ConnectCore® 8X Performance and Power

Benchmarking Report

Application Note

Revision history—90002448

Revision	Date	Description
A	March 2021	Initial release.

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Contents

Additional information

Introduction

This document characterizes power consumption and performance for the ConnectCore 8X SOM. It includes detailed measurements representing a variety of use cases and includes performance tests for key interfaces, including CPU, memory, Wi-Fi, and video and audio playback.

Note The tests have been performed on SOMs with the QuadXPlus and DualXZ processor variants. In cases where the performance-limiting factor is the interface, the tests have been executed only on the QuadXPlus.

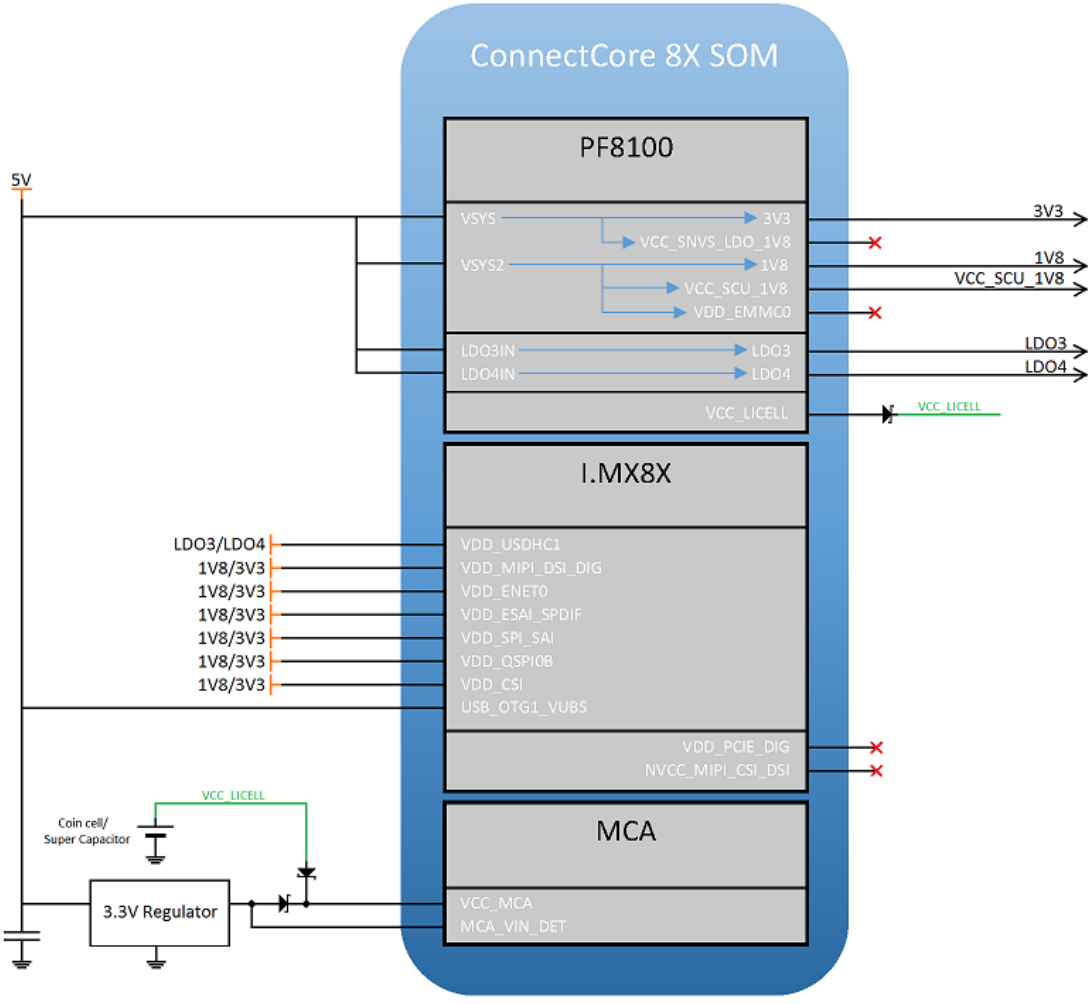
Note This information is provided as a reference on the capabilities of the ConnectCore 8X platform. You may see different figures due to software or other factors.

