From E-Paper Drivers to CRA Compliance: Open-EP Community's Upstream Journey

OSC-Nagoya 05/23/2026, Wig Cheng

Part 1

Open-EP: An Open E-Paper Community for Embedded Linux

About Me

Wig Cheng

@wigcheng

- Open-EP Community maintainer
- Linux/Android BSP Developer
- Open-Source Communities Contributor
  - AOSP
  - Linux Kernel Upstream
  - Open-EP(E-Paper), KAKIP, TOPST

Agenda

- Why the Open-EP community was created
- Current progress
- Future work

Why the Open-EP community was created

Pain points of e-paper in the market

- Most applications are not open source
- provide open-source solutions mostly support MCUs (like WAVESHARE)
- Too few open-source applications related to Linux.

Bus stop signs in Taiwan

Rakuten Kobo E-reader

Wireless electronic shelf labels at AEON in Nagoya

About Open-EP community

- Founded in December 2025
- In-house hardware design (all based on E-Ink panels)
- Fully open-source software
  - MPU: Linux User-Space program
  - **MPU: Linux Kernel DRM driver**
  - MCU: RTOS/Bare-Metal

Current Progress

Supported platforms

Raspberry Pi

[公式サポート]

Raspberry Pi 5
Raspberry Pi 2B
Raspberry Pi Zero 2W

NXP

[公式サポート]

ADLINK LEC-IMX95 (IMX95)
FRDM-IMX93 EVK
PANZER-PLUS (IMX8MP)

Renesas

[公式サポート]

KAKIP (RZ/V2H)
RZ/T2H EVK

Rockchip

[コミュニティ検証]

CUBE-RK3588 (RK3588)

Telechips

[コミュニティ検証]

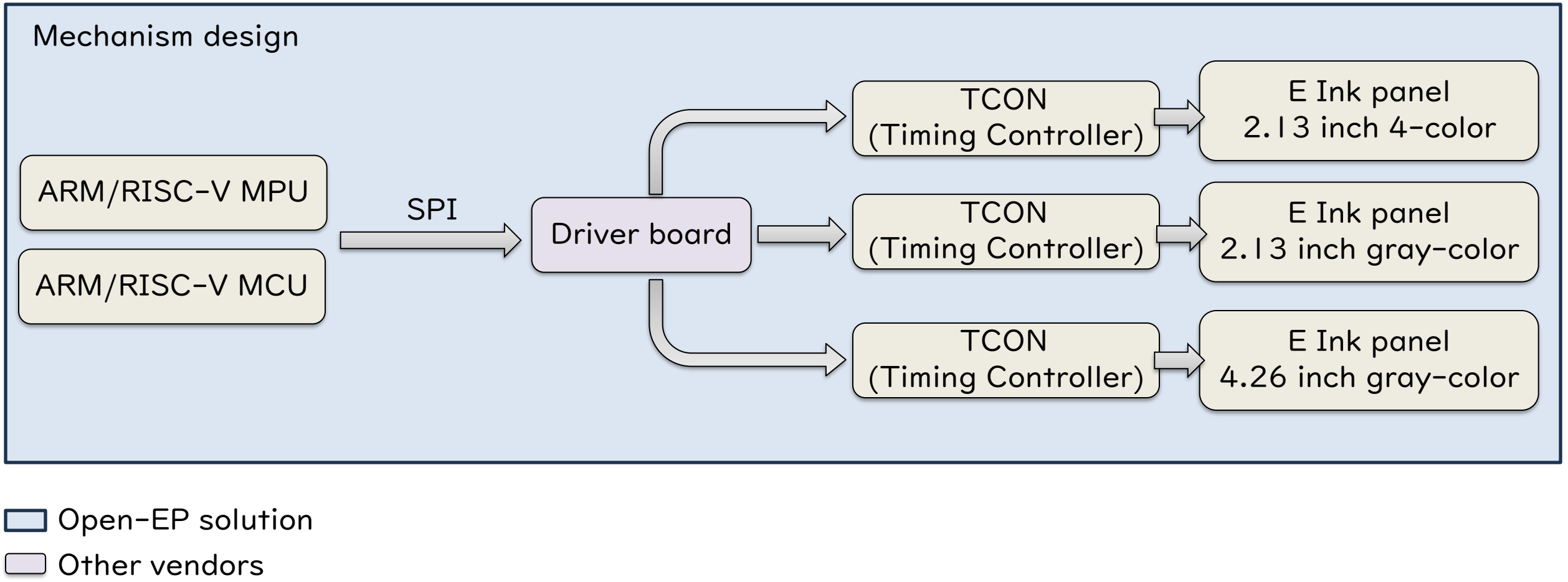
TOPST (D3-G)

STMicroelectronics

[コミュニティ検証]

STM32F1 series EVK

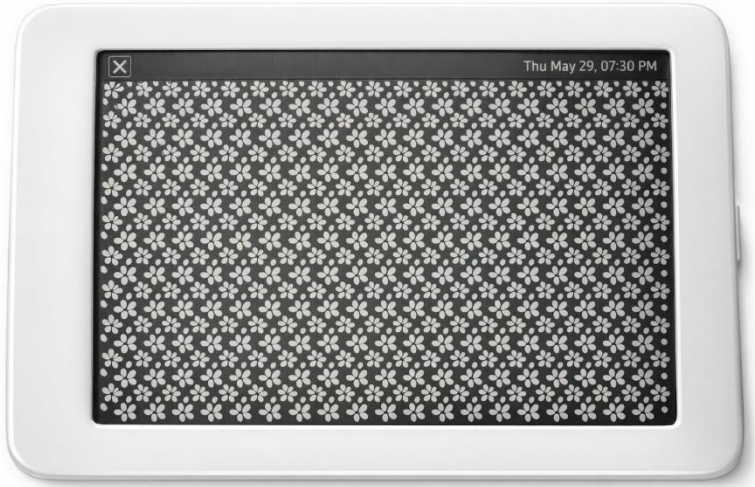
Hardware Architecture



Hardware Architecture (cont.d)

