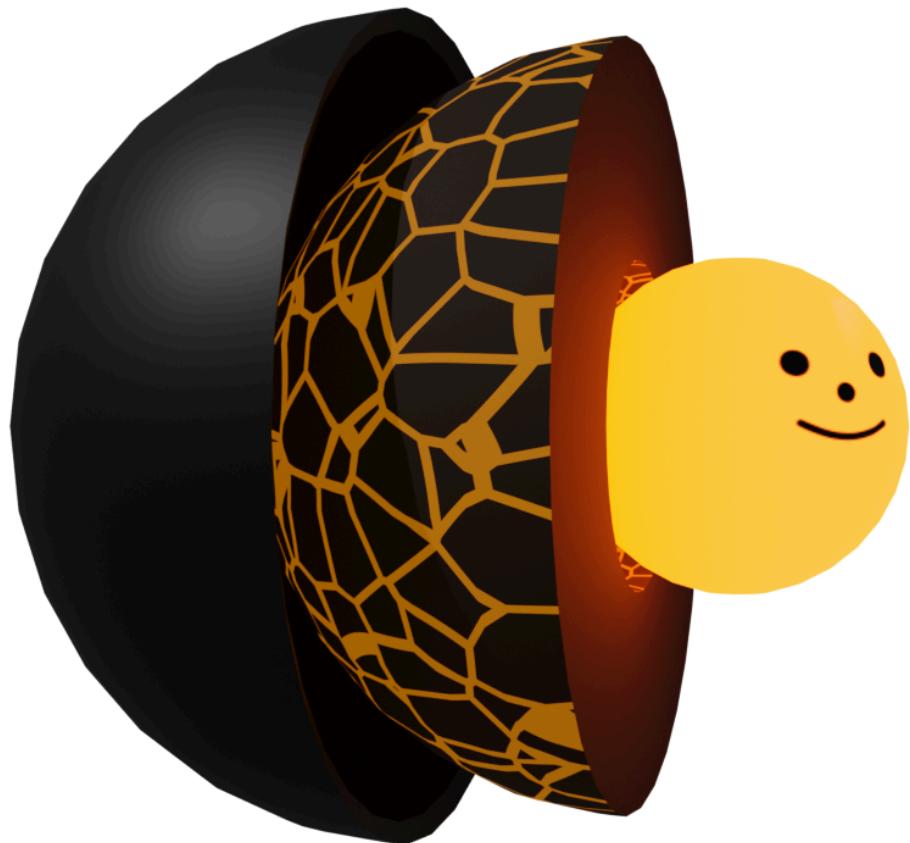


# RIT VEXU Software Engineering Notebook

2023-2024



# Table of Contents

<b>RIT VEXU Software Engineering Notebook.....</b>	<b>1</b>
<b>Table of Contents.....</b>	<b>2</b>
<b>Overview.....</b>	<b>3</b>
Core API.....	3
Open Source Software.....	3
Project Structure.....	4
Git Subrepo.....	4
Github Project Board.....	4
Github Actions.....	5
Auto-Notebook.....	5
Clang-Tidy.....	6
Wiki.....	6
<b>Core: Fundamentals.....</b>	<b>7</b>
Odometry.....	7
Drivetrain.....	9
Tank Drivetrain.....	9
Control Loops.....	14
Auto Command Structure (ACS).....	16
Serializer.....	18
Screen Subsystem.....	19
Catapult System.....	22
<b>Core: Ongoing Projects.....</b>	<b>23</b>
Rust.....	23
N-Pod Odometry.....	24
V5 Debug Board.....	30

# Overview

## Core API

All of the robot code we use is built on top of our own custom library, called the Core API, which itself is built on top of the official VEX V5 library. This API contains template code for common subsystems such as drivetrains, lifts, flywheels, and odometry, and common utilities such as vector math and command-based autonomous functions. This code remains persistent between years and is constantly updated and improved. The library can be found at [github.com/RIT-VEX-U/Core](https://github.com/RIT-VEX-U/Core)

The Core codebase is abstracted in a way that allows for simple use during a hectic build season, and creates a solid foundation for future expansion. Subsystems are divided into layers following an object-oriented approach to software development.