Power architecture

The following diagram represents the full power architecture distribution of the ConnectCore 8X module with its three main components:

- The PF8100 PMIC
- The i.MX8X SOC
- The Micro Controller Assist (MCA)

The following diagram shows a typical application with coin cell charger functionality supported:



Measurement conditions

Note The power consumption and performance figures described in this document were measured using Yocto Linux. Performance figures on systems running Android may differ.

Hardware used

The following hardware was used for the measurements:

- Device 1
  - ConnectCore 8X SOM
    - Variant 0x02: Industrial QuadXPlus 1.2GHz, 16GB eMMC, 2GB LPDDR4, -40/+85C, Wireless, Bluetooth
    - PN: 50001980-02 8P
    - SN: F2007001003075
  - ConnectCore 8X SBC Pro carrier board
    - Hardware version: 30015752-05
- Device 2
  - ConnectCore 8X SOM
    - Variant 0x0A: Industrial DualXZ 1.2GHz, 8GB eMMC, 1GB LPDDR4, -40/+85C
    - PN: 50001980-10 1P
    - SN: F203801000020
  - ConnectCore 8X SBC Pro carrier board
    - Hardware version: 30015752-05

Software used

Digi Embedded Yocto

The software used on the devices is the pre-built installer binary image for Digi Embedded Yocto 3.0-r2.4 release (md5sum: f8b276317dfba3a16b102c967bcc5946), available on the Digi support site.

To install the firmware, visit the documentation portal for your platform and follow the Get Started documentation.

After installing the firmware you can run **sysinfo** to verify the component versions:

Component	Version
U-Boot	dub-2020.04-r1.3+gb84d3443cc
Firmware	dey-3.0-r2-20201023151245
Kernel	5.4.64-dey+g8086dc5f8e29

MCA firmware

The firmware version used on the SOM during the tests is 1.0.

See the documentation for information on programming the MCA firmware.

Benchmark packages

A few additional packages with benchmark tools have been built and must be installed on the device after programming the firmware. Download these tools from the Digi FTP server.

Package	Description
coreutils	A set of system commands with more extended options than the ones in Busybox
coremark	CPU benchmark application (executable binary).
glmark2	GPU benchmark application.
iozone3	File system benchmark application.
iperf3	Network interfaces benchmark application.

Copy pre-built binary **coremark** directly to **/usr/sbin** on the target and give the application execution permissions.

```
~# chmod 755 /usr/sbin/coremark
```

To install RPM packages on the device, transfer the files to the target and then run for each package:

```
~# rpm -i <filename.rpm>
```

Host requirements

For the network tests your host system needs to have the **iperf3** tool. To install it:

```
~$ sudo apt-get install iperf3
```

General conditions

Location and environment

The power consumption and benchmark tests have been carried out at room temperature of 22ºC, 30% humidity.

The target sits on a table with no enclosure.

Instrumentation

The following instruments were used during the tests:

Qty	Instrument	Model	Details
1	Regulated power supply	RIGOL DP832	5V / 3A
1	Multimeter	FLUKE 8846A 6-1/2 Digit	
3	Multimeter	FLUKE 289 True RMS	

SOM power measurements

How to calculate SOM power

As depicted in the Power architecture diagram, current flows **into** the SOM through VSYS, VSYS2, and VCC_MCA.