2.13 inch 4-color
PIXPAPER-213-C

2.13 inch gray scale
PIXPAPER-213-M



4.16 inch gray scale
PIXPAPER-426-M

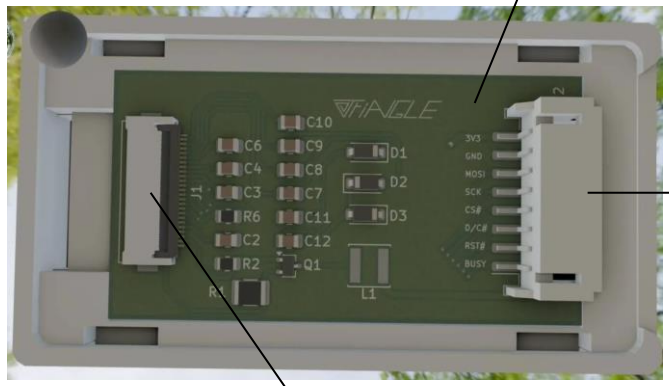
acrylic protective sheet

3D-printed enclosure

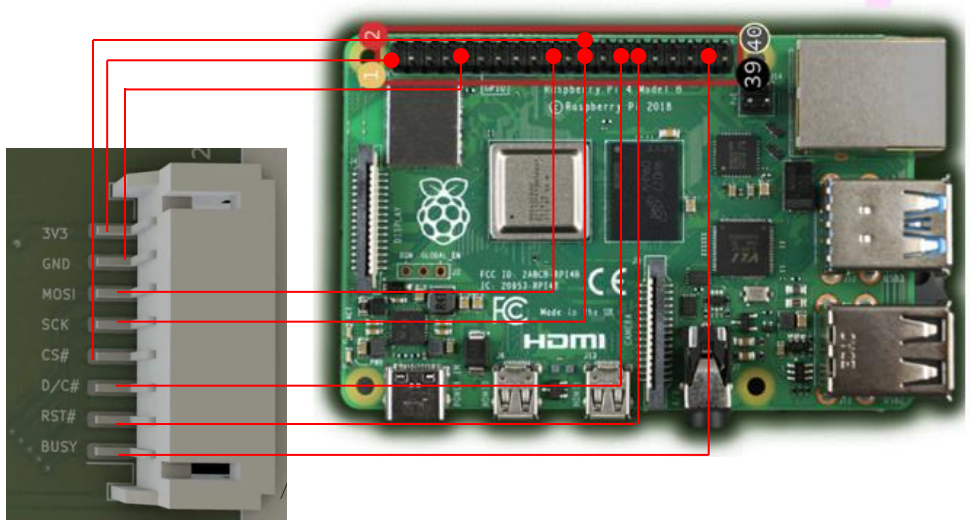
Driver board

SPI connector

Panel connector



User-Space Utilities (Linux)



Into low-power mode

Source Code

epd_init()

SoC
SPI + GPIO initialization

HW reset

TCON + E-paper
Registers initialization

epd_write_img()

CMD code: 0x10
Write data

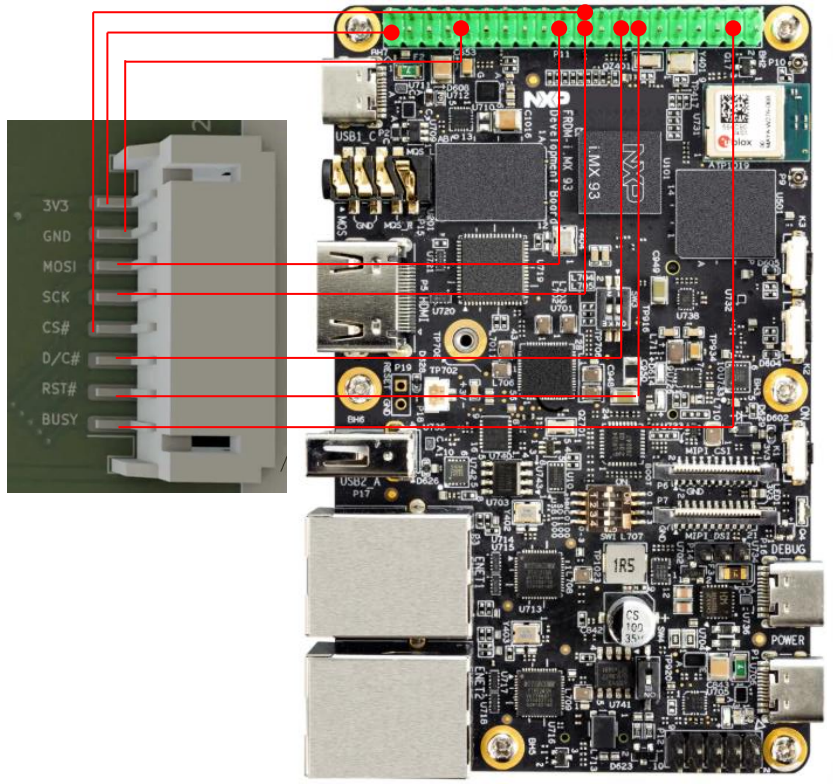
Load Image array
250x32 byte data

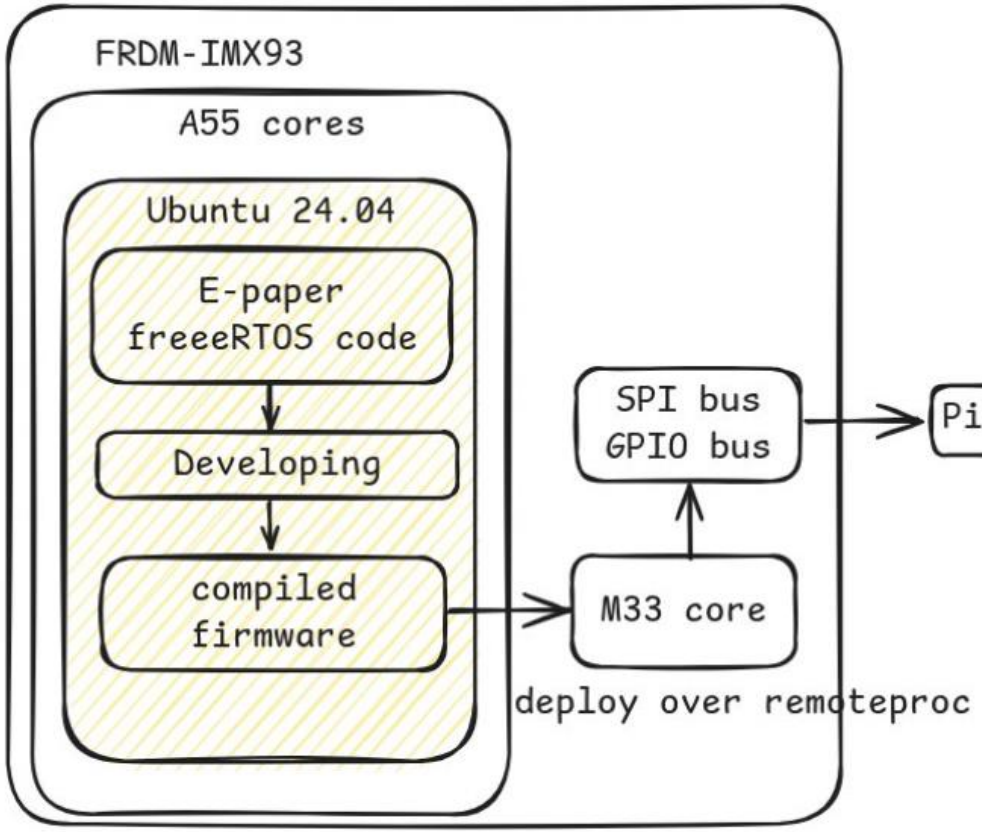
CMD code: 0x04 → 0x12
Power on and refresh panel

Python tool:
Transfer png to raw data

TCON memory space

User-Space Utilities (remoteproc RTOS)



