Low-power audio/video domain
LPDDR4	Low-power DDR4 SDRAM with 1.1 V I/O supply
LPDDR4x	Low-power DDR4 SDRAM with 0.6 V I/O supply
LPTMR	i.MX 93 low-power timer
LVD	Low-voltage detector
MIPI-CSI	MIPI - Camera serial interface controller
MIPI-DSI	MIPI - Display serial interface controller
MU	i.MX 93 messaging unit
ND	Nominal drive

Table 1. Acronyms...continued

Acronym	Meaning
OD	Overdrive
OTP	One-time programmable
PCB	Printed-circuit board
PLL	Phase-locked loop clock generator
PMC	Power management controller
PMIC	Power management-integrated circuit
RAM	Random access memory
ROM	Read-only memory
RTC	Real-time clock
SDK	Software development kit
SIM	i.MX 93 system integration module
SWFFC	Software Fast Frequency Change
SIRC	Slow internal reference clock
SoC	System on chip
SPLL	System phase-locked loop clock generator
SRAM	On-chip static random access memory
TCM	Cortex-M33 tightly coupled memory
UART	Universal asynchronous receiver/transmitter
USB	Universal serial bus
USB 2.0	USB version 2.0 peripheral
USB OTG	USB on-the-go
VFS	Voltage and frequency scaling
WFI	Wait for interrupt
WUU	Wake-up unit

3 i.MX 93 power architecture

The power architecture of the chip is established with the presumption that the most affordable systems are built for the scenario in which the PMIC is used to supply all the power rails to the processor.

Figure 1 shows the power architecture diagram for the entire SoC.

Note: Figure 1 shows only the power supplies and does not show the capacitors that can be required for internal LDO regulators.

The values in Figure 1 are for reference purpose only. For actual data, refer to the i.MX 93 Applications Processors Data Sheet. Refer Section 9

From an architectural standpoint, most SoC digital and analog logic can be power gated in Low-power mode through an external PMIC supply or an internal power switch.

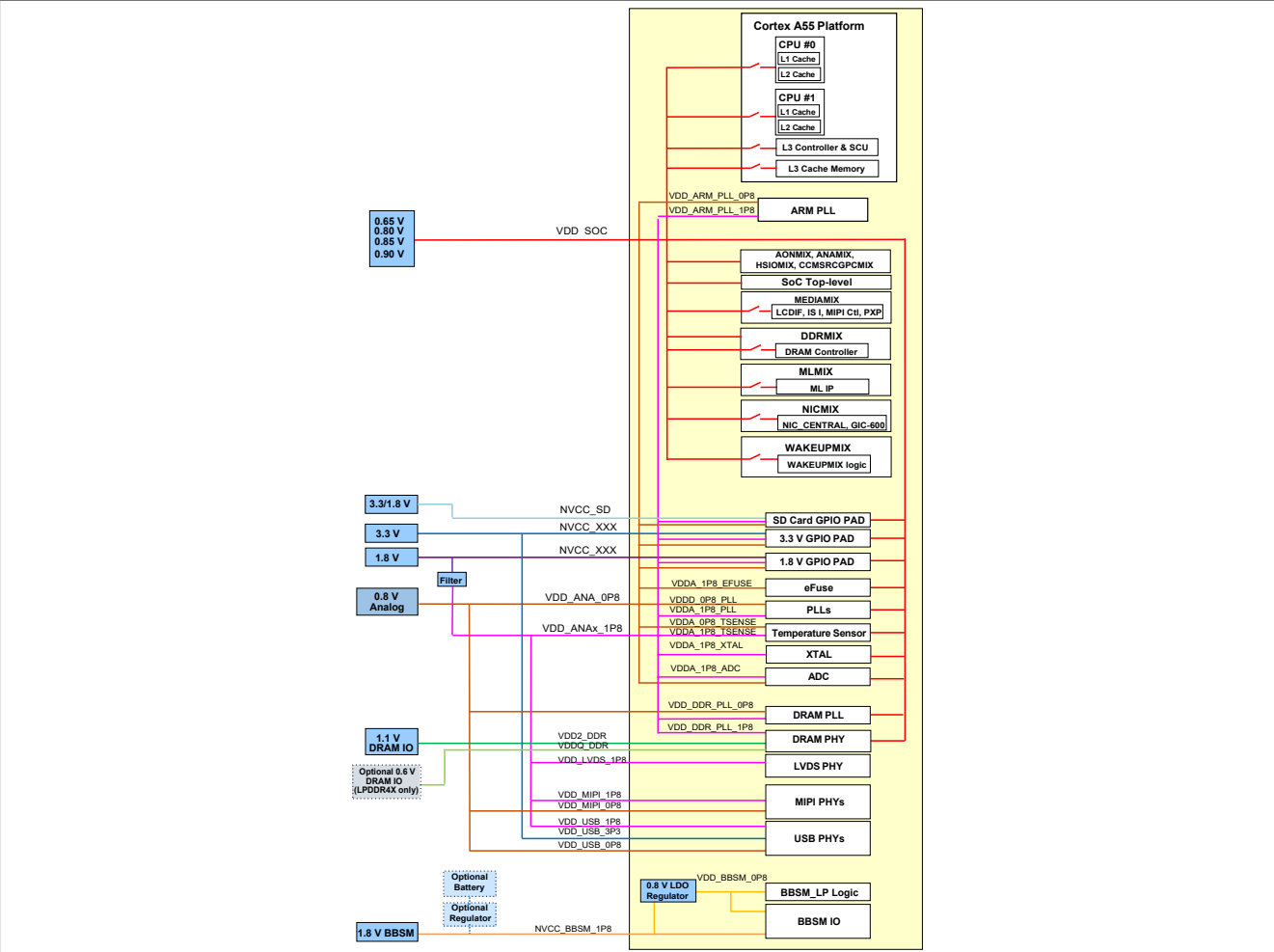


Figure 1. i.MX 93 power architecture

Table 2 summarizes the operating condition for all the external power rails.

Note: Table 2 does not include I/O for capacitors required to support internal LDO regulators. The values in this table are for reference purpose only. For actual data, refer to the i.MX 93 EVK Applications Processors Data Sheet. See Section 9.

Table 2. External power supply

Power rail	V _{min} (V)	V _{typ} (V)	V _{max} (V)	Description
VDD_SOC	0.85	0.90	0.95	Power supply for SoC, Overdrive mode
	0.80	0.85	0.90	Power supply for SoC, Nominal drive mode
	0.76	0.80	0.84	Power supply for SoC, Low-drive mode
	0.61	0.65	0.70	Power supply for SoC, Suspend mode
VDD_ANAx_0P8 VDD_MIPI_0P8 VDD_USB_0P8	0.76	0.80	0.84	Digital supply for PLLs, temperature sensor, LVCMOS I/O, MIPI, and USB PHYs
VDD_ANAx_1P8 VDD_LVDS_1P8 VDD_MIPI_1P8 VDD_USB_1P8 VDD_ANAVDET_1P8	1.71	1.80	1.89	1.8 V supply for PLLs, eFuse, temperature sensor, LVCMOS voltage detect reference, ADC, 24 MHz XTAL, LVDS, MIPI, and USB PHYs
VDD_USB_3P3	3.07	3.30	3.45	3.3 V supply for USB PHY (V _{max} consistent with V _{max} supported by NVCC GPIO supplies)
VDD2_DDR VDDQ_DDR (for LPDDR4)	1.06	1.10	1.14	Voltage tolerances as per LPDDR4 PHY
VDD2_DDR VDDQ_DDR (for LPDDR4X)	0.57	0.60	0.67	Voltage tolerances as per LPDDR4X PHY
NVCC_BBSPM_1P8	1.62	1.80	1.98	I/O supply for GPIO in BBSPM bank
NVCC_AON NVCC_SD2 NVCC_GPIO NVCC_WAKEUP	1.62	1.80	1.98	Power supply for GPIO when it is in 1.8 V mode
	3.00	3.30	3.47	Power supply for GPIO when it is in 3.3 V mode

4 i.MX 93 power overview

This section describes the power domains and modes for the i.MX 93 processor.

4.1 i.MX 93 power domains overview

To optimize the power consumption in Low-power modes, i.MX 93 has multiple power domains. As a result, most SoC digital and analog logics are power gated with an internal power switch or an external supply from PMIC in Low-power mode.

Note: The values in [Table 3](#) are for reference purpose only. For actual data, refer to the i.MX 93 EVK Applications Processors Data Sheet. Refer [Section 9](#)

Table 3. SoC power domains

Domain	Power supply	Type	Physical domains
CPU	VDD_SOC	Digital	Cortex-A55 core
PDCPU0	VDD_SOC with switch	Digital	Cortex-A55 core
PDCPU1	VDD_SOC with switch	Digital	Cortex-A55 core
PDPLAT	VDD_SOC with switch	Digital	Cortex-A55 core
PDL3	VDD_SOC with switch	Digital	Cortex-A55 core
ML	VDD_SOC with switch	Digital	MLMIX
SOC	VDD_SOC	Digital	CCMSRCGPCMIX, AONMIX, ANAMIX (digital portion), and SoC top level
MEDIA_LOGIC	VDD_SOC with switch	Digital	MEDIAMIX (excluding the always-on LDB/LVDS logic and PHYs)
Wake-up	VDD_SOC with switch	Digital	WAKEUPMIX
DRAM_LOGIC	VDD_SOC with switch	Digital	DDRC (controller/PLL-related logic, but not PHY-related logic)
NIC	VDD_SOC with switch	Digital	NICMIX
BBSM_LOGIC	VDD_BBSM_1P8	Digital	BBSMMIX
ANALOG_0P8	VDDA_0P8	Analog	ANAMIX (analog 0.8 portion)
ANALOG_1P8	VDDA_1P8	Analog	ANAMIX (analog 1.8 portion)
LVDS_PHY_1P8	VDD_LVDS_1P8	Analog	LVDS PHY (MEDIAMIX)
MIPI_PHY_0P8	VDD_MIPI_0P8	Digital	MIPI PHY (MEDIAMIX)
MIPI_PHY_1P8	VDD_MIPI_1P8	Analog	MIPI PHY (MEDIAMIX)
USB_PHY_3P3	VDD_USB_3P3	Analog	USB PHY (HSIOMIX)
USB_PHY_1P8	VDD_USB_1P8	Analog	USB PHY (HSIOMIX)
USB_PHY_0P8	VDD_USB_0P8	Digital	USB PHY (HSIOMIX)
DRAM_IO	VDDQ_DDR	I/O	DDRMIX
ANALOG_DRAM	VDDA_DRAM	Analog	DDRMIX
NVCC_<XXX>	NVCC_<XXX>	I/O	1.8 V/3.3 V GPIO
BBSM_IO	NVCC_BBSM	I/O	BBSM I/O Pads

Note:

- *For the recommended operating conditions of each supply rail, and a detailed description of the groups of pins powered by each I/O voltage supply, refer to the i.MX 93 Applications Processors Data Sheet. See [Section 9](#).*
- *For more details regarding the i.MX 93 power architecture, refer to the i.MX 93 Applications Processors Reference Manual (document [IMX93RM](#)).*

4.2 i.MX 93 power mode overview

The i.MX 93 supports the following power modes:

- **Run mode:** In this mode, the Cortex-A55 CPU is active and running. Some portions can be shut off for power saving.
- **Low-power run mode:** This mode is defined as a Low-power run mode with all external power rails on. In this mode, all unnecessary power domains (MIX) can be off. The AONMIX and internal modules, such as OSC24M/PLL, are an exception in this mode. The Cortex CPU in AONMIX handles all the computing and data processing. Cortex-A55 is powered down and DRAM can be in self-refresh/retention mode.
- **Idle mode:** This mode is defined as one that a CPU can enter automatically when no threads are engaged, and no high-speed devices are in use. CPU can be put into a power-gated state, but with L3 data retained, DRAM, and bus clocks are reduced. Most of the internal logic is clock-gated; yet is still powered. In this mode, all the external power from PMIC remains the same, and most IPs remain in their state. Therefore, the interrupt response in this mode is quick compared to the Run mode.
- **Suspend mode:** This mode is defined as the most power-saving mode since it shuts off all the clocks and all the unnecessary power supplies. In this mode, the Cortex-A55 CPU is fully power gated, all internal digital logic, and the analog circuits that can be powered down are off, and all PHYs are power gated. VDD_SOC (and related digital supply) voltage is reduced to the "Suspend mode" voltage. Compared to Idle, this mode takes a longer time to exit, but it also uses far less energy.
- **BBSM mode:** This mode is also called RTC mode. In this mode, to keep RTC and BBSM logic alive, only the power for the BBSM domain remains on.
- **Off mode:** In this mode, all power rails are off.