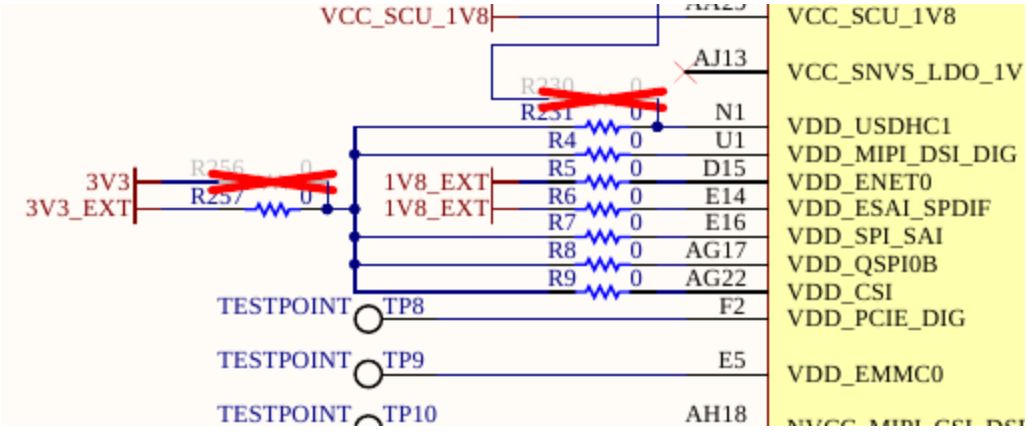
The power provided by the SOM to the carrier board peripherals through the 1V8_EX and 3V3_EXT power rails is application-specific and has been subtracted from the total input power to estimate the power consumed solely by the SOM.

Resistor swap

The 3V3_EXT power rail flows out of the SOM to power external circuitry, but it is also routed back to the SOM to power some of the SOC domains.

There is an optional resistor that can power these domains from the 3V3 power rail (instead of from 3V3_EXT), so that this power consumed by the SOM is properly taken into account.

1. Remove 0-ohm resistor R257.
2. Assemble 0-ohm resistor R256.



Console cable

The FTDI chip of the USB console cable introduces undesired voltage feedback to the CPU through the data lines. It must be disconnected to get accurate power measurements.

Measure points

The ConnectCore 8X SBC Pro has several 0-ohm shunt resistors for this purpose:

1. Remove R1 and connect an ammeter to measure the current flowing **in** through VSYS and VSYS2. Measure the voltage at this point too (~5V) to calculate the power more accurately.
2. Remove R2 and connect an ammeter to measure the current flowing **out** through 3V3_EXT. Measure the voltage at this point too (~3.3V) to calculate the power more accurately.
3. Remove R3 and connect an ammeter to measure the current flowing **out** through 1V8_EXT. Measure the voltage at this point too (~1.8V) to calculate the power more accurately.
4. Remove R31 and connect an ammeter to measure the current flowing **in** through VCC_MCA. Measure the voltage at this point too (~3.3V) to calculate the power more accurately.

Power	Measuring point	Power rail	Voltage	Direction with respect to SOM
P1	R1	VSYS + VSYS2	5V	In
P2	R2	EXT_3V3	3.3V	Out
P3	R3	EXT_1V8	1.8V	Out
P4	R31	VCC_MCA	3.3V	In