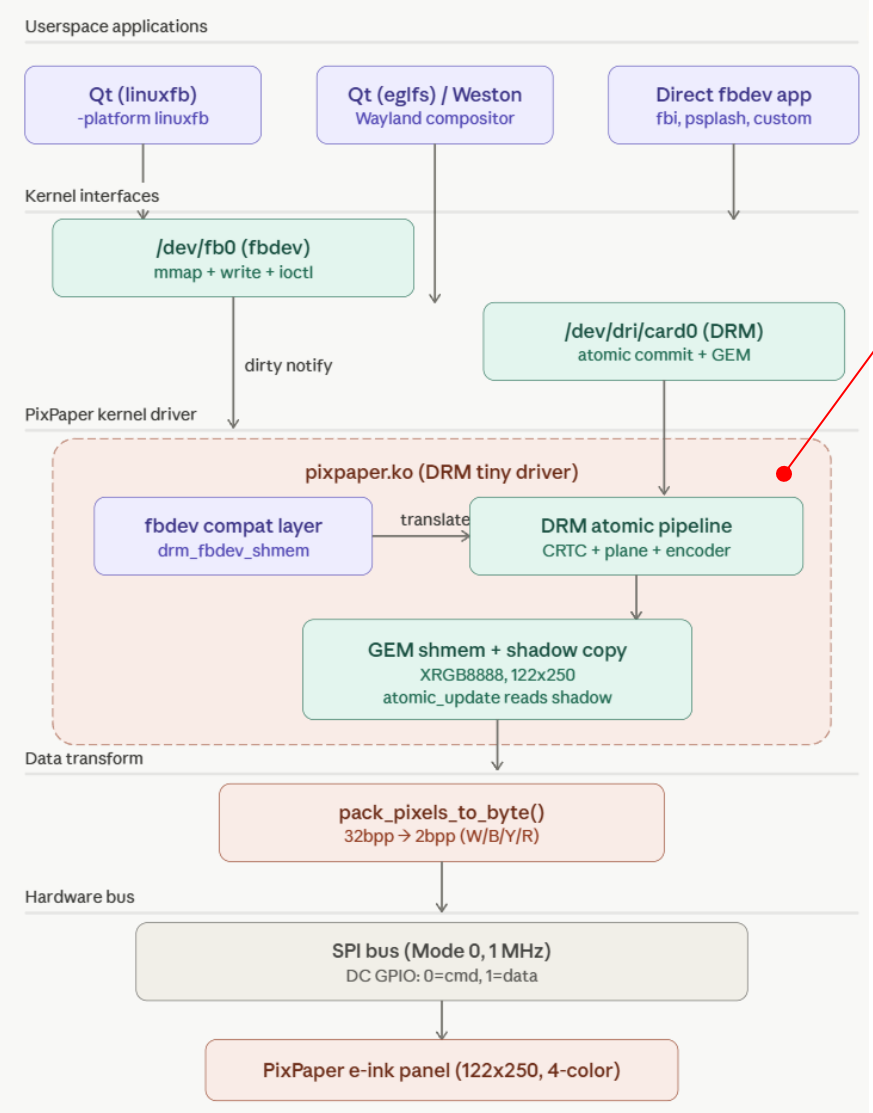


[Source Code]

Kernel-Space DRM driver

- Pros
  - Easy to change the display content (Especially text only)
  - As a primary panel, not just a display tag
  - Support more applications
- Cons
  - Big effort for driver implementation

Kernel-Space DRM driver



- Driver Author: LC Wang
  - Open-EP Github PR reviewer
  - Mainline DRM maintainer
- Release date: 2025/9/5
- Upstream: YES
- Presentation: COSCUP 2025

PIXPAPER-426-M example

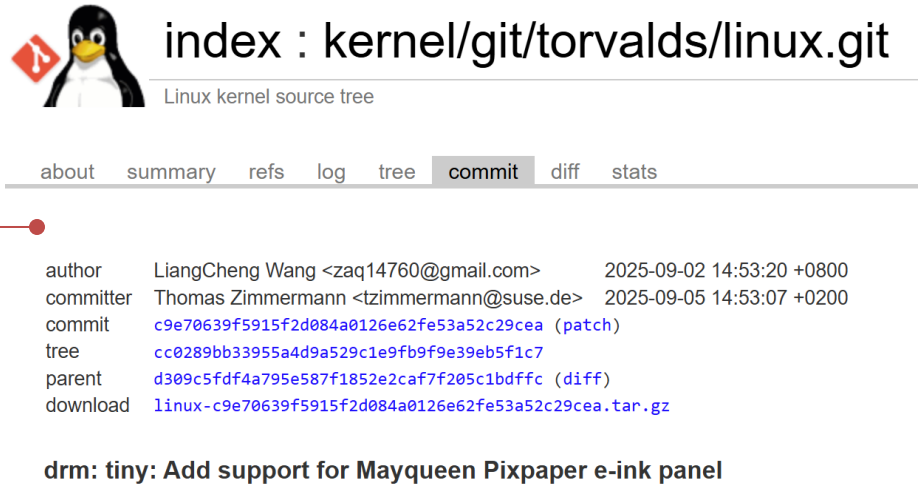
```
ubuntu@frdm-imx93:~$ ls /sys/class/drm/card0-SPI-1/status
/sys/class/drm/card0-SPI-1/status
ubuntu@frdm-imx93:~$
ubuntu@frdm-imx93:~$ cat  /sys/class/drm/card0-SPI-1/enabled
enabled
ubuntu@frdm-imx93:~$
ubuntu@frdm-imx93:~$ cat  /sys/class/drm/card0-SPI-1/connector_id
36
ubuntu@frdm-imx93:~$
ubuntu@frdm-imx93:~$ dmesg | grep pixpaper
[    2.550715] pixpaper-426m spi0.1: pixpaper_panel_hw_init: Starting hardware initialization
[    2.669351] pixpaper-426m spi0.1: Hardware reset complete, panel idle.
[    2.677480] pixpaper-426m spi0.1: pixpaper_panel_hw_init: Hardware initialization successful
[    2.686415] [drm] Initialized pixpaper 1.0.0 for spi0.1 on minor 0
[   77.137452] pixpaper-426m spi0.1: [drm] fb0: pixpaperdrmfb frame buffer device
ubuntu@frdm-imx93:~$
```

Mainline DRM driver

2025/09 (Kernel 6.18)
Pixpaer-213-C DRM driver be applied
Implementing DRM driver by contributor

2026/03 (Kernel 7.1)
FRDM-IMX93 does support Pixpaper-213-C
Implementing Device Tree Overlay file

2026/03 (Kernel 7.1)
KAKIP does support Pixpaper-213-C
Implementing Device Tree Overlay file



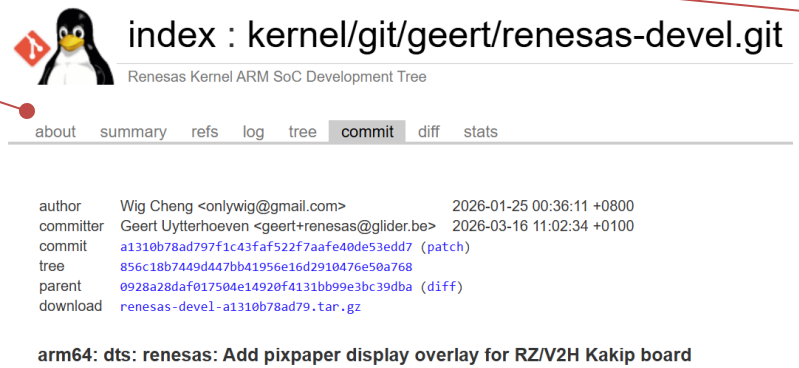
index : kernel/git/torvalds/linux.git

Linux kernel source tree

about summary refs log tree commit diff stats

author	LiangCheng Wang <zaq14760@gmail.com>	2025-09-02 14:53:20 +0800
committer	Thomas Zimmermann <tzimmermann@suse.de>	2025-09-05 14:53:07 +0200
commit	c9e70639f5915f2d084a0126e62fe53a52c29cea (patch)	
tree	cc0289bb33955a4d9a529c1e9fb9f9e39eb5f1c7	
parent	d309c5fdf4a795e587f1852e2caf7f205c1bdffc (diff)	
download	linux-c9e70639f5915f2d084a0126e62fe53a52c29cea.tar.gz	