4.2.1 Low-power modes

[Table 4](#) defines the state of each module in the Idle mode, Suspend mode, and BBSM mode.

Note: The values in [Table 4](#) are for reference purpose only. For actual data, refer to the i.MX 93 Applications Processors Data Sheet. See [Section 9](#)

Table 4. Low-power mode definition

Parameters	Idle	Suspend	BBSM
CCM LPM mode	WAIT	STOP	N/A
Cortex A55 CPU0	OFF	OFF	OFF
Cortex A55 CPU1	OFF	OFF	OFF
Shared L3 cache	ON	OFF	OFF
DISPLAY	OFF	OFF	OFF
DRAM controller and PHY	ON	OFF	OFF
WAKEUPMIX	ON	OFF	OFF
MLMIX	ON as needed	OFF	OFF
NICMIX	ON	OFF	OFF
ARM_PLL	OFF	OFF	OFF
DRAM_PLL	OFF	OFF	OFF
SYSTEM_PLL1	ON	OFF	OFF
XTAL	ON	OFF	OFF
RTC	ON	ON	ON

Table 4. Low-power mode definition...continued

Parameters	Idle	Suspend	BBSM
External DRAM device	Self-refresh ^[1]	Self-refresh ^[2]	OFF
USB PHY	In the low-power state	OFF	OFF
DRAM clock	266 MHz	OFF	OFF
AXI clock	133 MHz	OFF	OFF
Module clocks	ON as needed	OFF	OFF
EdgeLock Secure Enclave	ON	ON	OFF
GPIO wake-up	Yes	Yes	OFF
RTC wake-up	Yes	Yes	Yes
USB remote wake-up	Yes	No ^[3]	No
Other wake-up source	Yes	No	No

[1] When there is no DRAM access, the system automatically enters self-refresh.

[2] SW switches to Self-refresh mode before switching to Low-power mode.

[3] Remote wake-up can be supported if the USB PHY power is on in this mode.

5 i.MX 93 processor power measurement

This document provides details of several use cases run by NXP on the NXP MCIMX93-EVK board to measure i.MX 93 power. These use cases are described under [Section 6](#).

5.1 Hardware and software requirements

[Table 5](#) provides details of the hardware and software used during the power measurement.

Table 5. Hardware and software used

Category	Description
Hardware	NXP MCIMX93-EVK, 51943 A1 + 51961 B2
Software	Linux kernel version: L6.1.55
	Yocto rootfs
	BCU tool is available at bcu version: 1.1.72

Note: For the Software used, the measurements are performed using the onboard measurement circuitry and BCU software tool. These measurements are taken at room temperature without thermal forcing equipment.

5.2 Build the i.MX Yocto Project

To build the i.MX Yocto Project, perform the steps as follows:

- To download and build the i.MX Yocto Project community BSP recipe layers, run the following commands:
Note: For more information on the i.MX Yocto Project, refer to the [i.MX Yocto Project User's Guide](#).

```
repo init -u https://github.com/nxp-imx/imx-manifest -b imx-linux-mickledore -m imx-6.1.55-2.2.0.xml
repo sync
DISTRO=fsl-imx-xwayland MACHINE=imx93-11x11-lpddr4x-evk source imx-setup-release.sh -b build-imx93-11x11-lpddr4x-evk
```
- For some audio or video cases, gstreamer1.0-libav is necessary. Put the following commands at the end of the build-imx93-11x11-lpddr4x-evk/conf/local.conf file:

```
LICENSE_FLAGS_ACCEPTED += "commercial"
IMAGE_INSTALL:append = "gstreamer1.0-libav"
PACKAGECONFIG:append_pn-gstreamer1.0-libav = "x264"
```
- To build, run the following command:

```
bitbake imx-image-full
```

The build image can be found in build-imx93-11x11-lpddr4x-evk/tmp/deploy/image.

5.3 Power consumption measurement

To measure the i.MX 93 power consumption, the steps are as follows:

1. Connect a Type C cable between the host PC and the J1401 USB port on the MCIMX93-EVK board.
2. To start the monitor in the BCU path, run the following command:

```
bcu monitor -board=imx93evk11b1
```

3. Run the related use cases. These use cases are described under [Section 6](#).
4. To reset the value, press "3" once the use case starts.
5. To switch measurement precision: mA/auto/uA, press "4". This step is optional.
6. Wait for 1 minute and record the data in the BCU.

The measurements are taken mainly for the power supply domains shown in [Table 6](#). This table also provides a mapping between the power rails in BCU software, and the power supply domains in the i.MX 93 processor. For more information, download [BCU.pdf](#).

Note: Comparisons between identical cases in different Application Notes are not necessarily meaningful because they may have different scripts and parameters.

Table 6. Measured power supply domains

Power groups	Power supply domains	Description
GROUP_SOC_FULL	nvcc_1p8	Power supply for NVCC_WAKEUP rail
	nvcc_3p3	Power supply for NVCC_AON and NVCC_GPIO rails
	nvcc_bbsm_1p8	I/O supply for GPIO in BBSM bank
	nvcc_sd2	Power supply for GPIO in NVCC_SD2 rail
	vdd2_ddr	Power supply for DRAM PHY
	vdd_ana_0p8	Power supply for PLLs, temperature sensor, LVCMOS I/O, MIPI, and USB PHYs
	vdd_ana_1p8	1.8 V power supply for PLLs, eFuse, temperature sensor, LVCMOS voltage detect reference, ADC, 24 MHz XTAL, LVDS, MIPI, and USB PHYs
	vdd_soc	Power supply for VDD_SOC
	vdd_usb_3p3	Power supply for USB PHYs
	vddq_ddr	Power supply for DRAM PHY

6 Use cases and measurement results

The main use cases and subcases that form the benchmarks for the i.MX 93 internal power measurements on the MCIMX93-EVK platform are described in the following sections.

Note:

- Before running a use case, `<configuration_script>.sh` must be run to configure the environment, see [Section 8](#).
- For all use cases except TBD cases, the platform is booted from eMMC with the default DTB configuration (`imx93-11x11-evk.dtb`) in the U-Boot stage.
- The current sample resistors on the power path create a drop in the voltage on each power rail.

[Table 7](#) summarizes the power measurement results of various use cases performed on the MCIMX93-EVK board.

Table 7. MCIMX93-EVK power summary report

Use cases category	Use cases	Total power (sum of average powers in GROUP_SOC_FULL) (mW)
Core benchmark use cases	Dhrystone	805.9
	CoreMark	691.9
Memory use cases	memset	908.0
	memcpy	913.9
	Stream	1222.8
Audio/video playback use cases	Audio playback (gplay)	458.6
	Audio low-bus playback (gplay)	255.4
	Video playback local (gplay)	636.4
	Video playback streaming (gplay)	664.6
Graphic use case	PXP	544.0
Machine learning use cases	eIQ benchmark	725.5
	Machine vision	780.5
Storage use cases	DD_WRITE_eMMC	420.4
	DD_READ_eMMC	644.9
	DD_WRITE_SD	527.6
	DD_READ_SD	518.2
Low-power mode use cases	System Idle with display in Over Drive (OD) mode with DDRC auto clock gating	482.5
	System Idle with display in Normal Drive (ND) mode	382.0
	System Idle with display in Low Drive (LD) mode (DDR to half speed)	315.2
	System Idle with display in LD mode (DDR to lowest speed with SWFFC)	275.3

Table 7. MCIMX93-EVK power summary report...continued

Use cases category	Use cases	Total power (sum of average powers in GROUP_SOC_FULL) (mW)
	System Idle without display in Overdrive (OD) mode with DDRC auto clock gating	345.6
	System Idle without display in ND mode with DDRC auto clock gating	288.1
	System Idle without display in LD mode with DDRC auto clock gating (DDR to half speed)	227.2
	System Idle without display in LD mode with DDRC auto clock gating (DDR to lowest speed with SWFFC)	199.9
	System in DSM	7.6
	Battery	0.1
Stress test use cases	2 x A55 Dhrystone + PXP + M33 Core Mark + NPU	1230.5
	2 x A55 Stream + PXP + M33 Core Mark + NPU	1264.1
Product use cases	Linux Suspend + M33 CoreMark (TCM)	128.2
	Linux Suspend + M33 in WFI	122.4
	Linux Suspend + M33 FlexCAN Transaction	132.3
	Smart doorbell	772.1

6.1 Core benchmark use cases

The following use cases scenarios have been tested with Cortex A55 cores:

- Dhrystone
- CoreMark

6.1.1 Dhrystone

Dhrystone is a synthetic benchmark used to measure the integer computational performance of processors and compilers. The small size of the Dhrystone benchmark enables it to fit into the L1 cache and minimizes access to the L2 cache and DDR.

In this use case, the two Cortex-A55 cores perform the Dhrystone test. Because Dhrystone is a single thread benchmark, two instances have been started. All Cortex-A55 cores run the test in a loop at a frequency of 1.7 GHz.

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The display is OFF.
4. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of Dhrystone, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`, see [Section 8.1](#).
3. Run `dhrystone_loop.sh`:

```
while true;
do
    taskset -c 0 ./dhry2 &
    taskset -c 1 ./dhry2 &
done
```

4. Measure the power and record the results.

[Table 8](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 8. Measurement results for i.MX 93-11x11-EVK_B_Dhrystone_loop (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	0.6	1.1	6.72	40.35
	lpd4x_vdd2	1.1	5.1	5.6		
	lpd4x_vddq	0.6	0	0		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.3	0.6	805.87	
	nvcc_3p3	3.3	3.6	12		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	17.3	18.9		
	vdd_ana_0p8	0.79	16.5	13		

Table 8. Measurement results for i.MX 93-11x11-EVK_B_Dhrystone_loop (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_ana_1p8	1.79	12.5	22.4		
	vdd_soc	0.89	821.2	731.4		
	vdd_usb_3p3	3.3	0.03	0.1		
	vddq_ddr	0.6	6.8	4.1		

6.1.2 CoreMark

CoreMark is a modern, sophisticated benchmark that lets you accurately measure the processor performance and is intended to replace the older Dhrystone benchmark. Arm recommends using CoreMark over Dhrystone.