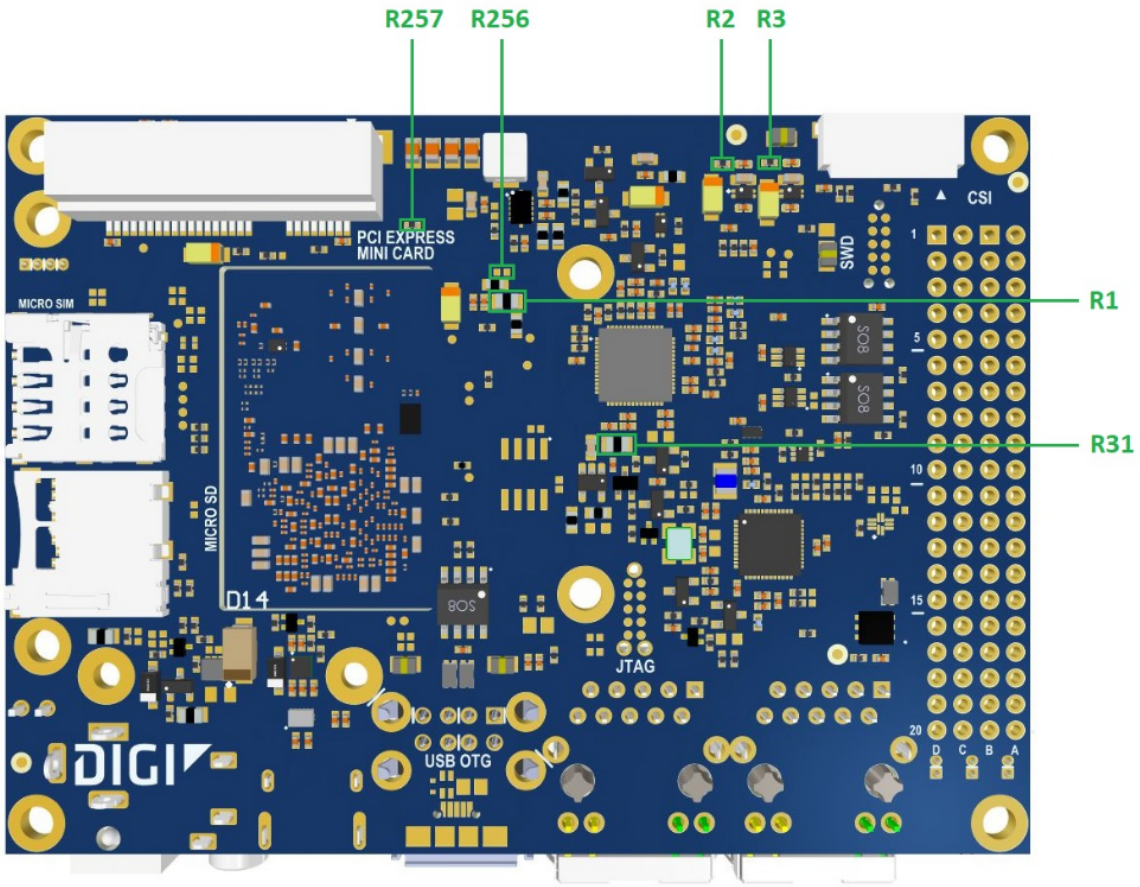
Formula

SOM power can be estimated as P1 - P2 - P3 + P4.

This is the closest estimation you can measure on the ConnectCore 8X SBC Pro. Note that part of EXT_1V8 power rail is routed back to the SOM to power some additional domains of the SOC (VDD_ENET0 and VDD_ESAI_SPDIF).

Resistors on ConnectCore 8X SBC Pro

All shunt resistors are located on the bottom side of the ConnectCore 8X SBC Pro:



Use cases

Digi measured power consumption of the ConnectCore 8X SOM in the following use cases:

- Low-power modes
  - Power-off
  - Suspend to RAM
  - System idle
- Active modes (I/O, video, audio, camera, network interfaces)

Note This chapter presents the power measurements for the low-power modes.

The next section, containing the performance benchmarks for different tests, presents the power measurements for the active modes beside each benchmark score.

Low-power modes

Power-off

To enter power-off mode, press the ON/OFF button of the carrier board for more than two seconds, or run:

```
~# poweroff
```

In this mode, the PMIC is switched off. Therefore, all power rails provided by the PMIC are disabled. The MCA is powered and in low-power mode. The MCA maintains the RTC system time and other low-power functionality, such as the capacity to wake from different sources (power button, RTC alarm, tamper pins, etc.)

SOM variant	SOM power
QuadXPlus	561 uW
DualXZ	575 uW

Suspend to RAM

To enter standby mode, press the ON/OFF button of the carrier board once, or run:

```
~# standby
```

In this mode, the system enters a low-power state where the CPU is halted and the content of the RAM is maintained (self-refresh mode). The state of the PMIC power rails is configurable (on/off/voltage) through the device tree. For this measurement, Digi used the default configuration, which disables the 3V3_EXT power domain when the SOM is suspended to RAM. In this state, the device can wake up from multiple wake-up sources (MCA and CPU peripherals).

SOM variant	SOM power
QuadXPlus	32 mW
DualXZ	20 mW *
** Tested with dey-3.0-r3 firmware*	

System idle

All power domains are active and the operating system will perform CPU frequency and voltage scaling according to the CPU load.

SOM variant	SOM power
QuadXPlus	2079 mW
DualXZ	2050 mW

Active modes

The Performance tests section, containing the performance benchmarks for different tests, presents the power measurements for active modes beside each benchmark score.

Performance tests

CPU

CoreMark

CoreMark is a benchmark tool specifically designed to test the functionality of a processor core. The test produces a single-number score in iterations per second.