drm: tiny: Add support for Mayqueen Pixpaper e-ink panel



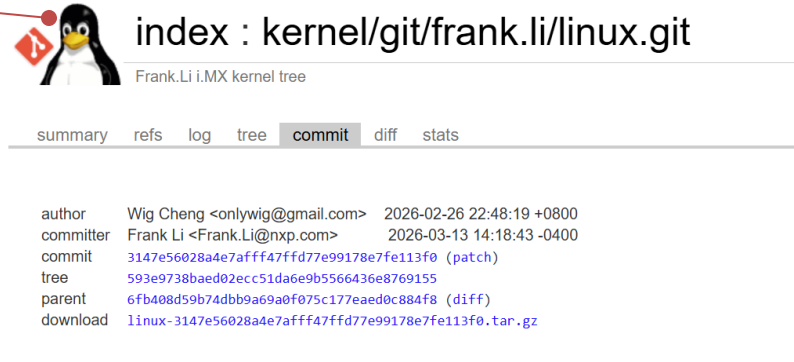
index : kernel/git/geert/renesas-devel.git

Renesas Kernel ARM SoC Development Tree

about summary refs log tree commit diff stats

author	Wig Cheng <onlywig@gmail.com>	2026-01-25 00:36:11 +0800
committer	Geert Uytterhoeven <geert+renesas@glider.be>	2026-03-16 11:02:34 +0100
commit	a1310b78ad797f1c43faf522f7aafe40de53edd7 (patch)	
tree	856c18b7449d447bb41956e16d2910476e50a768	
parent	0928a28daf017504e14920f4131bb99e3bc39dba (diff)	
download	renesas-devel-a1310b78ad79.tar.gz	

arm64: dts: renesas: Add pixpaper display overlay for RZ/V2H Kakip board



index : kernel/git/frank.li/linux.git

Frank.Li i.MX kernel tree

summary refs log tree commit diff stats

author	Wig Cheng <onlywig@gmail.com>	2026-02-26 22:48:19 +0800
committer	Frank Li <Frank.Li@nxp.com>	2026-03-13 14:18:43 -0400
commit	3147e56028a4e7afff47ffd77e99178e7fe113f0 (patch)	
tree	593e9738baed02ecc51da6e9b5566436e8769155	
parent	6fb408d59b74dbb9a69a0f075c177eaed0c884f8 (diff)	
download	linux-3147e56028a4e7afff47ffd77e99178e7fe113f0.tar.gz	

arm64: dts: freescale: add pixpaper display overlay for i.MX93 FRDM

Open-EP Text Sender

PixPaper EPD | Disconnected

DISPLAY TEXT

カーネル機能の変遷
BSD系UNIXが訴訟に巻き込まれて開発が停滞していたり、格好良い設計のHurd(マイクロカーネル型のPosix OS)がいつまで経っても、いつまで待っても完成しないでいる間に、Linuxカーネルは開発者を集めてどんどん進化を続けました。インターネットが丁度普及し始めたころというタイミングも開発を後押ししたように思います。

TEXT_RENDERER PARAMETERS

WIDTH (-W)	HEIGHT (-H)	FONT SIZE (-S)	FORMAT	FONT (-F)
800	480	30	rgba	./NotoSansCJK-B

OUTPUT (-O)

/dev/fb0

SERIAL CONNECTION

BAUD RATE	LINE ENDING
115200	LF (\n)

GENERATED COMMAND

```
$ ./text_renderer -t "カーネル機能の変遷\nBSD系UNIXが訴訟に巻き込まれて開発が停滞していたり、格好良い設計のHurd(マイクロカーネル型のPosix OS)がいつまで経っても、いつまで待っても完成しないでいる間に、Linuxカーネルは開発者を集めてどんどん進化を続けました。インターネットが丁度普及し始めたころというタイミングも開発を後押ししたように思います。" -f ./NotoSansCJK-Bold.ttc -w 800 -h 480 -s 30 --format rgba -o /dev/fb0
```

Connect Serial | Send to Board | Copy Command | Clear

COMMUNICATION LOG

```
[--:--:--] Open-EP Text Sender ready, waiting for connection... [23:57:49] Loaded example #3 [23:57:50] Loaded example #2
```

E-PAPER PREVIEW

カーネル機能の変遷
BSD系UNIXが訴訟に巻き込まれて開発が停滞していたり、格好良い設計のHurd(マイクロカーネル型のPosix OS)がいつまで経っても、いつまで待っても完成しないでいる間に、Linuxカーネルは開発者を集めてどんどん進化を続けました。インターネットが丁度普及し始めたころというタイミングも開発を後押ししたように思います。

23:57

800 × 480 font-size: 30px

QUICK EXAMPLES

- iMX93 FRDM — Multilingual Demo
- Kernel Evolution (Japanese)
- Kernel Development (Korean)
- Open-EP Intro (Chinese)

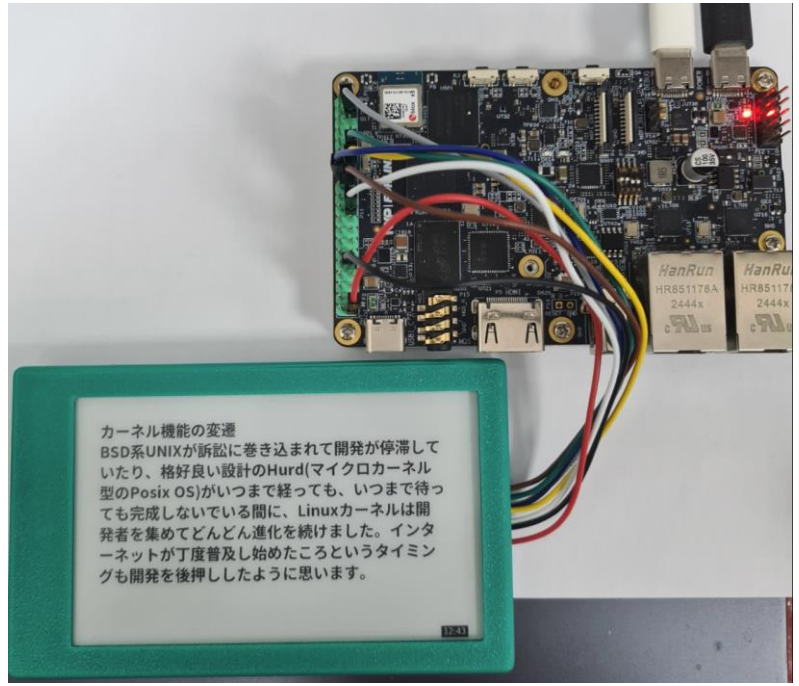
SHORTCUTS

Ctrl+Enter Send command
Ctrl+Shift+C Copy command

WebUI application from PC

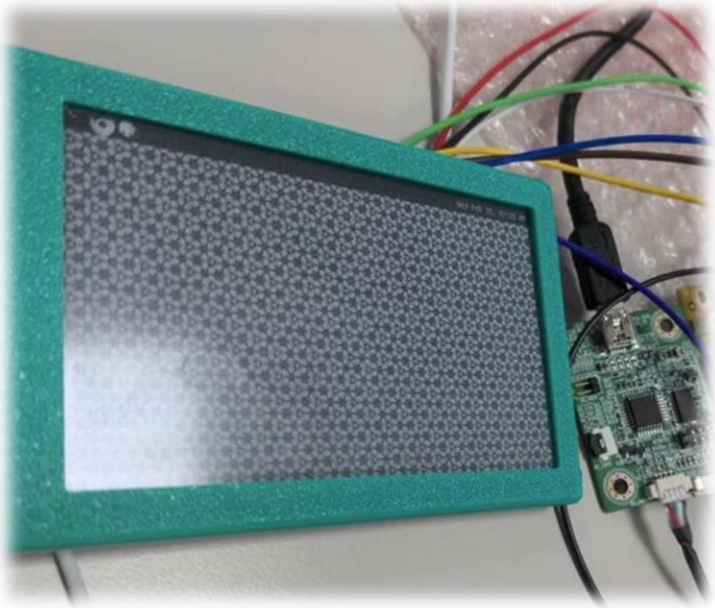
Debug console → Target board

DRM driver + SPI



Network-based update functionality will be added in the future.