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The display is OFF.
4. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of CoreMark, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`, see [Section 8.1..](#)
3. Run `coremark_loop.sh`:

```
while true; do
  ./coremark > /dev/null 2>&1
done
```

Note: For the best performance, compile as follows:

```
make XCFLAGS="-DMULTITHREAD=2 -DUSE_PTHREAD -pthread"
```

4. Measure the power and record the results.

[Table 9](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 9. Measurement results for i.MX 93-11x11-EVK_B_CoreMark_loop (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	0.44	0.8	5.91	38
	lpd4x_vdd2	1.1	4.7	5.2		
	lpd4x_vddq	0.6	0	0		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.56	1	691.85	
	nvcc_3p3	3.3	4.1	13.4		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	17.5	19.2		

Table 9. Measurement results for i.MX 93-11x11-EVK_B_CoreMark_loop (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_ana_0p8	0.79	16.5	13		
	vdd_ana_1p8	1.79	12.5	22.4		
	vdd_soc	0.89	689.8	615.5		
	vdd_usb_3p3	3.3	0.03	0.1		
	vddq_ddr	0.6	6.7	4		

6.2 Memory use cases

The following memory-centric use case scenarios have been tested:

- memset
- memcpy
- Stream

The memset and memcpy are part of a perf-bench, which is a general framework for benchmark suites.

6.2.1 memset

The memset use case is for evaluating the performance of a simple memory set in various ways.

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The size for the memory buffers is set to 1024 MB.
4. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of the memset, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`, see [Section 8.1](#).
3. Run `memset_loop.sh`:

```
while true; do
    buff_size=`cat /proc/meminfo | grep CmaFree | awk '{print$2}'`
    perf bench -f simple mem memset -l 20000 -s ${buff_size}KB
done
```

4. Measure the power and record the results.

[Table 10](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 10. Measurement results for i.MX 93-11x11-EVK_B_memset_loop (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	3.4	6	71.77	41
	lpd4x_vdd2	1.09	60.2	65.8		
	lpd4x_vddq	0.6	0	0		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.28	0.5	907.97	
	nvcc_3p3	3.3	3.7	12.3		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	44.4	48.5		
	vdd_ana_0p8	0.79	16.6	13.1		
	vdd_ana_1p8	1.79	12.5	22.4		
	vdd_soc	0.89	863.2	768.6		
	vdd_usb_3p3	3.3	0.06	0.2		

Table 10. Measurement results for i.MX 93-11x11-EVK_B_memset_loop (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vddq_ddr	0.59	66.2	39.2		

6.2.2 memcpy

The memcpy use case is for evaluating the performance of a simple memory copy in various ways.

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The size for the memory buffers is set to 1024 MB.
4. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of memcpy, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`, see [Section 8.1](#).
3. Run `memcpy_loop.sh`:

```
while true; do
    buff_size=`cat /proc/meminfo | grep CmaFree | awk '{print$2}'`
    perf_bench -f simple mem memcpy -l 20000 -s ${buff_size}KB
done
```

4. Measure the power and record the results.

[Table 11](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 11. Measurement results for i.MX 93-11x11-EVK_B_memcpy_loop (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	3.7	6.7	89.93	41
	lpd4x_vdd2	1.09	73.8	80.4		
	lpd4x_vddq	0.6	4.8	2.8		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.17	0.3	913.93	
	nvcc_3p3	3.3	3.7	12.3		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	41.1	45		
	vdd_ana_0p8	0.79	16.6	13.1		
	vdd_ana_1p8	1.79	12.4	22.3		
	vdd_soc	0.89	905.7	805.8		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	19.7	11.7		

6.2.3 Stream

The stream benchmark is a simple synthetic benchmark program that measures the sustainable memory bandwidth (in MB/s) and the corresponding computation rate for simple vector kernels.

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. All phases, such as Copy, Scale, Add, and Triad, are included.
4. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of the stream, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`, see [Section 8.1](#)..
3. Run `streamcpy_loop.sh`:

```
while true; do
    taskset -c 0 stream -M 200M -N 1000 &
    taskset -c 1 stream -M 200M -N 1000
done
```

4. Measure the power and record the results.

[Table 12](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 12. Measurement results for i.MX 93-11x11-EVK_B_stream_loop (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	4.9	8.8	109.65	45
	lpd4x_vdd2	1.09	87.1	94.9		
	lpd4x_vddq	0.6	10	6		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.11	0.2	1222.81	
	nvcc_3p3	3.3	3.8	12.5		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	50.7	55.5		
	vdd_ana_0p8	0.79	16.8	13.2		
	vdd_ana_1p8	1.79	12.4	22.3		
	vdd_soc	0.89	1241.6	1100.4		
	vdd_usb_3p3	3.3	0.03	0.1		
	vddq_ddr	0.6	25.6	15.2		

6.3 Audio/video playback use cases

The following audio use case scenarios have been tested:

- Audio playback (gplay)
- Audio low-bus playback (gplay)
- Video playback local (gplay)
- Video playback streaming (gplay)

6.3.1 Audio playback (gplay)

For this use case, the audio file is an MP3 file with a 128 kbit/s bit rate and a 44 kHz sample rate. CA55 handles audio decoding, I²S, and audio codec.

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of the audio playback, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`, see [Section 8.1](#).
3. Run `gplay_audio.sh`:

```
gplay-1.0 Mpeg1L3_44kHz_128kbps_s_Ed_Rush_Sabotage_mplayer.mp3
```

Note: Prepare your own MP3 file. To obtain similar results in this document, ensure that the audio bit rate is about 128 kbit/s.

4. Measure the power and record the results.

Note:

If there is no sound, use the following command to query and set the sound card:

```
pacmd list-sinks
pacmd set-default-sink $index #Select the item index with the wm8962 keyword
```

[Table 13](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 13. Measurement results for i.MX 93-11x11-EVK_B_gplay_audio-default (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	1	1.8	11.76	34
	lpd4x_vdd2	1.1	8.9	9.7		
	lpd4x_vddq	0.6	0.5	0.3		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.17	0.3	458.63	
	nvcc_3p3	3.3	6.2	20.4		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	17.8	19.5		
	vdd_ana_0p8	0.79	20.2	15.9		

Table 13. Measurement results for i.MX 93-11x11-EVK_B_gplay_audio-default (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_ana_1p8	1.79	13.7	24.5		
	vdd_soc	0.89	414.1	370.5		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	6.8	4.1		

6.3.2 Audio low-bus playback (gplay)

For this use case, the audio file is a WAV file with a 24 bit and a 32 kHz sample rate. CA55 handles audio decoding, I²S, and audio codec.

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to 1.4 GHz.
2. The DDR data rate is set to 625 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of the audio low-bus playback, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk-ld.dtb`.
2. Run `DDRC_625MTS_setup.sh` (625 MT/s data rate), see [Section 8.4](#).
3. Run `gplay_audio.sh`:

```
gplay-1.0 Mpeg1L3_44kHz_128kbps_s_Ed_Rush_Sabotage_mplayer.mp3
```

Note: Prepare your own MP3 file. To obtain similar results in this document, ensure that the audio bit rate is about 128 kbit/s.

4. Measure the power and record the results.

[Table 14](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 14. Measurement results for i.MX 93-11x11-EVK_B_audio_low_power_50 MHz (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	1.3	2.4	12.25	30
	lpd4x_vdd2	1.1	7.7	8.4		
	lpd4x_vddq	0.6	2.5	1.5		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.22	0.4	255.39	
	nvcc_3p3	3.3	6.2	20.6		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	4.7	5.1		
	vdd_ana_0p8	0.79	20.2	15.9		
	vdd_ana_1p8	1.79	9.9	17.7		
	vdd_soc	0.8	235.1	187.6		

Table 14. Measurement results for i.MX 93-11x11-EVK_B_audio_low_power_50 MHz (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	7.9	4.7		

6.3.3 Video playback local (gplay)

For this use case, the i.MX 93 EVK board is connected to an HDMI display through the MIPI-to-HDMI converter card ([IMX-MIPI-HDMI](#)).

The video file used for playback is an MP4 file format compressed using the H.264 480 p resolution at 24 frames per second (fps). The audio encoding is AACL with a 44.1 kHz sample rate in a two-channel configuration.

Note: In this SoC, there is no hardware decoder, so a software decoder is used.

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of video playback local, the steps are as follows:

1. Connect the HDMI display to the board through the MIPI-to-HDMI converter card ([IMX-MIPI-HDMI](#)).
2. Boot the Linux image with `imx93-11x11-evk.dtb`.
3. To put the system into Idle mode, run `setup_video.sh`. see [Section 8.2](#).
4. Run `gplay_videoplayback.sh`:

```
gplay-1.0 ./480p24.mp4
```

Note: Prepare your own MP4 file. To obtain similar results, ensure that this file is 480 p with a 24-frame rate, bit rate of about 1200 kbit/s, and encoded in H.264 format.

5. Measure the power and record the results.

[Table 15](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 15. Measurement results for i.MX 93-11x11-EVK_B_gplay_videoplayback (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	2.9	5.2	56.85	37
	lpd4x_vdd2	1.09	44.3	48.3		
	lpd4x_vddq	0.6	5.7	3.4		
GROUP_SOC_FULL	nvcc_1p8	1.79	0	0.7	636.4	
	nvcc_3p3	3.3	6.3	20.9		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	25.4	27.8		

Table 15. Measurement results for i.MX 93-11x11-EVK_B_gplay_videoplayback (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_ana_0p8	0.78	34.4	26.8		
	vdd_ana_1p8	1.78	23	41		
	vdd_soc	0.89	569.7	508.7		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	11.8	7		

6.3.4 Video playback streaming (gplay)

For this use case, the i.MX 93 EVK board is connected to an HDMI display through the MIPI-to-HDMI converter card ([IMX-MIPI-HDMI](#)).

The video file used for playback is streamed through HTTP. An MP4 file format compressed using the H.264 480 p resolution at 24 fps. The audio encoding is AACL with a 44.1 kHz sample rate in a two-channel configuration.

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of video playback streaming, the steps are as follows:

1. Connect your PC and board to the same local network.
2. Prepare the video file, named 480p24.mp4 on the PC.
3. On the server PC, perform the following steps:
 - a. For Windows, download the Node.js from <https://nodejs.org/en> and install it.
 - b. To install http-server, use the following command:

```
npm install http-server -g
```

- c. Enter a target folder that contains the target video in the terminal.
 - d. To obtain the <ip_server> similar to <ip address:port>, use "http-server -c-1".
4. On the board, perform the following steps:
 - a. Boot the Linux image with imx93-11x11-evk.dtb.
 - b. Connect the HDMI display to the board through the MIPI-to-HDMI converter card ([IMX-MIPI-HDMI](#)).
 - c. Run setup_video_stream.sh on the board. See [Section 8.3](#).
 - d. Run the following command on the board:

```
gplay-1.0 http://<ip_server>/480p24.mp4
```

- e. Measure the power for the board and record the results.

[Table 16](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 16. Measurement results for i.MX 93-11x11-EVK_B_gplay_video_stream (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	2.9	5.1	56.81	38

Table 16. Measurement results for i.MX 93-11x11-EVK_B_gplay_video_stream (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	lpd4x_vdd2	1.09	44.4	48.4		
	lpd4x_vddq	0.6	5.6	3.3		
GROUP_SOC_FULL	nvcc_1p8	1.79	6.5	11.6	664.63	
	nvcc_3p3	3.3	5.9	19.3		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	24.9	27.3		
	vdd_ana_0p8	0.78	34.7	27.1		
	vdd_ana_1p8	1.78	23	41		
	vdd_soc	0.89	591.2	527.8		
	vdd_usb_3p3	3.3	0.03	0.1		
	vddq_ddr	0.6	11.9	7.1		

6.4 Graphic use case

For this use case, the PXP is used to perform 2D operation.