Command

```
~# coremark
```

Results

Test	SOM variant	Score	Metric	SOM power	SOM temp
CoreMark	QuadXPlus	**13799**	iter./s	2800 mW	49 ºC
		2.60	CoreMark/MHz		
	DualXZ	**6865**	iter./s	1684 mW	43 ºC
		2.60	CoreMark/MHz		

Memory

perf-bench

perf-bench is a tool used to exercise and benchmark the RAM of the SOM.

Command: memset

```
~# perf bench -f simple mem memset -s 200MB
```

Command: memcpy

```
~# perf bench -f simple mem memcpy -s 200MB
```

Results

Test	SOM variant	LPDDR4 in SOM	Operation	Score	Metric	SOM power	SOM temp
perf-bench	QuadXPlus	SMIC 2GB LPDDR4 1.1V 32 bits 1600 MHz	memset	6730	MB/s	3560 mW	57 ºC
			memcpy	1475	MB/s	3360 mW	57 ºC
	DualXZ	SMIC 1GB LPDDR4 1.1V 16 bits 1600 MHz	memset	4044	MB/s	2251 mW	43 ºC
			memcpy	1113	MB/s	2181 mW	43 ºC

Note The DualXZ variant uses a 16-bit memory interface, while the QuadXPlus uses a 32-bit memory interface.

eMMC

IOzone3

IOzone3 is a file system benchmark tool that generates and measures a variety of file operations. The following test measures the file system performance on eMMC (vfat) media.

```
~# cd <mount-point-of-test-media>
~# iozone -i 0 -i 1 -b /tmp/iozone.xls -r 128k -s 2G -l 1 -u 1
```

The test:

- Runs write/rewrite (-i 0)
- Runs read/reread (-i 1)
- Uses a record size of 128k (-r 128 k)
- Uses a file size of 2 GB (-s 2 G)
- Runs on a single core (-u 1)

Results

Test	Media	SOM Variant	Media model	Operation	Score	Metric	SOM power	SOM temp
IOzone3	eMMC	QuadXPlus	SMIC 16GB eMMC 153FBGA	Read	266	MB/s	3196 mW	54 ºC

Test	Media	SOM Variant	Media model	Operation	Score	Metric	SOM power	SOM temp
				Write	64	MB/s		

USB

IOzone3

IOzone3 is a file system benchmark tool that generates and measures a variety of file operations. The following test measures the file system performance on USB 2.0 (vfat).

Command

```
~# cd <mount-point-of-test-media>
~# iozone -i 0 -i 1 -b /tmp/iozone.xls -r 128k -s 2G -l 1 -u 1
```

The test:

- Runs write/rewrite (-i 0)
- Runs read/reread (-i 1)
- Uses a record size of 128k (-r 128 k)
- Uses a file size of 2 GB (-s 2 G)
- Runs on a single core (-u 1)

Results

Test	Media	SOM Variant	Media model	Operation	Score	Metric	SOM power	SOM temp
IOzone3	USB 2.0	QuadXPlus	Transcend Information, Inc. JetFlash 16 GB 2.0	Read	16	MB/s	2642 mW	54 ºC
				Write	13	MB/s		
		QuadXPlus	USB3.0 to SATA: Samsung v-nan SSD 860 PRO	Read	33	MB/s	2500 mW	54 ºC
				Write	33	MB/s		
	USB 3.0	QuadXPlus	USB3.0 to SATA: Samsung v-nan SSD 860 PRO	Read	280	MB/s	3030 mW	54 ºC
				Write	143	MB/s		

Ethernet

Environment conditions

- Ethernet cable: 3 m CAT6 patch cable
- Gigabit switch model: D-Link DGS-108
- 10/100 switch model: D-Link DES-1008D

iPerf3

iPerf3 is a tool for active measurements of the maximum achievable bandwidth on IP networks.

Command (host)

```
~# iperf3 -s
```

Command (target)

```
~# iperf3 -c <server ip>
```

Results

Test	SOM variant	Interface	Network	Score send/receive	Metric	SOM power	SOM temp
iPerf3	QuadXPlus	ETH1	Gigabit	939 / 936	Mbits/sec	2994 mW	55 ºC
			10/100	95 / 94	Mbits/sec	2379 mW	52 ºC
		ETH2	Gigabit	940 / 937	Mbits/sec	2984 mW	54 ºC
			10/100	95 / 94	Mbits/sec	2399 mW	52 ºC

FTP

FTP is a protocol for file transfer over the network.

