Retrospective Sprint V

Team 04

driva!pi

Sprint V Goal

Establish robust **Unit Testing (including Code Coverage and Static Analysis)** for the core STM32 firmware logic, and validate the performance of the data pipeline by modeling and measuring latency through the **KUKSA Vehicle Signal Specification (VSS) Data Broker**.

OSS VERIFICATION TOOLCHAIN STRATEGY

Why Open-Source Over Commercial Solutions?

Commercial Tools Discarded: VectorCAST, Parasoft, Helix QAC, Polyspace

OSS VERIFICATION TOOLCHAIN STRATEGY

A Unit Testing Framework & Mocking

Unity + CMock
Pure ANSI C, Minimal footprint, Auto-generated mocks for ThreadX RTOS

cargo test
Native Cargo integration, Deterministic host execution

⚠ Why NOT Google Test (GTest)?
C++ runtime overhead unsuitable for pure C embedded

B Static Analysis & Security (SAST)

CodeQL (Core)
Deep flow-of-data analysis, MISRA C/C++, AUTOSAR C++14, Formal compliance gating

Clang-Tidy + Clippy (Complementary)
Developer-facing quality checks, Clang-Tidy for C/C++, Clippy for Rust idioms

Unified Standards Enforcement — ISO 26262 compliance

C Code Coverage & Quality Metrics

gcovr / lcov (C/C++) and grcov (Rust): Branch Coverage → MC/DC (ASIL-D), Unified in SonarQube

MC/DC progression for ASIL-D compliance

OSS VERIFICATION TOOLCHAIN STRATEGY

LCOV - code coverage report

			Hit	Total	Coverage
Current view:	top level				
Test:	DrivaPi - Unified Test Coverage	**Lines:**	230	230	100.0 %
Date:	2025-12-19 09:41:31	**Functions:**	34	34	100.0 %

Directory	Line Coverage		Functions	
/home/sheila/Desktop/drivapi/tests/unit/speed_sensor/src	100.0 %	37 / 37	100.0 %	2 / 2
src	100.0 %	193 / 193	100.0 %	32 / 32

Generated by: LCOV version 1.14

LCOV - code coverage report

			Hit	Total	Coverage
Current view:	top level - /home/sheila/Desktop/drivapi/tests/unit/speed_sensor/src				
Test:	DrivaPi - Unified Test Coverage	**Lines:**	37	37	100.0 %
Date:	2025-12-19 10:39:38	**Functions:**	2	2	100.0 %

Filename	Line Coverage		Functions	
speed_sensor.c	100.0 %	37 / 37	100.0 %	2 / 2

Generated by: LCOV version 1.14

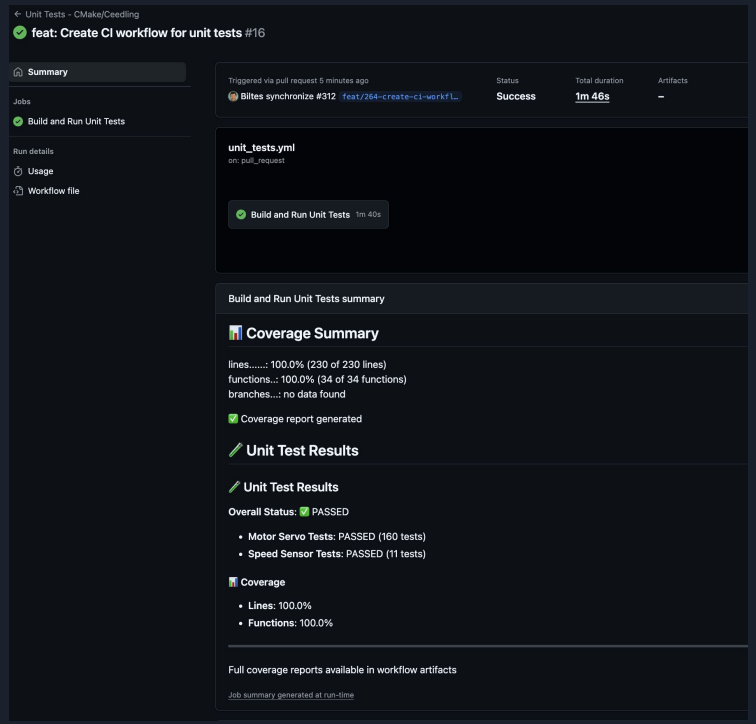
LCOV - code coverage report

			Hit	Total	Coverage
Current view:	top level - src				
Test:	DrivaPi - Unified Test Coverage	**Lines:**	193	193	100.0 %
Date:	2025-12-19 10:39:38	**Functions:**	32	32	100.0 %