When the use case is running, the state of the system is as follows:

- The CPU frequency is set to the maximum value of 1.7 GHz.
- The DDR data rate is set to 3733 MT/s.
- The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of the graphic, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup_video.sh`.
3. Run `PXP_test.sh`, see [Section 8.10](#).
4. Measure the power and record the results.

[Table 17](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 17. Measurement results for i.MX 93-11x11-EVK_B_PXP (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	2.9	5.2	55.25	36
	lpd4x_vdd2	1.09	43.2	47.1		
	lpd4x_vddq	0.6	4.9	2.9		
GROUP_SOC_FULL	nvcc_1p8	1.79	0.56	1	543.98	
	nvcc_3p3	3.3	4.1	13.4		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	26	28.5		
	vdd_ana_0p8	0.78	29.7	23.2		
	vdd_ana_1p8	1.78	21.8	38.9		
	vdd_soc	0.89	478.3	427.7		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	13	7.7		

6.5 Machine learning use cases

The tested use case scenarios for machine learning are as follows:

- eIQ benchmark
- Machine vision

6.5.1 eIQ benchmark

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is running the NPU software driver.

To measure the power consumption of the eIQ benchmark, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`, see [Section 8.1](#).
3. To generate the `mobilenet_v1_1.0_224_quant_vela.tflite` model file under the path `/usr/bin/tensorflow-lite-2.12.1/examples`, run the following command: See [Section 8](#).

```
vela mobilenet_v1_1.0_224_quant.tflite
```

4. Copy the `mobilenet_v1_1.0_224_quant_vela.tflite` to `/usr/bin/tensorflow-lite-2.12.1/examples` from the output.
5. Copy `ML_vela.sh` to `/usr/bin/tensorflow-lite-2.12.1/examples` in rootfs and run the following command:

```
cp ML_vela.sh /usr/bin/tensorflow-lite-2.12.1/examples
cd /usr/bin/tensorflow-lite-2.12.1/examples
./ML_vela.sh
```

6. Measure the power and record the results.

[Table 18](#) shows the measurement results when this use case applies to the i.MX 93 processor.

Table 18. Measurement results for i.MX 93-11x11-EVK_B_eIQ (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	2.1	3.7	32.61	38
	lpd4x_vdd2	1.09	24.8	27.2		
	lpd4x_vddq	0.6	2.9	1.7		
GROUP_SOC_FULL	nvcc_1p8	1.79	0.44	0.8	771.2	
	nvcc_3p3	3.3	4.1	13.6		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	21.9	23.9		
	vdd_ana_0p8	0.78	16.5	13.1		
	vdd_ana_1p8	1.78	12.5	22.4		
	vdd_soc	0.89	772.5	688.4		

Table 18. Measurement results for i.MX 93-11x11-EVK_B_elQ (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_dds	1.8	9.4	5.6		

6.5.2 Machine vision

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is running the NPU software driver.

To measure the power consumption of the machine vision, the steps are as follows:

1. Download the ap1302 firmware from [ON Semiconductor](#), and rename it as ap1302.fw.
2. Copy ap1302.fw to the target board under the path /lib/firmware/imx/camera/.
3. Connect AP1302 MIPI camera with J801 on i.MX 93 EVK.
4. Connect the display to the board through the HDMI interface.
5. Boot the Linux image with imx93-11x11-evk.dtb.
6. Download the trained neural network [ssd_mobilenet_v2_coco_quant_postprocess.tffile](#) and [coco_labels.txt](#) to the path /usr/bin/tensorflow-lite-2.12.1/examples. To generate the vela file, run the following command:

```
vela ssd_mobilenet_v2_coco_quant_postprocess.tflite
```

7. Run setup_video_stream.sh.
8. Copy MV_vela.sh, model file named mobilenet_v1_1.0_224_quant_vela.tflite, and label file named coco_labels.txt to /usr/bin/tensorflow-lite-2.12.1/examples in rootfs and run the following command:

```
/usr/bin/tensorflow-lite-2.12.1/examples/MV_vela.sh
```

9. Measure the power and record the results.

[Table 19](#) shows the measurement results when this use case applies to the i.MX 93 processor.

Table 19. Measurement results for i.MX 93-11x11-EVK_B_machine vision (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	4.1	7.4	84.29	40
	lpd4x_vdd2	1.09	66.1	72		
	lpd4x_vddq	0.6	8.2	4.9		
GROUP_SOC_FULL	nvcc_1p8	1.79	0.17	0.3	780.47	
	nvcc_3p3	3.3	3.5	11.5		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	30.5	33.4		

Table 19. Measurement results for i.MX 93-11x11-EVK_B_machine vision (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_ana_0p8	0.78	35	27.3		
	vdd_ana_1p8	1.78	24.6	43.9		
	vdd_soc	0.89	730.6	651.4		
	vdd_usb_3p3	3.3	0.03	0.1		
	vddq_ddr	0.6	15.5	9.3		

6.6 Storage use cases

The tested use case scenarios for storage are as follows:

- DD_WRITE_eMMC
- DD_READ_eMMC
- DD_WRITE_SD
- DD_READ_SD

6.6.1 DD_WRITE_eMMC

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.
4. The maximum amount of data the kernel reads ahead for a single file is set to 512 kB.

To measure the power consumption of DD_WRITE_eMMC, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`. See [Section 8.1](#).
3. Copy `dd_write.sh` on the eMMC partition and run.
4. Measure the power and record the results.

[Table 20](#) shows the measurement results when this use case applies to the i.MX 93 processor.

Table 20. Measurement results for i.MX 93-11x11-EVK_B_DD_WRITE_eMMC (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	0.67	1.2	8.62	34
	lpd4x_vdd2	1.1	6.8	7.4		
	lpd4x_vddq	0.6	0.17	0.1		
GROUP_SOC_FULL	nvcc_1p8	1.79	7.4	13.3	420.43	
	nvcc_3p3	3.3	4	13.4		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	17.9	19.6		
	vdd_ana_0p8	0.79	16.4	12.9		
	vdd_ana_1p8	1.79	12.5	22.4		
	vdd_soc	0.9	370.1	331.2		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	7	4.2		

6.6.2 DD_READ_eMMC

The state of the system, when the use case is running, is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.
4. The maximum amount of data the kernel reads ahead for a single file is set to 512 kB.

To measure the power consumption of DD_READ_eMMC, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`. See [Section 8.1](#).
3. Make sure the file `dd_obs_testfile` exists and rename it to `dd_ibs_testfile`.
4. Copy `dd_read_bs4096.sh` on the eMMC partition and run.
5. Measure the power and record the results.

[Table 21](#) shows the measurement results when this use case applies to the i.MX 93 processor.

Table 21. Measurement results for i.MX 93-11x11-EVK_B_DD_READ_eMMC (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	2.5	4.4	39.63	37
	lpd4x_vdd2	1.09	30.4	33.3		
	lpd4x_vddq	0.6	3.3	2		
GROUP_SOC_FULL	nvcc_1p8	1.79	7.7	13.7	644.85	
	nvcc_3p3	3.3	4	13.1		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	23.6	25.9		
	vdd_ana_0p8	0.79	16.7	13.1		
	vdd_ana_1p8	1.79	12.5	22.3		
	vdd_soc	0.89	612.1	546.3		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	11.7	7		

6.6.3 DD_WRITE_SD

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.
4. The maximum amount of data the kernel reads ahead for a single file is set to 512 kB.

To measure the power consumption of DD_WRITE_SD, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`. See [Section 8.1](#).
3. Copy `dd_write.sh` on the SD partition and run.
4. Measure the power and record the results.

[Table 22](#) shows the measurement results when this use case applies to the i.MX 93 processor.

Table 22. Measurement results for i.MX 93-11x11-EVK_B_DD_WRITE_SD10 (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	1.1	2	13.22	35
	lpd4x_vdd2	1.1	10.1	11		
	lpd4x_vddq	0.6	0.33	0.2		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.28	0.5	527.58	
	nvcc_3p3	3.3	0.76	2.5		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	1.79	14.7	26.3		
	vdd2_ddr	1.1	18.3	20		
	vdd_ana_0p8	0.79	16.6	13.1		
	vdd_ana_1p8	1.79	12.5	22.5		
	vdd_soc	0.89	490	438		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	7.4	4.4		

6.6.4 DD_READ_SD

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.
4. The maximum amount of data the kernel reads ahead for a single file is set to 512 kB.

To measure the power consumption of DD_READ_SD, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`. See [Section 8.1](#).
3. Make sure the file `dd_obs_testfile` exists and rename it to `dd_ibs_testfile`.
4. Copy `dd_read.sh` on the SD partition and run.
5. Measure the power and record the results.

[Table 23](#) shows the measurement results when this use case applies to the i.MX 93 processor.

Table 23. Measurement results for i.MX 93-11x11-EVK_B_DD_READ_SD10 (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	1.3	2.4	18.51	35
	lpd4x_vdd2	1.1	14.1	15.5		
	lpd4x_vddq	0.6	1.1	0.7		

Table 23. Measurement results for i.MX 93-11x11-EVK_B_DD_READ_SD10 (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_SOC_FULL	nvcc_1p8	1.8	0.22	0.4	518.22	
	nvcc_3p3	3.3	0.76	2.5		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	1.79	15.5	27.8		
	vdd2_ddr	1.1	19	20.8		
	vdd_ana_0p8	0.79	16.6	13.1		
	vdd_ana_1p8	1.79	12.5	22.4		
	vdd_soc	0.89	476.1	425.8		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	8.3	5		

6.7 Low-power mode use cases

The following Low-power mode use case scenarios have been tested:

- System Idle with display in OD mode with DDRC auto clock gating
- System Idle with display in ND mode
- System Idle with display in LD mode (DDR to half speed)
- System Idle with display in LD mode (DDR to lowest speed with SWFFC)
- System Idle without display in OD mode with DDRC auto clock gating
- System Idle without display in ND mode with DDRC auto clock gating
- System Idle without display in LD mode with DDRC auto clock gating (DDR to half speed)
- System Idle without display in LD mode with DDRC auto clock gating (DDR to lowest speed with SWFFC)
- System in DSM
- Battery

Attention:

1. By default (in OD mode), DDR auto clock gating is enabled with idle strap: 32768. However, once the system enters ND/LD mode, DDR auto clock gating is disabled.
2. Use the below command to manually enable DDR auto clock gating with idle strap: 256, which means entering auto clock gating more frequently:

```
echo 256 > /sys/devices/platform/imx93-lpm/auto_clk_gating
```

6.7.1 System Idle with display in OD mode with DDRC auto clock gating

The state of the system, when the use case is running, is as follows:

1. The CPU default frequency is set to 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption for the system Idle with display in OD mode with DDRC auto clock gating, the steps are as follows:

1. Connect the HDMI display to the board through the MIPI-to-HDMI converter card ([IMX-MIPI-HDMI](#)).
2. Boot the Linux image with `imx93-11x11-evk.dtb`.
3. Run `setup_video.sh`.
4. The default mode is the OD mode.
5. Measure the power and record the results.