Command (target)

On the target side, allow access to user **root** (forbidden by default):

```
~# sed /root/d -i /etc/vsftpd.ftpusers
```

Generate a 1 GB file with random data.

```
~# dd bs=1M count=1024 if=/dev/urandom of=testfile && sync
```

Command (host): GET

On the host side, connect to the target via FTP (user: root, pass: root) and get the file:

```
~$ ftp -p <target_ip_address>
ftp> get testfile
```

Command (host): PUT

Send the file to the target

```
ftp> put testfile
```

Results

Test	SOM variant	Network	Operation	Score	Metric	SOM power	SOM temp
iPerf3	QuadXPlus	Gigabit	GET (target to host)	111	MB/s	2920 mW	52 ºC
			PUT (host to target)	65	MB/s	3819 mW	55 ºC
		10/100	GET (target to host)	11	MB/s	2364 mW	51 ºC
			PUT (host to target)	11	MB/s	2586 mW	52 ºC

Wi-Fi

Environment conditions

- Dual band antennas connected to both U.FL connectors
- Access point model: NETGEAR Nighthawk X6 R8000
- Distance from target to access point: 2 m (with no obstacles in between)

iPerf3

iPerf3 is a tool for active measurements of the maximum achievable bandwidth on IP networks.

Note Wi-Fi performance is subject to many variables which are difficult or impossible to control, such as the electromagnetic radiation present in the place where the test is carried out, the channel used for the test, etc.

This test was not performed in an isolated chamber.

Setup

To measure the performance of the wireless interface, Digi set up two scenarios: one with the target working in station mode (the target is connected to an access point), and other scenario as AP (the target is acting as an access point)

Station

The target is connected to an access point. The setup requires an auxiliary device (host) connected to the same network as the access point. Ideally, the auxiliary device is connected to the access point using a Cat6 cable.

Soft-AP

The target is acting like an access point. This setup requires an auxiliary device connected to the network created by the target. A mobile phone with the 5GHz band can be used with the iperf3 application.

Command (host)

```
~# iperf3 -s
```

Command (target)

```
~# iperf3 -c <server ip>
```

Results

Test	Mode	SOM variant	Band	Score send /receive	Metric	SOM power	SOM temp
iPerf3	Station	QuadXPlus	2.4 GHz (802.11b/g/n)	32 / 32	Mbits/sec	4434 mW	55 ºC
			5 GHz (802.11ac)	556 / 556	Mbits/sec	6143 mW	71 ºC
	Soft-AP	QuadXPlus	2.4 GHz (802.11b/g/n)	59/59	Mbits/sec	2946 mW	53 ºC
			5 GHz (802.11ac)	156/156	Mbits/sec	3486 mW	55 ºC

FTP

FTP is a protocol for file transfer over the network.

Command (target)

On the target side, allow access to user **root** (forbidden by default):

```
~# sed /root/d -i /etc/vsftpd.ftpusers
```

Generate a 1 GB file with random data.

```
~# dd bs=1M count=1024 if=/dev/urandom of=testfile && sync
```

Command (host): GET

On the host side, connect to the target via FTP (user: root, pass: root) and get the file:

```
~$ ftp -p <target_ip_address>
ftp> get testfile
```

Command (host): PUT

Send the file to the target:

```
ftp> put testfile
```

Results

Test	Mode	SOM variant	Band	Operation	Score	Metric	SOM power	SOM temp
FTP	Station	QuadXPlus	2.4 GHz (802.11b/g/n)	GET (target to host)	6.2	MB/s	4392 mW	68 °C
				PUT (host to target)	8.45	MB/s	3292 mW	65 °C
			5 GHz (802.11ac)	GET (target to host)	65	MB/s	5792 mW	70 °C
				PUT (host to target)	37	MB/s	4062 mW	68 °C

GPU

Environment conditions

- Full screen

Glmark2

Glmark2 runs a series of tests, rendering different kinds of 2D and 3D graphics and animations on the screen and then measures the output performance in terms of frames per second (fps). It then averages out the fps across all the tests to calculate a score for the GPU.