Supported Operating System



Yocto 5.0 and above

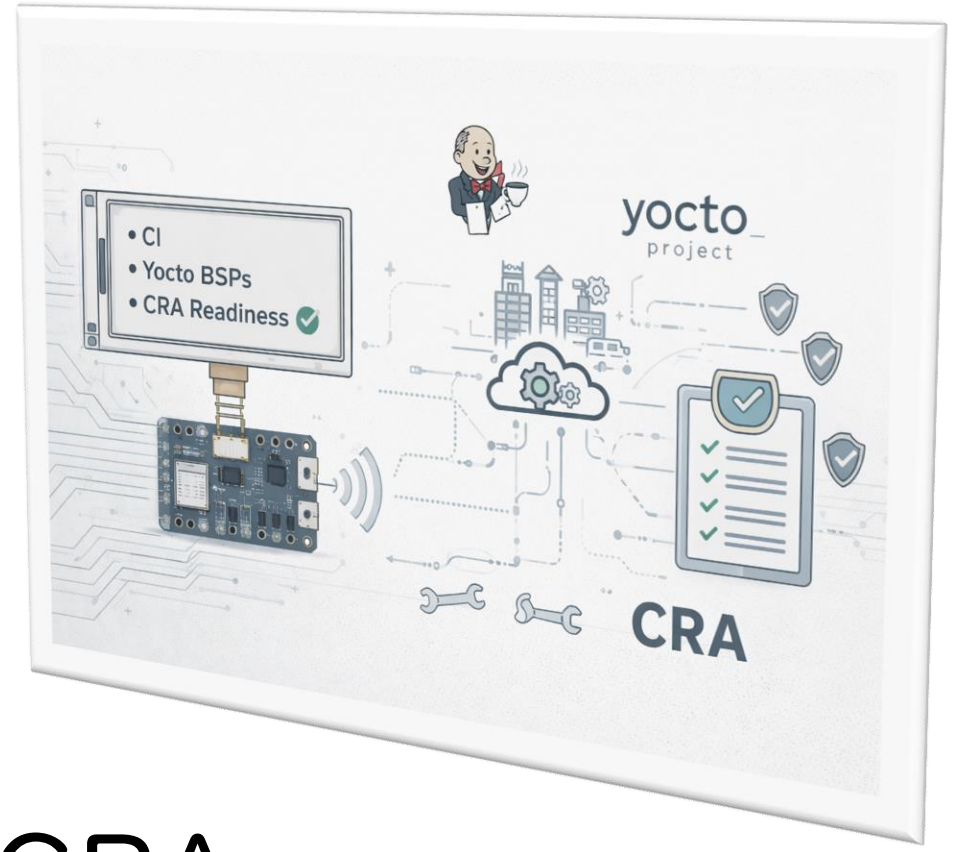
Android 15 and above

Ubuntu 24.04 ana above

Future work

Future work

- Support larger e-paper modules
- Wireless e-paper module coming soon (BLE 5.4)
- Support more mainline DRM driver for Open-EP e-paper modules
- Zephyr RTOS support
- Improved image update performance
- More contributors joining us



Part 2

CI, Yocto BSPs, and CRA Readiness

Co-author

Carolina Lin

@carolinalin

- IEI Integration Corp.
  - Cybersecurity Engineer in Linux BSP
- Yocto BSP Developer
- Open-EP contributor

Agenda

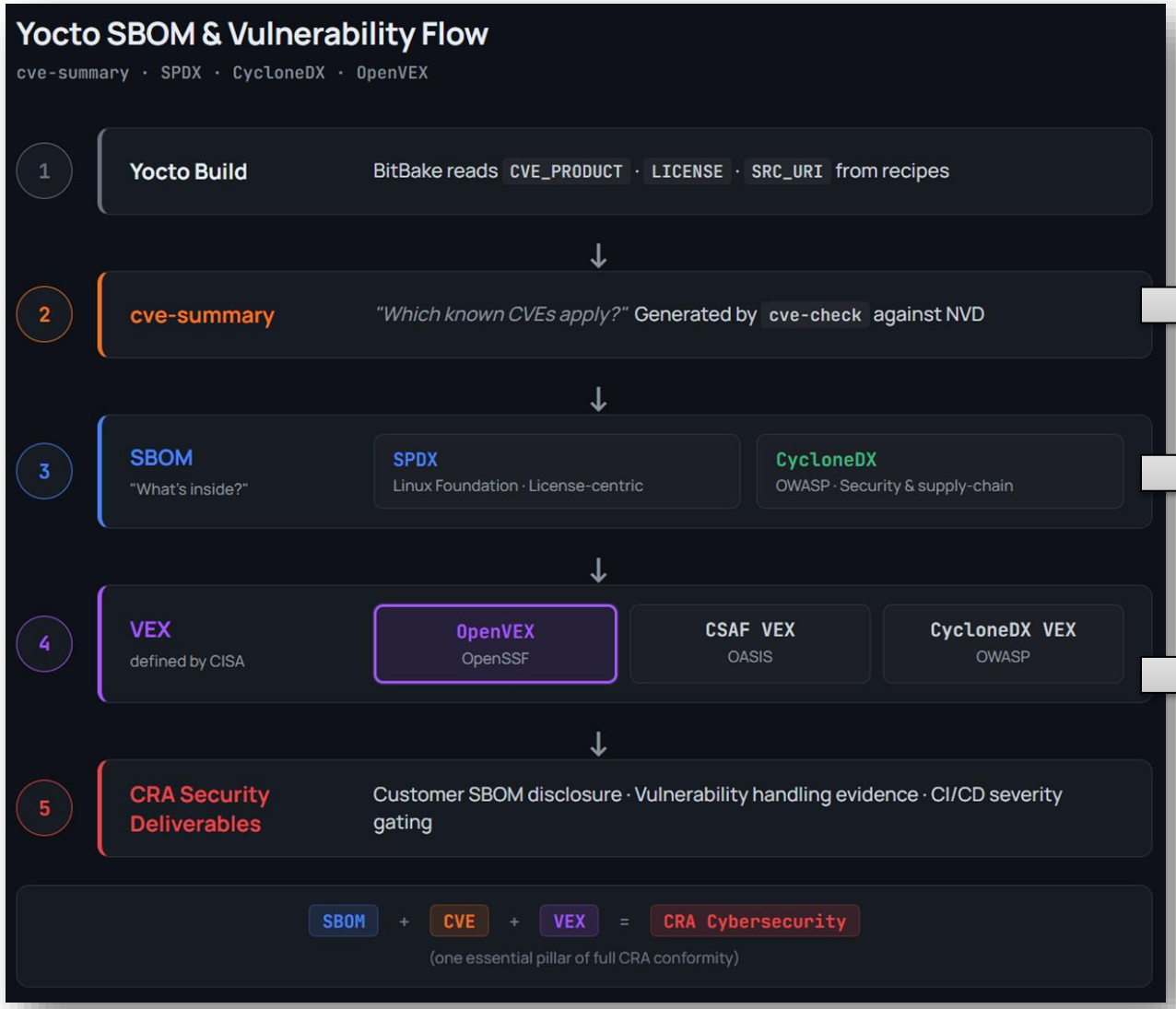
- Overview Cyber Resilience Act (CRA)
- Case study
- Vulnscout and CI integration
- Summary and future work