[Table 24](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 24. Measurement results for i.MX 93-11x11-EVK_B_System_idle_w_display_on_OD_mode_DDRC_auto_clock_gating (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	1.6	2.9	28.42	30
	lpd4x_vdd2	1.09	20.8	22.8		
	lpd4x_vddq	0.6	4.6	2.8		
GROUP_SOC_FULL	nvcc_1p8	1.79	2.23	0.4	482.51	

Table 24. Measurement results for i.MX 93-11x11-EVK_B_System_idle_w_display_on_OD_mode_DDRC_auto_clock_gating (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	nvcc_3p3	3.3	3.7	12.3		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	18.7	20.4		
	vdd_ana_0p8	0.78	30.6	23.9		
	vdd_ana_1p8	1.79	21.9	39.1		
	vdd_soc	0.9	423	378.6		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	7.3	4.4		

6.7.2 System Idle with display in ND mode

When the use case is running, the state of the system is as follows:

1. The CPU default frequency is set to 1.4 GHz.
2. The DDR data rate is set to 1866 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption for the system Idle with display on ND mode, follow the steps below:

1. Connect the HDMI display to the board through the MIPI-to-HDMI converter card ([IMX-MIPI-HDMI](#)).
2. Boot the Linux image with `imx93-11x11-evk.dtb`.
3. Run `setup_video.sh`.
4. To put the system into the ND mode, run the following command:

```
echo 1 > /sys/devices/platform/imx93-lpm/mode
```

5. Measure the power and record the results.

[Table 25](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 25. Measurement results for i.MX 93-11x11-EVK_B_System_idle_w_display_on_OD_mode_DDRC_auto_clock_gating (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	1.3	2.4	29.5	31
	lpd4x_vdd2	1.09	19.3	21.1		
	lpd4x_vddq	0.6	10.1	6		
GROUP_SOC_FULL	nvcc_1p8	1.79	0.17	0.3	381.95	
	nvcc_3p3	3.3	4	13.2		
	nvcc_bbsm_1p8	1.79	0.11	0.2		

Table 25. Measurement results for i.MX 93-11x11-EVK_B_System_idle_w_display_on_ND_mode_DDRC_auto_clock_gating (average value)...*continued*

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	11.6	12.7		
	vdd_ana_0p8	0.78	31.3	24.5		
	vdd_ana_1p8	1.78	22.1	39.5		
	vdd_soc	0.85	334.7	283.1		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	8.8	5.3		

6.7.3 System Idle with display in LD mode (DDR to half speed)

When the use case is running, the state of the system is as follows:

1. The CPU default frequency is set to 0.9 GHz.
2. The DDR frequency is set to 1866 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption for the system Idle with display on LD mode, DDR to half speed, the steps are as follows:

1. Connect the HDMI display to the board through the MIPI-to-HDMI converter card ([IMX-MIPI-HDMI](#)).
2. Boot the Linux image with `imx93-11x11-evk-ld.dtb`.
3. Run `setup_video.sh`.
4. To put the system into the LD mode (DDR to half speed), run the following command:

```
echo 2 > /sys/devices/platform/imx93-lpm/mode
```

5. Measure the power and record the results.

[Table 26](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 26. Measurement results for i.MX 93-11x11-EVK_B_System_idle_w_display_on_LD_mode_half_speed_DDR (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	1.5	2.8	29.73	31
	lpd4x_vdd2	1.09	19.1	20.9		
	lpd4x_vddq	0.6	10.2	6.1		
GROUP_SOC_FULL	nvcc_1p8	1.79	0.5	0.9	315.18	
	nvcc_3p3	3.3	4	13.2		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	11.6	12.7		

Table 26. Measurement results for i.MX 93-11x11-EVK_B_System_idle_w_display_on_LD_mode_half_speed_DDR (average value)...*continued*

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_ana_0p8	0.78	30.7	24		
	vdd_ana_1p8	1.78	21.8	38.9		
	vdd_soc	0.8	272	217		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	8.6	5.1		

6.7.4 System Idle with display in LD mode (DDR to lowest speed with SWFFC)

When the use case is running, the state of the system is as follows:

1. The CPU default frequency is set to 0.9 GHz.
2. The DDR frequency is set to 625 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption for the system Idle with display on LD mode (DDR to lowest speed with SWFFC), the steps are as follows:

1. Connect the HDMI display to the board through the MIPI-to-HDMI converter card ([IMX-MIPI-HDMI](#)).
2. Boot the Linux image with `imx93-11x11-evk-ld.dtb`.
3. Run `setup_video.sh`.
4. To put the system into the LD mode, DDR to the lowest speed with SWFFC, run the following command:

```
echo 3 > /sys/devices/platform/imx93-lpm/mode
```

5. Measure the power and record the result.

[Table 27](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 27. Measurement results for i.MX 93-11x11-EVK_B_System_idle_w_display_on_LD_mode_lowest_speed_DDR_SWFFC (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	1.9	3.4	42.17	30
	lpd4x_vdd2	1.1	20.3	22.2		
	lpd4x_vddq	0.59	27.9	16.5		
GROUP_SOC_FULL	nvcc_1p8	1.79	0.30	0.5	275.26	
	nvcc_3p3	3.3	3.7	12.3		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	9.7	10.6		
	vdd_ana_0p8	0.78	30.7	24		
	vdd_ana_1p8	1.79	18.1	32.3		

Table 27. Measurement results for i.MX 93-11x11-EVK_B_System_idle_w_display_on_LD_mode_lowest_speed_DDR_SWFFC (average value)...*continued*

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_soc	0.8	232.6	185.6		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	10.8	6.4		

6.7.5 System Idle without display in OD mode with DDRC auto clock gating

When the use case is running, the state of the system is as follows:

1. The CPU default frequency is set to 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of a system Idle without display on OD mode with DDRC auto clock gating, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`.
3. The default mode is the OD mode.
4. To enable `auto_clk_gating`, run the following command:

```
echo 256 > /sys/devices/platform/imx93-lpm/auto_clk_gating
```

Where 256 implies the duration for DDR Idle to enter self; the unit is the clock cycle.

5. Measure the power and record the results.

[Table 28](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 28. Measurement results for i.MX 93-11x11-EVK_B_System_idle_w/o_display_on_OD_mode_DDRC_auto_clock_gating (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	0.5	0.9	6.42	29
	lpd4x_vdd2	1.1	5.1	5.5		
	lpd4x_vddq	0.6	0	0		
GROUP_SOC_FULL	nvcc_1p8	1.8	0	0.2	345.56	
	nvcc_3p3	3.3	3.7	12.4		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	17.3	18.9		
	vdd_ana_0p8	0.79	16.3	12.9		
	vdd_ana_1p8	1.79	12.5	22.5		
	vdd_soc	0.9	302.6	271.2		

Table 28. Measurement results for i.MX 93-11x11-EVK_B_System_idle_w/o_display_on_OD_mode_DDRC_auto_clock_gating (average value)...*continued*

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_dds	0.6	6.7	4		

6.7.6 System Idle without display in ND mode with DDRC auto clock gating

When the use case is running, the state of the system is as follows:

1. The CPU default frequency is set to 1.4 GHz.
2. The DDR data rate is set to 1866 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of a system Idle without display on ND mode with DDRC auto clock gating, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Run `setup.sh`.
3. To put the system into the ND mode with DDRC auto clock gating, run the following command:

```
echo 1 > /sys/devices/platform/imx93-lpm/mode
```

4. To enable `auto_clk_gating`, run the following command:

```
echo 256 > /sys/devices/platform/imx93-lpm/auto_clk_gating
```

Where 256 implies the duration for DDR Idle to enter self; the unit is the clock cycle.

5. Measure the power and record the results.

[Table 29](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 29. Measurement results for i.MX 93-11x11-EVK_B_system_idle_w/o_display_on_ND_mode_DDRC_auto_clock_gating (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	0.39	0.7	5.72	29
	lpd4x_vdd2	1.1	4.5	5		
	lpd4x_vddq	0.6	0.17	0.1		
GROUP_SOC_FULL	nvcc_1p8	1.8	0	0.3	288.11	
	nvcc_3p3	3.3	3.8	12.5		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_dds	1.1	8.7	9.6		
	vdd_ana_0p8	0.79	17	13.4		
	vdd_ana_1p8	1.79	12.7	22.8		
	vdd_soc	0.85	261.8	221.6		

Table 29. Measurement results for i.MX 93-11x11-EVK_B_system_idle_w/o_display_on_ND_mode_DDRC_auto_clock_gating (average value)...*continued*

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	7.5	4.5		

6.7.7 System Idle without display in LD mode with DDRC auto clock gating (DDR to half speed)

When the use case is running, the state of the system is as follows:

1. The CPU default frequency is set to 0.9 GHz.
2. The DDR data rate is set to 1866 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption for the system Idle without display on LD mode with DDRC auto clock gating (DDR to half speed), the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk-ld.dtb`.
2. Run `setup.sh`.
3. To put the system into the LD mode (DDR to half speed), run the following command:

```
echo 2 > /sys/devices/platform/imx93-lpm/mode
```

4. To enable `auto_clk_gating`, run the following command:

```
echo 256 > /sys/devices/platform/imx93-lpm/auto_clk_gating
```

Where 256 implies the duration for DDR Idle to enter self; the unit is the clock cycle.

5. Measure the power and record the results.

[Table 30](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 30. Measurement results for i.MX 93-11x11-EVK_B_system_idle_w/o_display_on_LD_mode_DDRC_auto_clock_gating_half_speed_DDR (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	0.44	0.8	5.42	29
	lpd4x_vdd2	1.1	4.2	4.6		
	lpd4x_vddq	0.6	0	0		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.17	0.3	227.21	
	nvcc_3p3	3.3	3.9	12.9		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3		
	vdd2_ddr	1.1	8.9	9.8		
	vdd_ana_0p8	0.79	16.3	12.9		
	vdd_ana_1p8	1.79	12.5	22.3		

Table 30. Measurement results for i.MX 93-11x11-EVK_B_system_idle_w/o_display_on_LD_mode_DDRC_auto_clock_gating_half_speed_DDR (average value)...*continued*

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_soc	0.8	201.7	161.1		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	7.5	4.5		

6.7.8 System Idle without display in LD mode with DDRC auto clock gating (DDR to lowest speed with SWFFC)

When the use case is running, the state of the system is as follows:

1. The CPU default frequency is set to 0.9 GHz.
2. The DDR data rate is set to 625 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption for the system Idle without display on LD mode with DDRC auto clock gating (DDR to lowest speed with SWFFC), the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk-ld.dtb`.
2. Run `setup.sh`.
3. To put the system into the LD mode, DDR to the lowest speed with SWFFC, run the following command:

```
echo 3 > /sys/devices/platform/imx93-lpm/mode
```

4. To enable `auto_clk_gating`, run the following command:

```
echo 256 > /sys/devices/platform/imx93-lpm/auto_clk_gating
```

Where 256 implies the duration for DDR Idle to enter self; the unit is the clock cycle.

5. Measure the power and record the results.

[Table 31](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 31. Measurement results for i.MX 93-11x11-EVK_B_system_idle_w/o_display_on_LD_mode_DDRC_auto_clock_gating_lowest_speed_DDR_SWFFC (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	0.44	0.8	5.12	28
	lpd4x_vdd2	1.1	3.9	4.3		
	lpd4x_vddq	0.6	0	0		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.22	0.4	199.88	
	nvcc_3p3	3.3	4	13.1		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	3.5	3.8		
	vdd_ana_0p8	0.79	16.3	12.9		

Table 31. Measurement results for i.MX 93-11x11-EVK_B_system_idle_w/o_display_on_LD_mode_DDRC_auto_clock_gating_lowest_speed_DDR_SWFCC (average value)...*continued*

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_ana_1p8	1.79	8.8	15.7		
	vdd_soc	0.8	183.6	146.6		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_dds	0.6	6.7	4		

6.7.9 System in Deep Sleep Mode (DSM)

The use case is based on the Suspend mode, which implies the following:

- CA55 cluster is OFF
- MEDIAMIX is OFF
- NICMIX is OFF
- WAKEUPMIX is OFF
- PLL is OFF
- 24 M OSC is OFF
- PMIC is in STBY mode

When the use case is running, the state of the system is as follows:

1. The DDR is in the Retention mode.
2. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of the system in the DSM, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk-DSM.dtb`.
2. To put the system into the Suspend (Deep sleep) mode, run the following command:

```
echo mem > /sys/power/state
```

3. Measure the power and record the results.

[Table 32](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 32. Measurement results for i.MX 93-11x11-EVK_B_DSM (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	0.39	0.7	1.77	Die temperature cannot be measured as the CA55 core has been suspended.
	lpd4x_vdd2	1.1	0.9	1.0		
	lpd4x_vddq	0	0	0		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.5	0.9	7.56	
	nvcc_3p3	3.3	0.33	1.1		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.24	0.8		
	vdd2_dds	1.1	0.18	0.2		

Table 32. Measurement results for i.MX 93-11x11-EVK_B_DSM (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_ana_0p8	0.8	0.75	0.6		
	vdd_ana_1p8	1.8	0.78	1.4		
	vdd_soc	0.65	3.5	2.3		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0	0	0		

6.7.10 Battery

BBSM mode of the i.MX 93 processor is a Low-power mode where only the power for the BBSM domain remains on.