Filename	Line Coverage		Functions	
dc_motor_functions.c	100.0 %	29 / 29	100.0 %	8 / 8
dc_motor_testable.c	100.0 %	100 / 100	100.0 %	8 / 8
pca9685_testable.c	100.0 %	8 / 8	100.0 %	1 / 1
servo_functions.c	100.0 %	22 / 22	100.0 %	6 / 6
servo_motor_testable.c	100.0 %	12 / 12	100.0 %	2 / 2
speed_sensor_functions.c	100.0 %	22 / 22	100.0 %	7 / 7

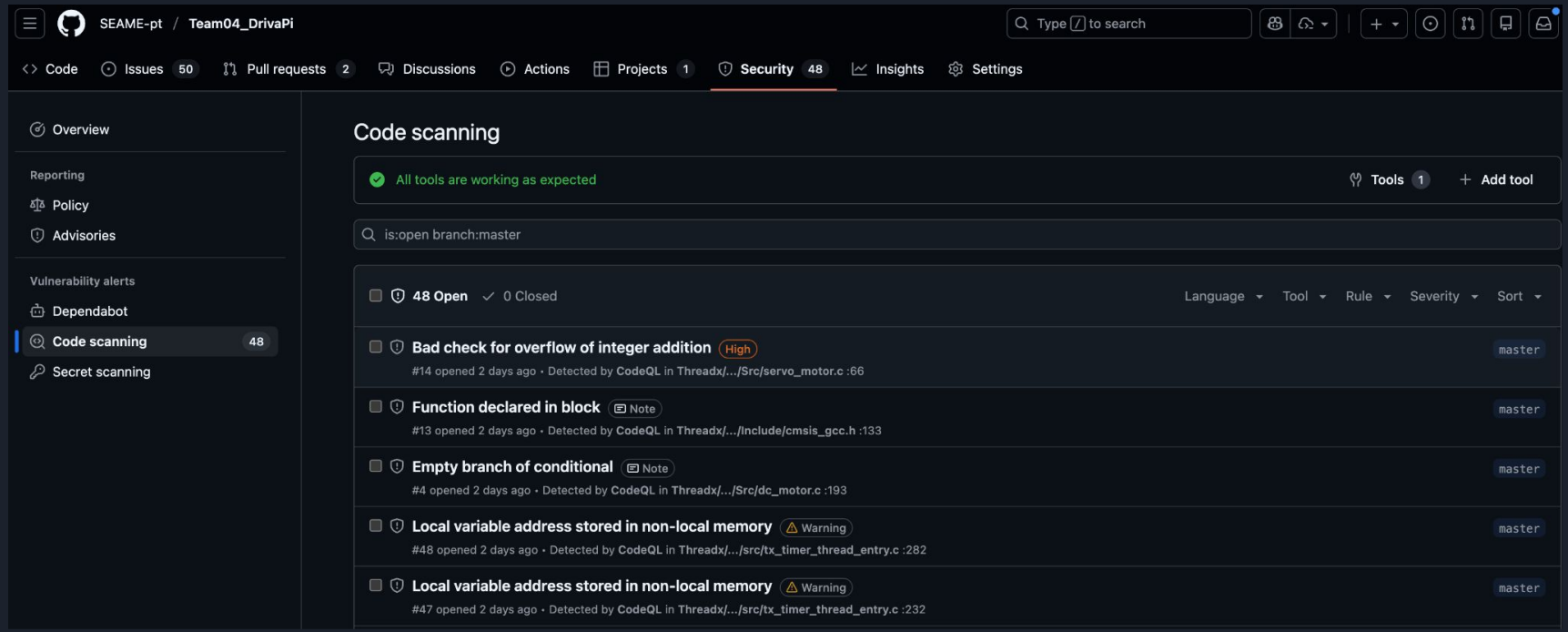
Generated by: LCOV version 1.14

OSS VERIFICATION TOOLCHAIN STRATEGY