Figure 1 - Example of Object-Oriented Programming

## Open Source Software

The Core API is under the MIT open-source license, and is open for other teams to use and improve upon via pull requests. This system was modeled after the Okapi library from the Pros ecosystem, and offers similar functionality for the VexCode ecosystem. Teams that use this API are also encouraged to open source their software.

# Project Structure

During the season, there are three repositories (repos) that are actively developed. Two repositories for the two competition robots, and one for the Core API. Development and code building occurs in the robot repos, and any changes to shared code (drivetrain, math utilities, major subsystems) are merged with the Core repo. This method reduces redundant code and development time.



Figure 2 - Project Structure

## Git Subrepo

The Core API uses a unique type of version control called Git Subrepo ([github.com/ingydotnet/git-subrepo](https://github.com/ingydotnet/git-subrepo)). This allows users to simply clone the repository into an existing VexCode project to have instant access to all the tools. It also allows users to instantly receive updates by pulling from the main branch, and makes sharing code between two robot projects easier with git code merges.

Before choosing Subrepo, the team experimented with using Git Submodules to incorporate the Core API into projects. This however made Core development cumbersome and difficult for anyone unfamiliar with Git submodules specifically. Subrepo made inter-project merges more streamlined, and simplified development.

## Github Project Board

In order for our software team to collaborate together with these projects, we use the Github Projects kanban-style project board. This allows us to create and assign tasks, link it to a repository and additionally notify the assigned programmer through a slackbot.

Over Under Development	In Progress	Done
<p><span style="color: green;">●</span> Todo 20 This item hasn't been started</p> <ul style="list-style-type: none"><li>Core #32 New Project Streamlining Wiki</li><li>Core #33 Core Cleanup / Documentation</li><li>Core #36 Wiki Entries</li></ul>	<p><span style="color: orange;">●</span> In Progress 4 This is actively being worked on</p> <ul style="list-style-type: none"><li>Core #5 Pure Pursuit functionality</li><li>Core #34 Motion Profiles</li><li>Core #73 Accelerometer for Lateral Odometry Tracking</li><li>Core #39 Add 3 Pod Odometry to Core</li></ul>	<p><span style="color: purple;">●</span> Done 13 This has been completed</p> <ul style="list-style-type: none"><li>Core #44 ACS Command Timeout</li><li>Core #39 Add 3 Pod Odometry to Core</li><li>Core #43 Add Pose2D Class</li></ul>

Figure 3 - Software Project Board

## Github Actions

This year, our team enhanced our workflow by integrating GitHub Actions into our software development process. One notable addition was an action to build our C/C++ code in the appropriate Vex environment. This automated process involves a series of steps, including checking out the repository, downloading and unzipping the Vex Robotics SDK and toolchain, and compiling the code using a Makefile. A key feature of this GitHub Action is its ability to send a Slack notification to our team channel whenever a build fails, ensuring prompt awareness and response. Furthermore, it helps maintain code integrity by preventing the merging of pull requests with failing builds. This complements our other GitHub Action for building Doxygen documentation and deploying it to GitHub Pages, allowing for seamless documentation and code management. This systematic approach aligns with our commitment to maintaining a neat, organized, and efficient engineering process.



Figure 4: Continuous Integration directly improves the quality of our code.



Figure 5: Automatically generated documentation.

## Auto-Notebook

Alongside the automatic documentation, whenever Core is updated or we manually trigger it, a Github Action copies the reference manual, exports the most up to date version of our written notebook document, stitches them together, and deploys to a webpage. This is publicly available for any person wishing to see our software development process. The most valuable effect, though, is automating most of the formatting work for our notebook, work that used to require a team member to use valuable pre-competition time to sit down, append, format and export the notebook.