When the use case is running, the state of the system is as follows:

1. All power supplies except NVCC_BBSM_1P8 are off externally.
2. The secure real-time clock (SRTC) is maintained and is running.
3. Tamper logic is retained.
4. SNVS is at 1.8 V DGO (VBAT input: 3 V).
5. All clocks and PLLS in CA55 and LPAV are turned off.

To configure and run the use case, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb` in CA55.
2. Press the ON/OFF key for 5 seconds.
3. Measure the power and record the results.

Table 33 shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 33. Measurement results for i.MX 93-11x11-EVK_B_Battery (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (μW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	0	0	0	-0.075	Die temperature cannot be measured as the CA55 core has been suspended.
	lpd4x_vdd2	0	0	0		
	lpd4x_vddq	0	0	0		
GROUP_SOC_FULL	nvcc_1p8	0	0	0	97.978	
	nvcc_3p3	0	0	0		
	nvcc_bbsm_1p8	1.79	0.06	0.1		
	nvcc_sd2	0	0	0		
	vdd2_ddr	0	0	0		
	vdd_ana_0p8	0	0	0		
	vdd_ana_1p8	0	0	0		
	vdd_soc	0	0	0		
	vdd_usb_3p3	0	0	0		

Table 33. Measurement results for i.MX 93-11x11-EVK_B_Battery (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (μW)	Zone 0 die temperature (°C)
	vddq_ddr	0	0	0		

6.8 Stress test use cases

The following stress use case scenarios have been tested:

- 2 x CA55 Dhrystone + PXP + CM33 CoreMark + NPU
- 2 x CA55 Stream + PXP + CM33 CoreMark + NPU

6.8.1 2 x CA55 Dhrystone + PXP + CM33 CoreMark + NPU

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The LCDIF and PXP are used for GUI rendering and display.
4. The CA55 is used for the Dhrystone.
5. The CM33 is used for CoreMark and NPU.

To measure the power consumption of the 2 x CA55 Dhrystone + PXP + CM33 CoreMark + NPU, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Backup `/lib/firmware/ethosu_firmware`. Copy `ethosu_apps_rpmsg_coremark.out` to `/lib/firmware` and rename it to `ethosu_firmware`. For the other NPU-related cases, use the default one.
3. Copy the model named `mobilenet_v1_1.0_224_quant_vela.tflite` to `/usr/bin/tensorflow-lite-2.12.1/examples`. The TensorFlow version in `ML_vela.sh` must be the same.
4. Run `setup_video.sh`.
5. Run the `dhrystone_loop.sh`, `PXP_test.sh`, and `ML_vela.sh` simultaneously.
6. Measure the power and record the results.

[Table 34](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 34. Measurement results for i.MX 93-11x11-EVK_B_2xCA55_Dhrystone_PXP_CM33_CoreMark_NPU (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	4	7.3	98.7	48
	lpd4x_vdd2	1.09	76.7	83.4		
	lpd4x_vddq	0.59	13.6	8.1		
GROUP_SOC_FULL	nvcc_1p8	1.79	0.45	0.8	1230.48	
	nvcc_3p3	3.3	3.7	12.1		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	33	36.2		
	vdd_ana_0p8	0.78	33.8	26.4		
	vdd_ana_1p8	1.78	22.9	40.8		
	vdd_soc	0.89	1243.2	1101.3		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	15.9	9.5		

6.8.2 2 x CA55 Stream + PXP + CM33 CoreMark + NPU

The state of the system, when the use case is running, is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The LCDIF and PXP are used for GUI rendering and display.
4. The CA55 is used for the Stream.
5. The CM33 is used for CoreMark and NPU.

To measure the power consumption of the 2 x CA55 Stream + PXP + CM33 CoreMark + NPU, the steps are as follows:

1. Boot the Linux image with `imx93-11x11-evk.dtb`.
2. Backup `/lib/firmware/ethosu_firmware`. Copy `ethosu_apps_rpmsg_coremark.out` to `/lib/firmware` and rename it to `ethosu_firmware`. For the other NPU-related cases, use the default one.
3. Copy the model named `mobilenet_v1_1.0_224_quant_vela.tflite` to `/usr/bin/tensorflow-lite-2.12.1/examples`. The TensorFlow version in `ML_vela.sh` must be the same.
4. Run `setup_video.sh`.
5. Run the `streamcpy_loop.sh`, `PXP_test.sh`, and `ML_vela.sh` simultaneously.

```
./streamcpy_loop.sh &
./PXP_test.sh &
cd /usr/bin/tensorflow-lite-2.12.1/examples
./ML_vela.sh
```

6. Measure the power and record the results.

[Table 35](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 35. Measurement results for i.MX 93-11x11-EVK_B_2xCA55_Stream_PXP_CM33_CoreMark_NPU (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	7.1	12.6	158.25	48
	lpd4x_vdd2	1.08	122.5	132.9		
	lpd4x_vddq	0.59	21.6	12.7		
GROUP_SOC_FULL	nvcc_1p8	1.79	0.22	0.4	1264.123	
	nvcc_3p3	3.3	3.8	12.6		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.09	47.6	52		
	vdd_ana_0p8	0.78	34	26.5		
	vdd_ana_1p8	1.78	22.8	40.7		
	vdd_soc	0.89	1256.9	1113.1		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	25.7	15.3		

6.9 Product use cases

The following product use case scenarios have been tested:

- Linux Suspend + CM33 Coremark (TCM)
- Linux Suspend + CM33 in WFI
- Linux Suspend + CM33 FlexCAN transaction
- Smart doorbell

6.9.1 Linux Suspend + CM33 CoreMark (TCM)

When the use case is running, the state of the system is as follows:

1. The Linux OS is configured to be in Suspend mode.
2. The DDR is in Self-refresh mode.
3. The CM33 is running CoreMark.

To measure the power consumption of Linux Suspend + CM33 CoreMark (TCM), the steps are as follows:

1. Copy `power_mode_switch_flexcan_coremark.bin` to bootpartition on eMMC.
2. Boot the Linux image with `imx93-11x11-evk.dtb`.
3. Stop in U-Boot.
4. Run:

```
setenv mmcargs $mmcargs clk_ignore_unused
fatload mmc 0:1 0x80000000
power_mode_switch_flexcan_coremark.bin
cp.b 0x80000000 0x201e0000 0x10000
cp power_mode_switch_flexcan_coremark.bin /run/media/boot-mmcb1k0p1/
bootaux 0x1ffe0000 0
```

5. To boot to kernel, run `boot`.
6. To put the system into suspend, run the following command:

```
echo mem > /sys/power/state
```

7. Switch to the CM33 console and input the letter "Z" to run CoreMark.
8. Measure the power and record the results.

[Table 36](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 36. Measurement results for i.MX 93-11x11-EVK_B_DSM_CM33_CoreMark_(TCM) (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	0.5	0.9	1.89	Die temperature cannot be measured as the CA55 core has been suspended.
	lpd4x_vdd2	1.1	0.9	1		
	lpd4x_vddq	0.6	0	0		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.33	0.6	128.16	
	nvcc_3p3	3.3	3.7	12.4		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	0.18	0.2		

Table 36. Measurement results for i.MX 93-11x11-EVK_B_DSM_CM33_CoreMark_(TCM) (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	vdd_ana_0p8	0.79	12.8	10.2		
	vdd_ana_1p8	1.79	3.3	5.9		
	vdd_soc	0.9	106.3	95.5		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_ddr	0.6	0	0		

6.9.2 Linux Suspend + CM33 in wait for interrupt

When the use case is running, the state of the system is as follows:

1. The Linux OS is configured to be in Suspend mode.
2. The DDR is in Self-refresh mode.
3. The CM33 is in Wait for interrupt (WFI) mode.

To measure the power consumption of Linux Suspend + CM33 in WFI, the steps are as follows:

1. Copy `power_mode_switch_flexcan_coremark.bin` to the boot partition on the SD card:

```
cp power_mode_switch_flexcan_coremark.bin /run/media/boot-mmcb1k0p1/
```

2. Boot the Linux image with `imx93-11x11-evk.dtb`.
3. Stop in U-Boot.
4. Run:

```
setenv mmcargs $mmcargs clk_ignore_unused
fatload mmc 0:1 0x80000000 power_mode_switch_flexcan_coremark.bin
cp.b 0x80000000 0x201e0000 0x10000;bootaux 0x1ffe0000 0
```

5. To boot to kernel, run `boot`.
6. To put the system into suspend, run the following command:

```
echo mem > /sys/power/state
```

7. Switch to the CM33 console and input the letter "B" to enter WFI mode.
8. Measure the power and record the results.

[Table 37](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 37. Measurement results for i.MX 93-11x11-EVK_B_DSM_CM33_WFI (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	0.44	0.8	1.84	Die temperature cannot be measured as the CA55 core has been suspended.
	lpd4x_vdd2	1.1	1	1.1		
	lpd4x_vddq	0.6	0	0		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.28	0.5	122.41	
	nvcc_3p3	3.3	3.7	12.2		
	nvcc_bbsm_1p8	1.79	0.11	0.2		

Table 37. Measurement results for i.MX 93-11x11-EVK_B_DSM_CM33_WFI (average value)...continued

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_dds	1.1	0.09	0.1		
	vdd_ana_0p8	0.79	12.8	10.2		
	vdd_ana_1p8	1.79	6.14	11.01		
	vdd_soc	0.9	100.3	90.1		
	vdd_usb_3p3	3.3	0.06	0.2		
	vddq_dds	0.6	0	0		

6.9.3 Linux Suspend + CM33 FlexCAN transaction

When the use case is running, the state of the system is as follows:

1. The Linux OS is configured to be in Suspend mode.
2. The DDR is in Self-refresh mode.
3. The CM33 is in sending/receiving CAN frames.