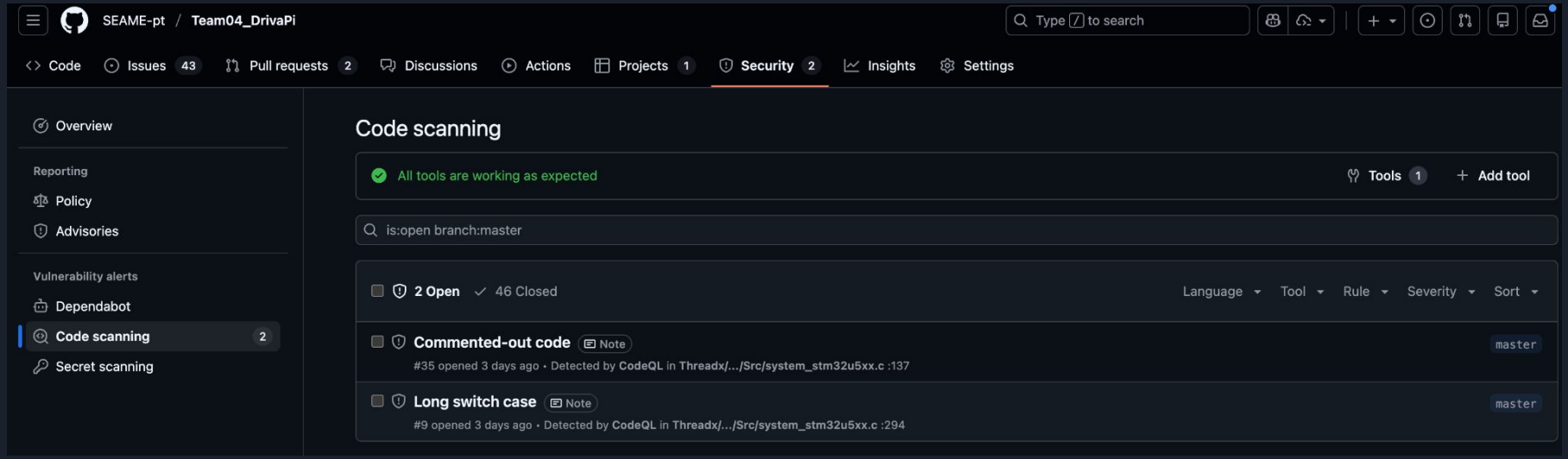
OSS VERIFICATION TOOLCHAIN STRATEGY

CODEQL GITHUBACTION



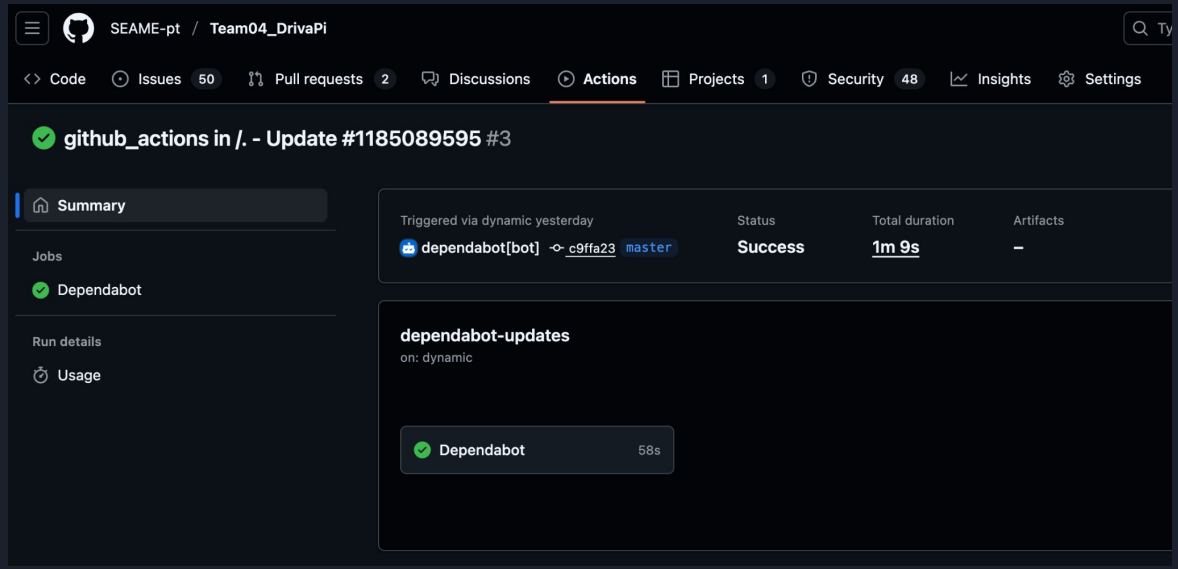
OSS VERIFICATION TOOLCHAIN STRATEGY

CODEQL GITHUBACTION



DEPENDENCIES CHECK

Dependabot for Repo's dependencies



QEMU SPIKE

QEMU does not support the STM32U5 (B-U585I-IOT02A) because there is no emulated machine or peripherals for this board.
It can run ARM code, but it cannot model the board’s actual hardware.