Cyber Resilience Act (CRA)

- EU regulation by the European Union for cybersecurity of connected products
- Relevance to Linux BSP
  - BSP must ensure secure kernel, drivers, and boot chain
  - Ongoing security patching (CVE fixes) is mandatory
  - Requires Software Bill of materials (SBOM) and vulnerability tracking for open-source components (e.g., Linux)
  - Enforces update mechanisms (OTA) and long-term maintenance
  - Impacts Yocto / embedded Linux development workflows

- The Cyber Resilience Act entered into force on 10 December 2024.
- The main obligations introduced by the Act will apply from 11 December 2027.

Software Bill of materials (SBOM)



yocto PROJECT

Yocto configuration file:
#CVE
INHERIT += "cve-check"

Yocto configuration file:
#SPDX
INHERIT += "create-spdx"
#CycloneDX
INHERIT += "dependency-track"

The tool that is independent of Yocto

SPDX, CycloneDX, and OpenVEX are all **JSON-based** formats, with differences in the type of information they capture.

SBOM (cont.d)

Yocto version	Codename	Release date	Default SPDX	Comments
4.0	Kirkstone (LTS)	2022-05 ~ 2026-04	SPDX 2.2	First native support for SPDX
5.0	Scarthgap (LTS)	2024-04 ~ 2028-04	**SPDX 2.2**	Starting from 5.0.14, *create-spdx-3.0.bbclass* is also provided, but it is not enabled by default
5.2	Walnascar	2025-05 ~ 2025-10	**SPDX 3.0**	Starting from 5.1, SPDX 3.0 is the default
5.3	Whinlatter	2025-12 ~ 2026-5	SPDX 3.0	SPDX 2.2 is still retained and continues to be maintained. # command: INHERIT += "create-spdx-2.2"
6.0	Wrynose	2026-04 ~ 2030-04	SPDX 3.0	TBC

CVE Vulnerability

SECURITY FUNDAMENTALS

What is a CVE Vulnerability?

CVE = Common Vulnerabilities and Exposures

A standardized identifier for publicly disclosed security vulnerabilities

Maintained by MITRE, sponsored by CISA · format: `CVE-YYYY-NNNNN`

HOW IT'S SCORED

CVSS	Severity 0.0–10.0
	Low 0.1–3.9 · Med 4.0–6.9 · High 7.0–8.9 · Crit 9.0–10
EPSS	Exploit probability (next 30 days)
KEV	CISA's actively exploited list

DON'T CONFUSE

Vuln	The underlying weakness in code
CVE	The public ID for that weakness
Exploit	Code that abuses the weakness
CNA	Authority that assigns CVE IDs (e.g., Linux kernel, NXP, Red Hat)

WHY IT MATTERS FOR EMBEDDED / BSP

A typical Yocto image contains **200–400 packages** → hundreds of potential CVEs at any time. **EU CRA** mandates vulnerability handling across the full product lifecycle — detection alone isn't enough; CVEs must be triaged with **VEX** to filter false positives.

Special thanks to Yocto Project Virtual Summit 2025 for introducing us to Vulnscout, a powerful tool designed specifically for CVE vulnerability scanning in Yocto.

VulnScout.io

CVE scan using Vulnscout

VulnScout · SBOM Vulnerability Scanning & Assessment

savoirfairelinux/vulnscout · primary input: Yocto cve-check JSON

INPUTS

cve-check.json
Yocto INHERIT += "cve-check"

SPDX 2.3 / 3.0
create-spdx bbclass

CycloneDX 1.4-1.6
meta-dependencycheck (optional)

→

ENGINE

VulnScout

Docker · :7275

1 Parse SBOM & CVE

2 Scan with Grype

3 Enrich (NVD · EPSS)

4 Triage & assess

→

OUTPUTS

OpenVEX
vulnerabilities + assessments

Enriched SBOM
SPDX 3.0 / CycloneDX 1.6

Reports
PDF · HTML · AsciiDoc · CSV

DATA SOURCES ↑ NVD · EPSS · Grype DB · OSV (planned)

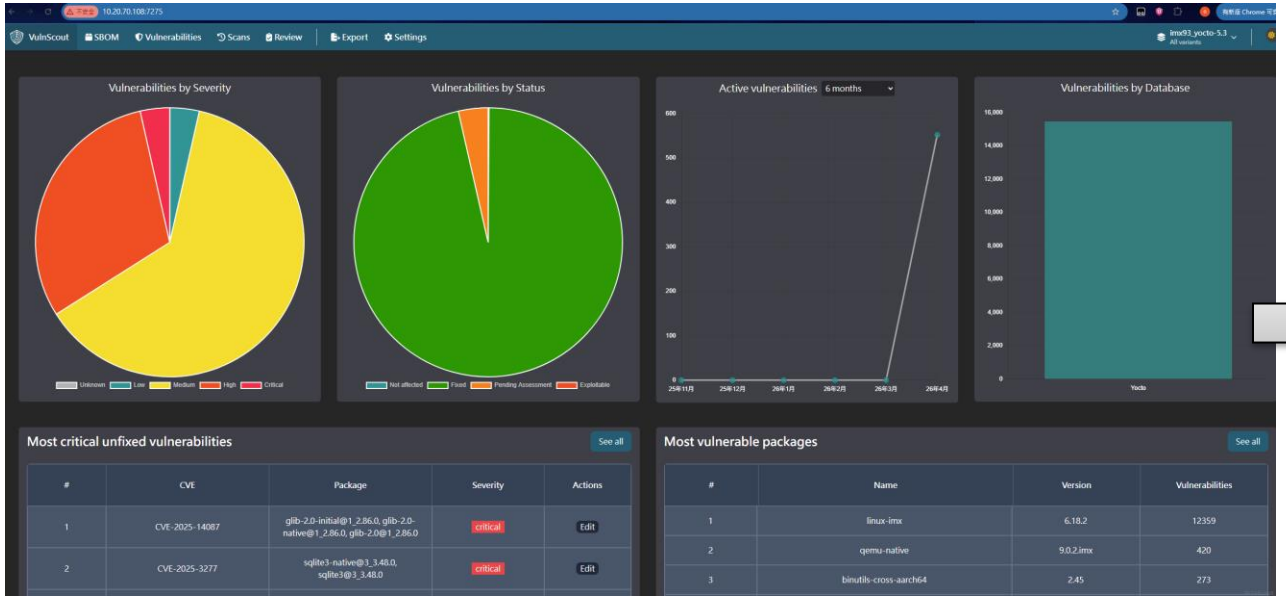
UI Interactive Mode

Web dashboard at `localhost:7275`
Manual triage · annotate · export VEX

CI Non-Interactive (CI/CD)