To measure the power consumption of Linux Suspend + CM33 in WFI, the steps are as follows:

1. Prepare two i.MX 93 EVK boards, namely boards A and B.
2. Connect the CAN connector of the two boards together.
3. On both the boards, perform the following steps:
 - a. Copy `power_mode_switch_flexcan_coremark.bin` to boot partition on eMMC.

```
cp power_mode_switch_flexcan_coremark.bin /run/media/boot-mmcb1k0p1/
```

- b. Boot the Linux image.
- c. Stop in U-Boot.
- d. Run:

```
setenv mmcargs $mmcargs clk_ignore_unused
fatload mmc 1:1 ${loadaddr} power_mode_switch_flexcan_coremark.bin;
cp.b ${loadaddr} 0x201e0000 0x10000;bootaux 0x1ffe0000 0
fatload mmc ${mmcdev}:${mmcpart} ${fdt_addr_r} ${fdtfile}
fdt addr ${fdt_addr_r};
fdt rm /soc/bus@44000000/can@443a0000;
run mmcargs;
fatload mmc ${mmcdev}:${mmcpart} ${loadaddr} ${image};
run boot_os
```

- e. Switch to the CM33 console and input the letter "Y" to enter CAN test mode.
4. On board B in the CM33 console, input the letter "B" to start receiving the CAN message from board A.
 5. On board A, perform the following steps:
 - a. In the CM33 console, input the letter "A" to start transmitting and receiving the CAN message. Both the CM33 consoles start to print the log.
 - b. To suspend the CA55 cores, run the following command:

```
echo mem > /sys/power/state
```

- c. Measure the power numbers from board A only.

[Table 38](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 38. Measurement results for i.MX 93-11x11-EVK_B_DSM_M33_FlexCAN (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.8	0.5	0.9	2.07	Die temperature cannot be measured as the CA55 core has been suspended.
	lpd4x_vdd2	1.1	1	1.1		
	lpd4x_vddq	0.6	0	0		
GROUP_SOC_FULL	nvcc_1p8	1.8	0.39	0.7	132.32	
	nvcc_3p3	3.3	3.8	12.7		
	nvcc_bbsm_1p8	1.79	0.11	0.2		
	nvcc_sd2	3.3	0.9	3.1		
	vdd2_ddr	1.1	0.27	0.3		
	vdd_ana_0p8	0.79	12.9	10.2		
	vdd_ana_1p8	1.79	3.3	6		
	vdd_soc	0.9	110.4	99.1		
	vdd_usb_3p3	3.3	0.03	0.1		
	vddq_ddr	0.6	0	0		

6.9.4 Smart doorbell

For this use case, a doorbell is simulated with a camera. The video stream collected on the doorbell can be sent to other devices through the network. The AP1302 MIPI camera is used to record the video. The video is 480 p, encoded in H.264 format, and then the RTP protocol transfers the video. On the host PC, video playback software VLC helps to open the session description protocol (SDP) file. By opening the file, the stream video can be viewed.

When the use case is running, the state of the system is as follows:

1. The CPU frequency is set to the maximum value of 1.7 GHz.
2. The DDR data rate is set to 3733 MT/s.
3. The CM33 is in reset hold, waiting for the reset signal release.

To measure the power consumption of the smart doorbell, the steps are as follows:

1. Download the ap1302 firmware from [ON Semiconductor](#), and rename it as ap1302.fw.
2. Copy ap1302.fw to the target board under the path /lib/firmware/imx/camera/.
3. Connect AP1302 MIPI camera with J801 on i.MX 93 EVK.
4. Boot the Linux image with imx93-11x11-evk.dtb.
5. Run setup_video_stream.sh.
6. To record the video and transfer the video through the RTP protocol, run the following command:

```
gst-launch-1.0 v4l2src device=/dev/video0 ! \
video/x-raw,width=640,height=480,framerate=30/1 ! \
x264enc tune=zerolatency bitrate=500 speed=superfast ! \
rtph264pay config-interval=10 pt=96 ! \
udpsink host=[HOST PC IP] port=50000
```

Open the SDP file with VLC on the host PC. The content in the SDP file includes the following:

```
v=0
m=video 5000 RTP/AVP 96
```

```
c=IN IP4 [BOARD IP]
a=rtpmap:96 H264/90000
```

[Table 39](#) shows the measurement results when this use case is applied to the i.MX 93 processor.

Table 39. Measurement results for i.MX 93-11x11-EVK_B_smart_doorbell (average value)

Rail label		Average voltage (V)	Average current (mA)	Average power (mW)	Sum of average powers (mW)	Zone 0 die temperature (°C)
GROUP_DRAM	lpd4x_vdd1	1.79	3	5.4	54.3	40
	lpd4x_vdd2	1.09	40.4	44.1		
	lpd4x_vddq	0.6	8.1	4.8		
GROUP_SOC_FULL	nvcc_1p8	1.79	6.5	11.6	772.06	
	nvcc_3p3	3.28	3.2	10.4		
	nvcc_bbsm_1p8	1.81	0.11	0.2		
	nvcc_sd2	3.28	0.9	3		
	vdd2_ddr	1.09	22.7	24.9		
	vdd_ana_0p8	0.78	33	25.7		
	vdd_ana_1p8	1.78	23	41.1		
	vdd_soc	0.89	729.6	648.7		
	vdd_usb_3p3	3.28	0.03	0.1		
	vddq_ddr	0.6	10.6	6.4		

7 Reducing power consumption

The overall system power consumption depends on the software optimization and the system hardware implementation. The following list of suggestions can help reduce system power consumption. Some of these suggestions are already implemented in the Linux BSP and/or SDK. The system of each individual user can undergo further optimizations.

Note: *Further power optimizations are planned in future software releases. To obtain the latest software releases, refer [i.MX Software and Development Tools](#).*

- Apply clock gating by configuring registers in the CCM, whenever clocks or modules are not used.
- For Run modes, use the slowest frequency that can still meet the application requirements.
- Minimize the number of operating PLLs. Enabled PLLs can consume a few milliamps of current.
- Applying voltage and frequency scaling (VFS) for the Arm cores and scaling the frequencies of the AXI, AHB, and IPG bus clocks can significantly reduce power consumption. However, the operation frequency reduction causes longer access times to the DDR, which increases the power consumption of the DDR I/O and memories. Consider this trade-off for each mode to quantify the overall effect on system power.
- Put the SoC into Low-power modes whenever possible, as long as it can still support the application requirements. Consider the following example:
 - Put the system into Suspend mode when it can enter deep sleep.
 - Put the system into Low-power run mode by only using the CM33 core.
 - Power off the CA55 cores and other domains for low-load use cases.
- For each operating mode, use the lowest voltage (with the power supply tolerance) that can still meet the requirements of voltage specifications in the data sheet.
- DDR interface optimization:
 - Use careful board routing of the DDR memories, maintaining PCB trace lengths as short as possible.
 - Use the proper output driver impedance for DDR interface pins that provides good impedance matching. To save current through DDR I/O pins, select the lowest possible drive strength that provides the required performance.
 - Use of LPDDR4/LPDDR4x memory offerings in the latest process technology can significantly reduce the power consumption of the DDR devices and the DDR I/O.

The following sections provide more details for system optimization. These sections are not exhaustive lists of features that can provide power reductions, but they are the easiest and most common ones.

- [Run fast and idle](#)
- [Clock gating](#)
- [DDRC auto clock gating](#)
- [PLL reduction](#)
- [Core VFS and system bus scaling](#)
- [Lower DDR frequencies](#)
- [DDR interface optimization](#)
- [Power gating of PHYs](#)
- [Distribution of workloads](#)
- [Use OCRAM to minimize DDR access](#)
- [Thermal management to reduce leakage](#)
- [Nominal drive mode](#)

7.1 Run fast and idle

NXP testing and various research have shown that for most customer use cases, the best power/energy management protocol is to run the cores at maximum speeds for the workload and then drop to the lowest power mode as soon as possible. This strategy cannot provide optimal energy savings for the use cases where constant data is being processed, for example, low-latency audio playback. However, this strategy does work for other standard workloads. Consider this trade-off for each application to quantify the overall effect on the system power/energy consumption.

Users must place the i.MX 93 into the Low-power mode as far as possible.

7.2 Clock gating

The CCM inside the i.MX 93 provides a programmable method to disable the clock sources for modules when the modules are not used. To reduce energy waste, always configure the CCM registers. Driving any inactive signal, whether on the SoC or the PCB, is simply charging and discharging the line and the load capacitance of this signal. The NXP BSP-released software implements clock gating by default.

7.3 DDRC auto clock gating

When the bus is idle after the number of cycles configured in the `ssi_idle_strap` field in the DDR BLK_CTRL module, the DDRC does auto clock gating to save power. This feature can be used to balance DDR subsystem performance and power significantly. The number of idle cycles before clock gating can be adjusted dynamically based on the actual use case to fine-tune the power saving.

In the i.MX 93, `auto_clk_gating` is used to enable the DDRC auto clock gating. Therefore, power is saved when there is no access to the DDR after the programmed idle count expires. "Write 0" disables the auto clock gating and the "write non-zero" value sets the `ssi_idle_strip` to this non-zero value and enable the auto clock gating. A value < 256 has some significant side effort for DDR performance, so a value ≥ 256 is suggested when the user wants to enable it. When the auto clock gating is enabled, a high-resolution display like 1080 P 60 fps can flicker at lower DDR frequency. It is recommended not to adjust the `auto_clk_gating` when the display/NPU is running.

7.4 PLL reduction

Each PLL block consumes significant energy when active. Each application has unique requirements, but, if possible, reduce the number of operating PLLs. The CCM within the i.MX 93 provides Root Clock mux and programmable control to each PLL either by direct control mode or CPU Low-power mode. As a result, the Root Clocks source is allowed to modify to limit the PLL source and reduce the number of active PLLs when operating. Ensure that the application considers the PLL relock time when transitioning back to full operation.

7.5 Core VFS and system bus scaling

Applying VFS for the Arm cores and scaling (not dynamic) the frequencies of the NOC, AXI, AHB, and IPG system bus clocks can significantly reduce the power consumption of the VDD_SOC domains. However, the operation of system frequency reduction causes longer access times to the DDR, which can increase the energy consumption for specific use cases. Consider this trade-off for each mode to quantify the overall effect on the system power consumption.

7.6 Lower DDR frequencies

As explained previously, the DDR I/O bus frequency also contributes to the DDR I/O current. Software interfaces allow for the use of the HWFFC/SWFFC technology of DDRC, which allows for the significant reduction of power consumption by lowering the DDR frequency.

7.7 DDR interface optimization

To optimize the DDR interface, the suggestions are as follows:

- Employ careful board routing of the DDR memories, maintaining the PCB trace lengths as short as possible. Longer trace lengths and more vias create more PCB capacitance for the signal, resulting in more energy wastage along the signal path.
- Keep the on-die termination (ODT) value as low as possible. The termination used greatly influences the power consumption of the DDR interface pins. To ensure the ODT variance does not reduce the bus signal integrity, simulate the DDR interface.
- Use an appropriate output driver impedance for the DDR interface pins that provide good impedance matching. Select the lowest possible drive strength that provides the required performance to reduce the current flowing through the DDR I/O pins. Remember that simulation must be done to ensure signal integrity.
- The use of the DDR memory offerings in the latest process technology can significantly reduce the power consumption of the DDR devices and the DDR I/O.
- Sizing DDR memory is important. If you select 4 GB memory when only 2 GB is used, you are wasting the refresh current for the unused 2 GB of DDR.
- Sizing of ECC DDR regions is important as they use more energy for this feature.

7.8 Power gating of PHYs

The PHYs of unused modules often get overlooked when searching for power savings. Many PHYs contain local PLLs or clocking circuits and voltage references, which consume power even when not in use. As a result, high-speed PHYs like Ethernet, MIPI, and USB get affected.

7.9 Distribution of workloads

The concept of distributed workloads is to review the system requirements and determine which SoC block is best suited for each task. By spreading the workload, the system can return to the "Idle" state sooner. This process applies to multicore distributions and functions that suit the CM33 core or ML engine. System designers must ensure that the design uses the optimal cores for the specific workloads or tasks, on the i.MX 93 for maximum efficiency. While often easier said than done, it does provide significant power savings if the system can return to the low-power state faster (run fast and idle).