CAN BUS LATENCY ANALYSIS

Round-Trip Median

789 µs

One-Way Est.

395 µs

STM32 Internal

248 µs

CAN BUS LATENCY ANALYSIS

Performance Across Three Test Configurations

Configuration	Min	Mean	Median	Max	Std Dev	Jitter	Determinism
STM32 ↔ RPi	710	1 003.47	789	16 724	1 456.21	16 014	⭐⭐ Linux scheduling
RPi Loopback	522	592.37	593	721	18.96	199	⭐⭐⭐ Good
STM32 Internal	244	247.77	248	256	2.08	12	⭐⭐⭐⭐⭐ Excellent

✅ STM32 hardware demonstrates real-time determinism suitable for safety-critical control loops

⚠️ Linux kernel introduces scheduling variance; outliers caused by OS, not CAN hardware

CAN BUS LATENCY ANALYSIS

Key Findings & Recommendations

System Assessment

- Motor Control Loops: 789 µs RTT suitable for 10–100 Hz control
- Safety-Critical: STM32 determinism excellent for ASIL-compliant systems
- Hardware Performance: CAN transceiver + CAN solid at 500 kbps

Proposed Upgrade:

1000 kbps

SPIKE: NATIVE AGL KUKSA & C++ INTEGRATION

Migration from direct CAN to VSS-based Databroker architecture

WHY KUKSA?

SPIKE: NATIVE AGL KUKSA & C++ INTEGRATION

perplexity.ai

Critério	KUKSA	SOME/IP	FastDDS	MQTT	Zenoh
VSS Standardization	✅ SIM	❌ NÃO	❌ NÃO	❌ NÃO	❌ NÃO
Avg Latency (ms)	< 1 (teórico, gRPC)	7–8 (Navet 2015)	5–6 (ECRTS 2023)	100–300 (Azure)	? (não verificado)
Max Latency (ms)	< 1 (teórico)	?	17 (WATERS 2019)	1000+	?
Jitter	?	?	±1–2 ms (6–14% relativo)	Alto (>50%)	?
AGL Native Support	**Excelente**	Bom	Emergente	Bom	Emergente
AUTOSAR Compliance	Moderado	Excelente	Nenhuma	Nenhuma	Nenhuma
Determinismo (ASIL)	Moderado (AGL)	Bom	Bom	❌ Não	?
Resource Overhead	~100 MB	~50 MB	~150–200 MB	~20 MB	?
Cloud Ready	SIM	SIM	SIM	SIM	?

SPIKE: NATIVE AGL KUKSA & C++ INTEGRATION

- KUKSA Latência Teórica (gRPC) – gRPC Specification (HTTP/2 based) ;
- SOME/IP Latência & Resource Overhead – Nicolas Navet, “Time-Triggered vs Event-Triggered Real-Time Systems”, SAE Preprint 2015 (benchmark automotive com vSomeIP, 7–8 ms, ~50 MB) ;
- FastDDS Latência & Jitter – Sciangula et al., “Real-Time DDS Middleware Evaluation for Automotive Systems”, ECRTS 2023, ETH Zurich (Dell Optiplex 7070, Ubuntu 20.04, 3 topics, 1 kB, 50k samples, 5.4 ms, jitter 6–14%, max 17 ms com WATERS 2019 Bosch) ;
- MQTT Latência & Resource Overhead – Microsoft Azure IoT Operations Official Benchmarks (100–300 ms média, 1000+ ms máx, jitter >50%, ~20 MB) ;
- KUKSA AGL Native Support – COVESA Official Documentation & AGL Integration (Docker pronto, integração VSS nativa) ;
- SOME/IP AGL Support – AGL Documentation & AUTOSAR Stack (suportado, requer stack AUTOSAR) ;
- FastDDS AGL Support – AGL + OpenDDS communities (experimental em AGL, foco em Ubuntu/Fedora) ;
- MQTT AGL Support – Mosquitto MQTT Broker (open-source em AGL Linux, repositórios padrão) ;
- Zenoh AGL Support – Eclipse uProtocol Integration / Zenoh project roadmap (estado emergente, integração em desenvolvimento) ;
- SOME/IP AUTOSAR Compliance – AUTOSAR Standard Specification (Classic & Adaptive), journals.plos.org (middleware nativo
- AUTOSAR, usado em ECUs críticos) ;
- KUKSA Determinismo ASIL – gRPC over Linux + AGL PREEMPT_RT patches (moderado sem RT, pode atingir ASIL-C/D com PREEMPT_RT) ;
- SOME/IP Determinismo ASIL – AUTOSAR Safety Standards + vSomeIP benchmarks (excelente com Ethernet TSN, jitter 5–10% até ASIL-C, possível ASIL-D) ;
- KUKSA Resource Overhead – gRPC specification + GitHub KUKSA (estimado ~100 MB, não medido) ;
- FastDDS Resource Overhead – ECRTS 2023 + multi-threading analysis (estimado ~150–200 MB, não especificado no paper) ;
- KUKSA Cloud Ready – KUKSA.cloud & gRPC/HTTP2 architecture (cloud-first, suporta Google Cloud, AWS, Azure, integração VISS) .