Command

```
~# glmark2-es2-wayland --fullscreen
```

Results

Test	Resolution	SOM variant	Interface	Score	Metric	SOM power	SOM temp
Glmark2	1280x800	QuadXPlus	LVDS0	554	Glmark2 score	3889 mW	64 °C
		DualXZ	LVDS0	270	Glmark2 score	2371 mW	47 °C

VPU

Environment conditions

- Full screen
- **Playback:**
  - Video files (video codec, audio codec)
    - You can find videos with different resolutions and format here: https://filesamples.com/categories/video
- **Recording**:
  - MIPI camera model: Pcam 5C Digilent
  - Video codecs
    - MOV H264

Gstreamer video playback (decoding)

This test plays videos with different codecs and measures the performance in frames per second (fps).

Command

```
~# gplay-1.0 <video-file>
```

Results

Test	Display resolution	SOM variant	Video codec	Audio codec	Video resolution	Score	Metric	SOM power	SOM temp
Gstreamer video playback (decoding)	1280x800	QuadXPlus	MOV H264	AAC surround	3840x2160 (UHDV/4K) *	24	fps	4020 mW	66 ºC
					2560x1440 (2K)	24	fps	3816 mW	65 ºC
			MOV H264		1920x1080 (Full-HD)	24	fps	3771 mW	64 ºC
					1280x720 (HD)	24	fps	3402 mW	58 ºC
			MOV H264		1920x1080 (Full-HD)	24	fps	2604 mW	52ºC
** Tested with dey-3.0-r3.2 firmware*									

Gstreamer video recording (encoding)

This test records videos from a camera and encodes them to a RAM-based file system. Score is represented as the average of the fps recorded in one minute.

Command

```
~# gst-launch-1.0 v4l2src device=/dev/video1 ! video/x-
raw,width=1920,height=1080 ! waylandsink
```

The command line considers the MIPI camera was detected as **/dev/video1**.
Parameters **width** and **height** are adjusted for each resolution.

Results

Test	SOM variant	Video codec	Video resolution	Score	Metric	SOM power	SOM temp
Gstreamer video recording (encoding)*	QuadXPlus	MOV H264	1920x1080 (Full-HD)	15	fps	2600 mW	48 ºC
			1280x720 (HD)	21	fps	2600 mW	48 ºC
** Tested with dey-3.0-r3.2 firmware*							

Audio

Environment conditions

- Playback audio files
  - WAV 44100 Hz, 16 bit, stereo
  - MP3 128 Kbps, 16 bit, stereo
- Recording audio files
  - WAV 44100 Hz, 16 bit, stereo
  - WAV 22050 Hz, 16 bit, stereo

Audio playback

This test plays audio files in different formats. The only score is the power consumption.
You can find sample audio files here: https://filesamples.com/categories/audio.

Command

```
/* Wav files */
~# aplay <file>
/* MP3 files */
~# gst-launch-1.0 filesrc location=<file> ! id3demux ! queue ! beepdec !
alsasink
```

Results

Test	SOM variant	Audio file	SOM power	SOM temp
Audio playback (decoding)	QuadXPlus	WAV 44100 Hz, 16 bit, stereo	2202 mW	50 ° C
		MP3 128Kbps, 16 bit, stereo	2272 mW	50 °C

Audio recording

This test records audio files in different formats. The only score is the power consumption.

Command

```
~# arecord -f cd sound.wav --duration 60
~# arecord -f S16_LE -c 2 -r22050 sound.wav --duration 60
```

Results

Test	SOM variant	Audio file	SOM power	SOM temp
Audio playback (decoding)	QuadXPlus	WAV 44100 Hz, 16 bit, stereo	2201 mW	50 °C
		WAV 22050 Hz, 16 bit, stereo	2216 mW	50 °C

Additional information

See the ConnectCore 8X documentation portal for additional information, including hardware reference manuals, comprehensive software documentation, links to design documents, and hardware compatibility reports.