7.10 Use OCRAM to minimize DDR access

To achieve significant power savings, load highly accessed code into the On-Chip RAM (OCRAM). As a result, both the i.MX 93 and the DDR memory current consumption reduces. Another advantage of using the OCRAM is a performance increase since DDR memory access time delays this code.

7.11 Thermal management to reduce leakage

Thermal management is also a key element of power reduction. As temperature increases, so does the SoC gate leakage current for each gate within the device. Millions of high-gate leakages add up when looking for the lowest power consumption. As explained earlier, with any power savings, the temperature of the SoC reduces, and the lifetime reliability of the device improves.

As each system is unique, the system designer must ensure that the operating temperature of the SoC is as low as possible to reduce the leakage current loss. If this temperature cannot be achieved from software controls, the designer must include a heat sink or other thermal management methods to remove the heat from the SoC.

7.12 Nominal drive mode

The NXP-supplied Linux BSP GA release configures the system to run in Overdrive mode (ODM) by default. This Overdrive mode and associated performance are not necessary for some user applications. Users can transition to Nominal or Low-drive mode as defined in the i.MX 93 data sheet instead.

8 Important commands and scripts

Before running a use case, the `<configuration_script>.sh` script must be run to configure the environment. Details for these scripts are as follows:

8.1 setup.sh

`setup.sh`: The CPU frequency is set to the maximum value of 1.7 GHz to achieve the best performance. Disable the Ethernet, stop the Weston service, and blank the display. Set 512 kB as the maximum amount of data the kernel reads ahead for a single file.

```
#!/bin/bash
systemctl stop weston.service
echo 1 > /sys/class/graphics/fb0/blank
partitions=$(lsblk |awk '$1 !~/-/{print $1}' |grep 'blk\|sd')
for partition in $partitions; do
    echo 512 > /sys/block/$partition/queue/read_ahead_kb
done
eth_int=$(ifconfig -a | grep 'eth[0-9]|awk {'print substr($1, 0, 4)'}')
for eth in $eth_int; do
    ifconfig $eth down
done
```

8.2 setup_video.sh

`setup_video.sh`: The CPU frequency is set to the maximum value of 1.7 GHz to achieve the best performance. Disable the Ethernet and awake the display. Set 512 kB as the maximum amount of data the kernel reads ahead for a single file.

```
#!/bin/bash
partitions=$(lsblk |awk '$1 !~/-/{print $1}' |grep 'blk\|sd')
for partition in $partitions; do
    echo 512 > /sys/block/$partition/queue/read_ahead_kb
done
eth_int=$(ifconfig -a | grep 'eth[0-9]|awk {'print substr($1, 0, 4)'}')
for eth in $eth_int; do
    ifconfig $eth down
done
echo 1 > /sys/class/graphics/fb0/blank
echo 0 > /sys/class/graphics/fb0/blank
```

8.3 setup_video_stream.sh

`setup_video_stream.sh`: The CPU frequency is set to the maximum value of 1.7 GHz to achieve the best performance. To play the video online, open the Ethernet and awake the display. Set 512 kB as the maximum amount of data the kernel reads ahead for a single file.

```
#!/bin/bash
partitions=$(lsblk |awk '$1 !~/-/{print $1}' |grep 'blk\|sd')
for partition in $partitions; do
    echo 512 > /sys/block/$partition/queue/read_ahead_kb
done
eth_int=$(ifconfig -a | grep 'eth[0-9]|awk {'print substr($1, 0, 4)'}')
for eth in $eth_int;do
    ifconfig $eth up
done
echo 1 > /sys/class/graphics/fb0/blank
echo 0 > /sys/class/graphics/fb0/blank
```


8.4 DDRC_625MTS_setup.sh

DDRC_625MTS_setup.sh: After running the shell scripts below, the DDR frequency switches to Low-bus mode 312.5 MHz (data rate is 625 MT/s). The CPU frequency is set to the minimum value of 1400 MHz. DDR VFS aims at saving power. Disable the Ethernet, stop the Weston service, and blank the display.

```
#!/bin/bash
systemctl stop weston.service
if [ -f /sys/class/graphics/fb0/blank ]; then
    echo 1 > /sys/class/graphics/fb0/blank
fi
eth_int=`ifconfig -a | grep 'eth[0-9]'|awk {'print substr($1, 0, 4)'} `
for eth in $eth_int; do
    ifconfig $eth down
done
echo 3 > /sys/devices/platform/imx93-lpm/mode
```

8.5 dd_read.sh

dd_read.sh: This script is used to run the `dd read` command on the memory device.

```
#!/bin/bash
# Since we're dealing with dd, abort if any errors occur
set -e
TEST_FILE=${1:-dd_ibs_testfile}
if [ -e $TEST_FILE ]; then
    echo "NOTE: Kernel cache will not be cleared between tests without sudo. This will likely
    cause inaccurate results." 1>&2 ;fi
count=$COUNT conv=fsync > /dev/null 2>&1
# Header
PRINTF_FORMAT="%8s : %s\n"
printf "$PRINTF_FORMAT" 'block size' 'transfer rate'
while true
do
    BLOCK_SIZE=4096
    # Clear kernel cache to ensure more accurate test
    [ $EUID -eq 0 ] && [ -e /proc/sys/vm/drop_caches ] && echo 3 > /proc/sys/vm/drop_caches
    # Read test file out to /dev/null with specified block size
    DD_RESULT=$(dd if=$TEST_FILE of=/dev/null bs=$BLOCK_SIZE 2>&1 1>/dev/null)
    # Extract transfer rate
    TRANSFER_RATE=$(echo $DD_RESULT | \grep --only-matching -E '[0-9.]+ ([MGk]?B|bytes)/
    s(ec)?')
    printf "$PRINTF_FORMAT" "$BLOCK_SIZE" "$TRANSFER_RATE"
done
```

8.6 dd_write.sh

dd_write.sh: This script is used to run the `dd write` command on the memory device.

```
#!/bin/bash
# Since we're dealing with dd, abort if any errors occur
set -e
TEST_FILE=${1:-dd_obs_testfile}
TEST_FILE_EXISTS=0
if [ -e "$TEST_FILE" ]; then TEST_FILE_EXISTS=1; fi
TEST_FILE_SIZE=1024000000
if [ $EUID -ne 0 ]; then
    echo "NOTE: Kernel cache will not be cleared between tests without sudo. This will likely
    cause inaccurate results." 1>&2
fi
# Header
```

```

PRINTF_FORMAT="%8s: %s\n"
printf "$PRINTF_FORMAT" 'block size' 'transfer rate'
while true
BLOCK_SIZE=4096
do
# Calculate number of segments required to copy
COUNT=$(( $TEST_FILE_SIZE / $BLOCK_SIZE ))
if [ $COUNT -le 0 ]; then
echo "Block size of $BLOCK_SIZE estimated to require $COUNT blocks, aborting further
tests."
break
fi
# Clear kernel cache to ensure more accurate test
[ $EUID -eq 0 ] && [ -e /proc/sys/vm/drop_caches ] && echo 3 > /proc/sys/vm/drop_caches
# Create a test file with the specified block size
DD_RESULT=$(dd if=/dev/zero of=$TEST_FILE bs=$BLOCK_SIZE count=$COUNT conv=fsync 2>&1 1>/
dev/null)
# Extract the transfer rate from dd's STDERR output
TRANSFER_RATE=$(echo $DD_RESULT | \grep --only-matching -E '[0-9.]+ ([MGk]?B|bytes)/
s(ec)?')
# Output the result
printf "$PRINTF_FORMAT" "$BLOCK_SIZE" "$TRANSFER_RATE"
done

```

8.7 dhrystone_loop.sh

dhrystone_loop.sh: The script starts the Dhrystone example:

```

while true; do
taskset -c 0 ./dhry2 &
taskset -c 1 ./dhry2
done

```

8.8 ML_vela.sh

ML_vela.sh: The script starts the machine learning example:

```

#!/bin/bash
echo 4 > /proc/sys/kernel/printk
cd /usr/bin/tensorflow-lite-2.12.1/examples
while true; do
/usr/bin/tensorflow-lite-2.12.1/examples/benchmark_model \
--graph=./output/mobilenet_v1_1.0_224_quant_vela.tflite \
--num_runs=22000 --external_delegate_path=/usr/lib/libethosu_delegate.so
done

```

8.9 MV_vela.sh

MV_vela.sh: The script starts the machine vision example:

```

gst-launch-1.0 -v v4l2src device=/dev/video0 ! \
video/x-raw,width=640,height=480,framerate=30/1 ! \
tee name=t.t. ! queue max-size-buffers=2 leaky=2 ! \
max-size-buffers=2 leaky=2 ! \imxvideoconvert_pxp ! \
video/x-raw,width=300,height=300,format=BGRA ! \
videoconvert ! video/x-raw,format=RGB ! tensor_converter ! \
tensor_filter framework=tensorflow-lite \
model=./output/ssd_mobilenet_v2_coco_quant_postprocess_vela.tflite \
custom=Delegate:External,ExtDelegateLib:libethosu_delegate.so ! \
tensor_decoder mode=bounding_boxes option1=tf-ssd option2=coco_labels.txt \
option3=0:1:2:3,50 option4=640:480 option5=300:300 ! \

```

```
videoconvert ! mix. t. ! queue max-size-buffers=2 leaky=2 ! \  
imxcompositor_pxp name=mix sink_0::zorder=2 sink_1::zorder=1 sink_0::alpha=0.5 \  
latency=14000000 min-upstream-latency=14000000 ! waylandsink
```

8.10 PXP_test.sh

PXP_test.sh: The script starts the PXP example:

```
gst-launch-1.0 -v imxcompositor_pxp \  
name=comp sink_0::xpos=0 sink_0::ypos=0 \  
sink_0::width=1280 sink_0::height=800 ! \  
waylandsink videotestsrc ! comp.sink_0
```

8.11 streamcpy_loop.sh

streamcpy_loop.sh: The script starts the stream example:

```
while true; do  
    taskset -c 0 stream -M 200M -N 1000 &  
    taskset -c 1 stream -M 200M -N 1000  
done
```

9 Related documentation

For the list of current documents, refer to [i.MX 93/Documentation](#). Additional literature would be published as and when new NXP products become available.

- For actual values of SoC power domains, refer to:
 - i.MX 91 Application Processors Data Sheet for Industrial Products [IMX93IEC](#)
 - i.MX 91 Application Processors Data Sheet for Consumer Products [IMX93CEC](#)
 - i.MX 93 Automotive Application Processors Data Sheet [IMX93AEC](#)
- For more details regarding the i.MX 91 power architecture, refer to the document:
 - i.MX 91 Applications Processors Reference Manual (document [IMX93RM](#))
- For more information on the i.MX Yocto Project, refer [i.MX Yocto Project User's Guide](#)

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11 Revision history

[Table 40](#) summarizes revisions to this document.

Table 40. Revision history

Document ID	Release date	Description
AN13917 v.4.0	23 January 2025	Updated commands including Section 8.9 and other updates
AN13917 v.3.0	29 February 2024	<ul style="list-style-type: none">Updated the Q3 power consumption dataUpdated tables referring to measurement results for i.MX 93-11x11-EVK for all use casesAdded Battery and DDRC auto clock gatingUpdated Video playback streaming (gplay)
AN13917 v.2.0	14 September 2023	<ul style="list-style-type: none">Updated the Q2 power consumption dataAdded the SoC temperature data for all use casesUpdated tables, which include measurement results for i.MX 93-11x11-EVK
AN13917 v.1.0	24 April 2023	Initial public release

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