SPIKE: NATIVE AGL KUKSA & C++ INTEGRATION

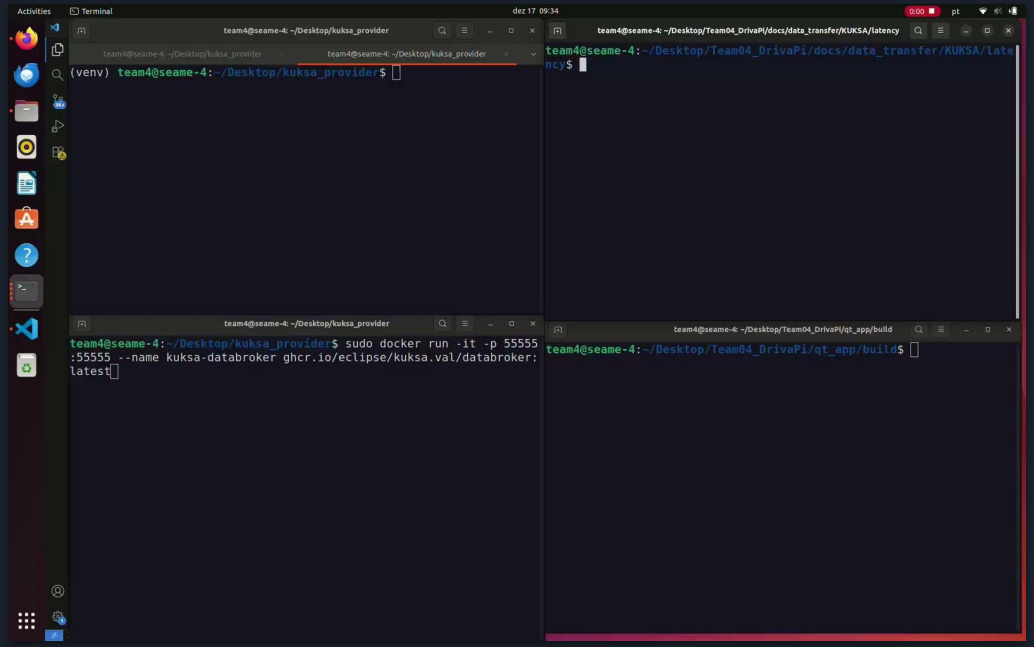
CAN vs KUKSA Databroker Performance

```
./latency_analyzer latency_sent_kuksa.txt latency_received_kuksa_1000.txt
Method: Nearest Time Match (Steady Clock Precision)...
[Sender] Loaded: 1000 packets.

=== PERFORMANCE REPORT ===
Sender Lines:      1000
Receiver Parsed:   1001
Receiver Matched:  1000
--------------------------
Packet Loss:       0.00 %
Avg Latency:       2.212 ms
Min Latency:       0.825 ms
Max Latency:       37.023 ms
```

```
./latency_analyzer latency_sent_can.txt latency_received_can_1000.txt
Method: Nearest Time Match (Steady Clock Precision)...
[Sender] Loaded: 1000 packets.

=== PERFORMANCE REPORT ===
Sender Lines:      1000
Receiver Parsed:   1000
Receiver Matched:  1000
--------------------------
Packet Loss:       0.00 %
Avg Latency:       0.148 ms
Min Latency:       0.033 ms
Max Latency:       0.763 ms
```