`--fail_condition "cvss ⩾ 9.0 or epss ⩾ 50%"`
Gate the build pipeline

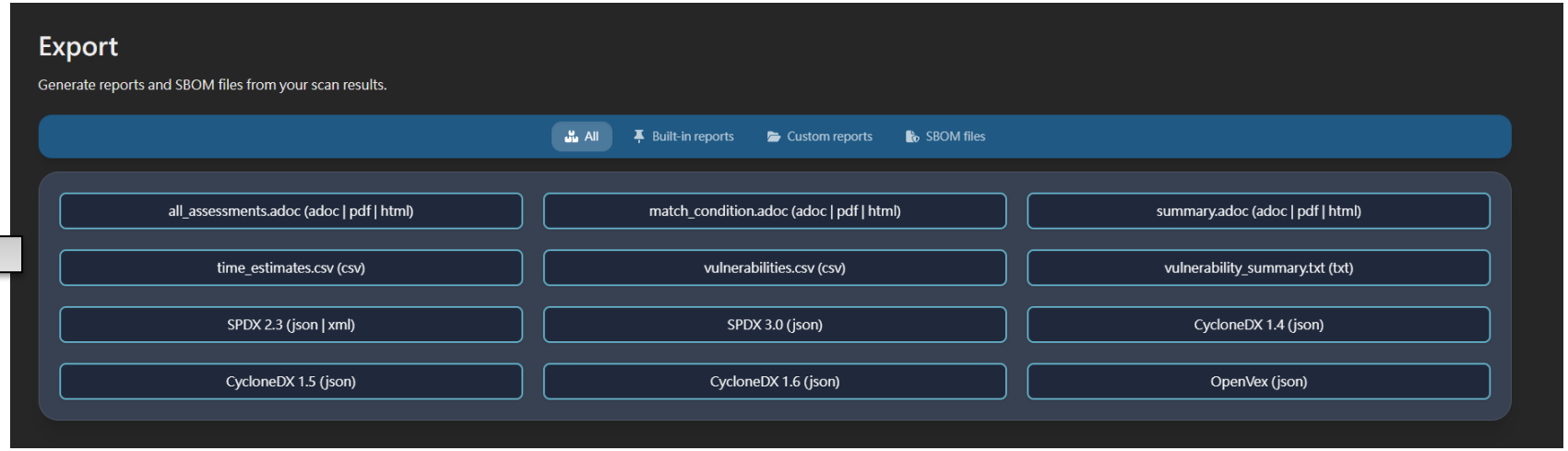
Vulnscout (cont.d)



After importing the cve-check-summary.json file, you can scan and analyze various statistics of this BSP, including real-time queries for EPSS and CVSS scores.

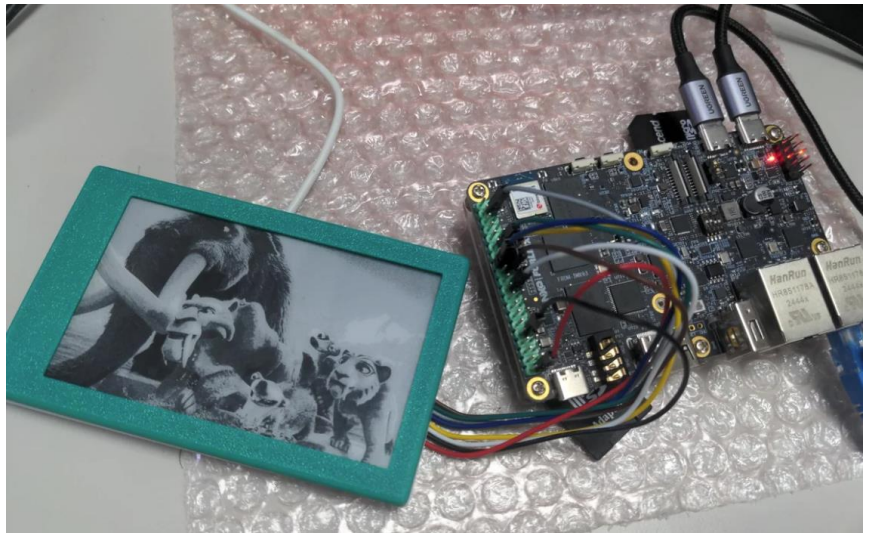
Export format:

- CVE report
- SPDX 2.3, 3.0
- CycloneDX 1.4, 1.5, 1.6
- OpenVex



Scenario 1

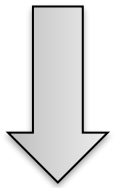
- NXP IMX93 Platform
- PIXPAPER-426-M (gray-scale), SPI interface
- Yocto 5.3 with vendor Kernel 6.18.2
  - own meta-layer



Yocto scan results

```
$ MACHINE=imx93-11x11-lpddr4x-frdm
DISTRO=fsl-imx-wayland source ./imx-setup-
release.sh -b build-imx93-pixpaper

$ bitbake core-image-weston
```



Input cve-check output json file to vulnscout server

```
$ sudo ./vulnscout --project imx93_yocto-5.3 --
add-cve-check
/home/wig/workspace/sbom/vulnscout/cve-
summary-20260411234547.json --serve
```

Summary

Number of vulnerabilities found: **15458**

Number of vulnerabilities present in this report: **15458**

They are classified as follow: CVSS

Status	Critical	High	Medium	Low	Unknown	Total
Pending investigation	5	153	381	13	0	**552**
Confirmed and exploitable	0	0	0	0	0	**0**
Fixed	538	4549	9267	532	3	**14889**
Ignored or false positive	4	3	10	0	0	**17**

Most critical vulnerabilities

The following list use EPSS ranking to outline the vulnerabilities which are most used. The EPSS ranking is a metric that takes into account the number of known exploits, the ease of exploitation, the impact of the vulnerability, and the availability of a fix.

Zero critical vulnerabilities

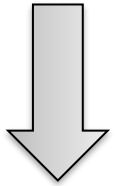
Scenario II

- Rockchip RK3588 Platform
- PIXPAPER-426-M (gray-scale), SPI interface
- Yocto 5.0 with vendor Kernel 6.1.75
  - own meta-layer

Yocto scan results

```
$ MACHINE=opi5-rk3588 DISTRO=openep-wayland source openep-rk-setup-release.sh

$ bitbake core-image-weston
```



Input cve-check output json file to vulnscout server

```
$ sudo ./vulnscout --project rk3588_yocto-5.0 --add-cve-check /home/wig/workspace/sbom/vulnscout/cve-summary-20260410203518.json --serve
```

Summary

Number of vulnerabilities found: **16649**

Number of vulnerabilities present in this report: **16649**

They are classified as follow: CVSS

Status	Critical	High	Medium	Low	Unknown	Total
Pending investigation	23	1331	3346	44	0	**4744**
Confirmed and exploitable	0	0	0	0	0	**0**
Fixed	719	3619	6871	629	2	**11840**
Ignored or false positive	7	24	30	4	0	**65**

1. CVE-2024-1086 (High) - EPSS: 84.47 %
2. CVE-2023-0386 (High) - EPSS: 59.16 %
3. CVE-2023-44466 (High) - EPSS: 13.17 %
4. CVE-2024-53104 (High) - EPSS: 13.02 %
5. CVE-2023-3338 (Medium) - EPSS: 11.23 %
6. CVE-2023-5178 (High) - EPSS: 8.36 %