SPIKE: NATIVE AGL KUKSA & C++ INTEGRATION

CAN vs KUKSA Databroker Performance

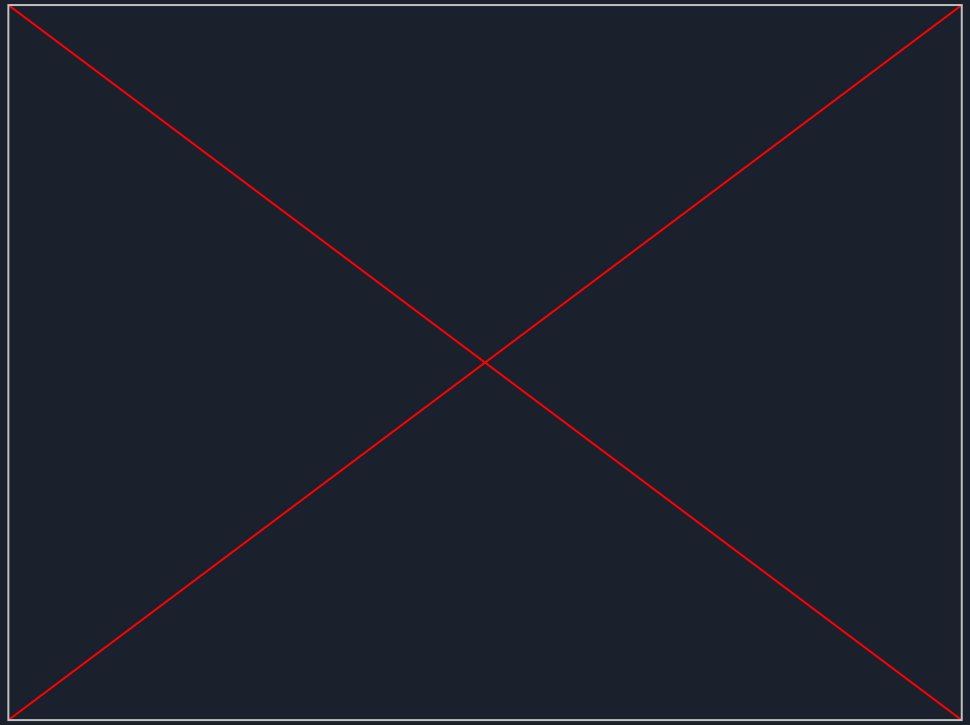


Rasperry Pi/AGL CAN Communication

Configure and validate the **CAN interface on a Raspberry Pi running AGL.** This includes enabling **SocketCAN, bringing up the CAN interface with the correct bitrate**, and verifying **bidirectional communication with the STM32 using command-line tools**. A minimal C/Rust application is used to confirm application-level access to the CAN interface. **This ensures the AGL application layer can communicate with the STM32 control board.**

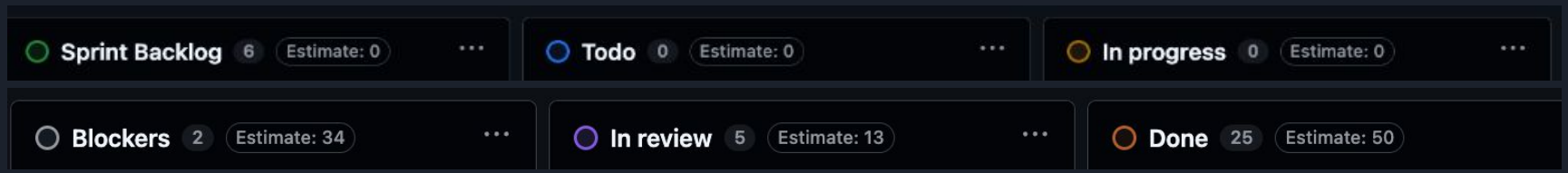
Joystick Control DC MOTOR

Rust-based CAN communication and a joystick-controlled DC motor controller, enabling real-time motor control via **CAN ID 44 using a ShanWan gamepad**. It includes a simple CAN message sender and a full controller application that maps joystick input to motor direction and speed.



RUST CROSS-COMPILATION FOR AGL

Set up the **host development environment** to cross-compile Rust applications for AGL running on a Raspberry Pi. This includes **installing the required Rust target** and **cross-compilation toolchain**, building a minimal Rust proof-of-concept application, and validating that the **generated binary runs correctly on the AGL** device without linker or dependency errors. **This ensures Rust applications can be safely and reliably developed for the AGL platform**.


Sprint Backlog 6 Estimate: 0
Todo 0 Estimate: 0
In progress 0 Estimate: 0
Blockers 2 Estimate: 34
In review 5 Estimate: 13
Done 25 Estimate: 50

In sum...

Thank you!