6 critical vulnerabilities

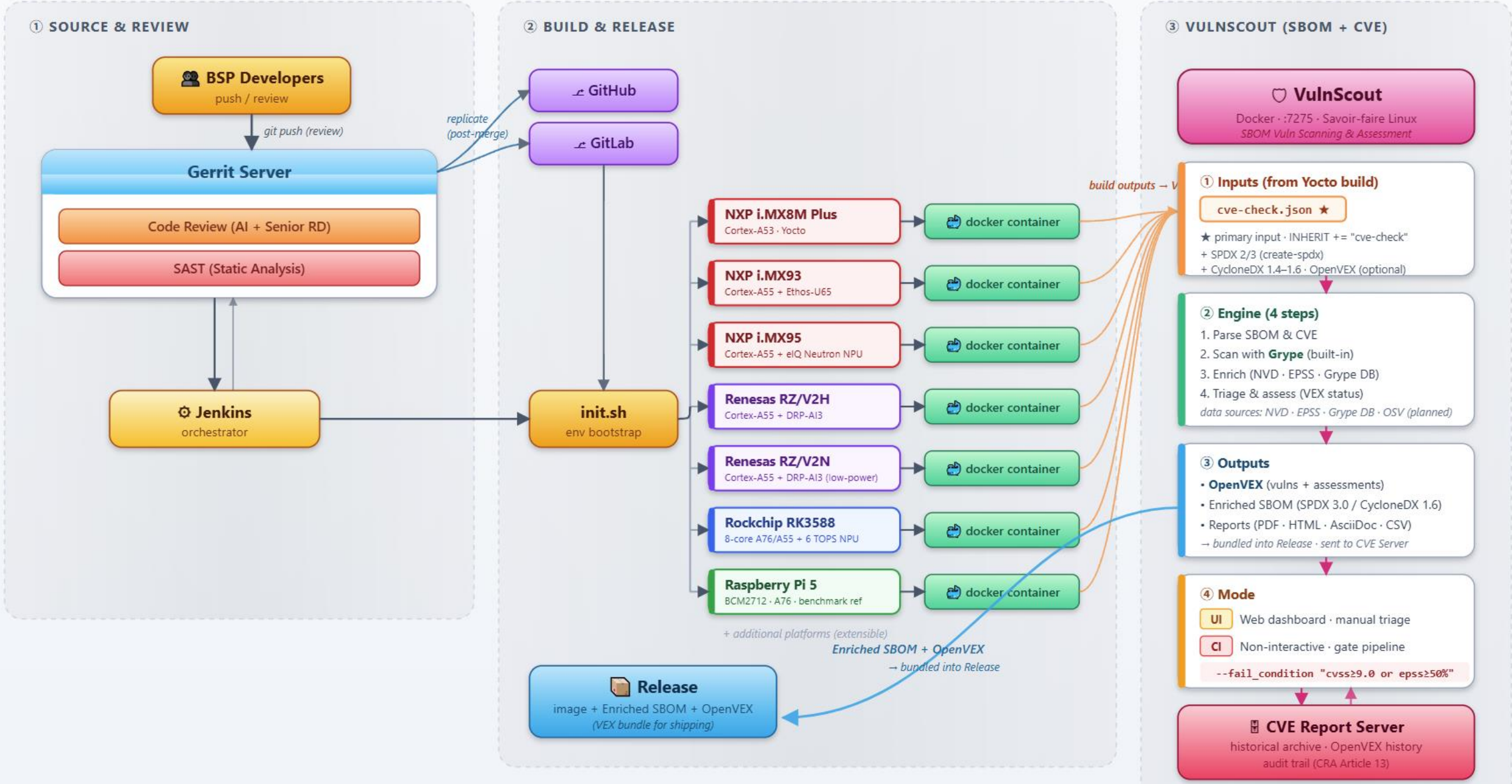
Vulnscout with CI mode

```
sudo docker run --rm –v /home/carolinalin:/scan/input  -v
/home/carolinalin/vulnscout/output:/scan/outputs sflinux/vulnscout:latest
--project imx93_yocto-5.3
--add-cve-check /scan/input/cve-summary-20260421121806.json
--export-cdx --export-spdx --export-openvex
--match-condition "((cvss >= 9.0 or (cvss >= 7.0 and epss >= 30%)) and (pending == true or affected
== true))"
```

	Web mode	CI mode
Trigger	Runs on demand	Jenkins/Gitlab CI
Key flag	--serve (default web UI)	--match-condition
Use case	Manual triage	Automated build pipeline gate
Best for	Triage, root-cause analysis	Nightly build, release gating
CRA/Audit	Manual collection	Auto-archived per build

BSP CI/CD Pipeline with VulnScout SBOM & CVE Workflow

Source → Review → Build → VulnScout → Release



Summary and future work

Summary: Vendor BSP vs Mainline BSP

Trade-offs between vendor support and long-term maintainability

Vendor BSP

Pre-integrated SoC vendor BSP

PROS

+ **Day-1 hardware support**
  NPU, ISP, GPU, codec, secure enclave validated
+ **Faster time-to-market**
  Reference designs, demo images, BSP guides
+ **Vendor support channel**
  FAE access, community forums, escalation path
+ **Production middleware**
  eIQ / DRP-AI, V4L2 plugins, Android HAL, OP-TEE
+ **Pre-certified components**
  Wi-Fi / BT / Widevine / FCC / CE bundles

CONS

– **Locked to old kernel**
  Stuck on 5.4 / 5.10 / 6.6 LTS for years
– **Heavy out-of-tree patches**
  Rebase pain; thousands of vendor-only patches
– **Slow CVE / security updates**
  Backports lag mainline; some BSPs frozen entirely
– **CRA / SBOM compliance burden**
  Vendor binaries (firmware, TA) hard to scan
– **Vendor lock-in**
  BSP-specific deps leak into application layer
– **Closed-source blobs**
  GPU firmware, NPU runtime, codec libs proprietary

Mainline BSP

Upstream Kernel · Yocto

PROS

+ **Latest kernel, long-term maintainable**
  Track mainline 6.x / 7.x; upstream fixes flow in
+ **Fast CVE response**
  linux-stable patches in days, not months
+ **CRA / SBOM friendly**
  Clean provenance, accurate SBOMs, fewer blobs
+ **Vendor-independent**
  Same codebase across SoCs; multi-vendor strategy
+ **Upstream contribution path**
  Merge improvements; community shares maintenance

CONS

– **Hardware feature gap**
  NPU, ISP, codec lag mainline by 1-3 years
– **Higher engineering effort upfront**
  DT overlays, drivers, integration glue you write
– **Needs deep kernel expertise**
  DT bindings, subsystems, upstream process
– **No vendor accountability**
  No SLA; debug yourself or ask the community
– **Performance / power gap**
  Missing vendor tuning (DDR, thermal, power)
– **Yocto layer assembly work**
  Combine community layers, resolve conflicts yourself

Future work

- Upgrade to Yocto 6.0 BSP
- Transition to a mainline BSP or align with the CRA-compliant vendor BSP
- Drop and phase out the legacy vendor BSP

	Mainline BSP	Vendor BSP
NXP IMX8MP, IMX93, IMX95	YES	Yocto 5.3 with Kernel 6.18
Renesas RZ/V2H, RZ/V2N	YES	Yocto 5.0 with CIP Kernel 6.1
Raspberry PI Series	YES	No
Rockchip RK3588	YES	Yocto 5.0 with Kernel 6.1
Telechips D3-G	NO	Yocto 4.0 with Kernel 5.10

Thanks for your time