## Clang-Tidy

In an effort to improve the quality, reduce headaches, and make our code easier to read, write, and understand, we enabled many more warnings than what is supplied with the default Vex project Makefile. These warnings deal with uninitialized variables, missing returns, and other simple code errors that nonetheless have the tendency to introduce tiny, hard to track down bugs. However, sometimes these warnings do not explore deep enough and another tool must be used. We integrated clang-tidy, a c++ linter developed by the clang compiler project, to inspect our code. With a simple switch of a variable in the Makefile, we run clang-tidy during builds which gives many insights into the code that plain compiler warnings do not. Though it does increase compilation times, it tells us about code that is bug prone or poor for performance and tests many other checks developed and validated by the wider C++ community.

## Wiki

Whenever a new feature is added to Core, we create a Wiki page on the Core Github repository that provides documentation on what the function does, how to use it, and some examples of how it can be used. This documentation is easily accessible as it can be found online within the Core repository itself. This allows for new members to get acquainted with Core faster and easier than before. This allows us to speed up our training process and allow new members to start developing sooner rather than later. In addition it provides us and anyone using Core great documentation that not only goes into method signatures and descriptions, but also detailed explanations of what different methods, classes or functions do.

### Opcontrol

This class provides two ways of driving the robot with a controller: Tank drive and Arcade drive. Drivers can choose what they're most comfortable with.

Tank Drive - The left joystick controls the left-side motors, and the right joystick controls the right-side motors

Arcade Drive - Acts somewhat to how modern racing video games are controlled. The left joystick controls the forward / backward speed, and the right joystick controls turning left / right.

Both functions also have an optional parameter called `power`, and refers to how the joystick is scaled to the motors. The higher the power is, the more control you have over low-speed maneuvers. Because the scaling is non-linear, it may feel weird to those who aren't used to it.

### Method Signatures

```
void drive_tank(double left, double right, int power=1);
void drive_arcade(double forward_back, double left_right, int power=1);
```

### Usage Examples

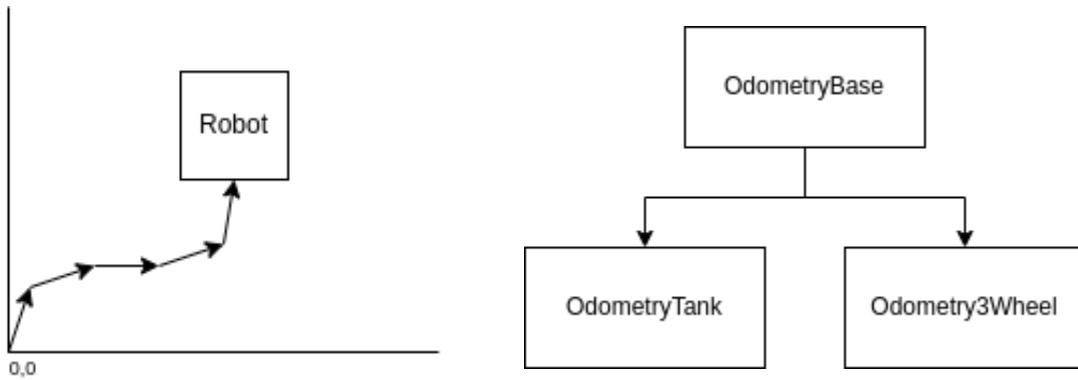
```
drive_system.drive_tank(controller.Axis3.position() / 100.0, controller.Axis2.position() / 100.0);
drive_system.drive_arcade(controller.Axis3.position() / 100.0, controller.Axis1.position() / 100.0);
```

Figure 6: A screenshot of the Core Wiki

# Core: Fundamentals

## Odometry

In order for the robot to drive autonomously, it needs to know where it is, and constantly monitor changes to sensors. The Odometry subsystem takes inputs from encoders, and using vector math and previous position data, calculates the position and rotation of the robot on the field as a point in space (X, Y), and heading (deg).



The Odometry subsystem is broken down into an OdometryBase class, which controls the asynchronous behavior and getters/setters, and OdometryTank and Odometry3Wheel classes, which both extend OdometryBase and implement a two-encoder algorithm and a three-encoder algorithm, respectively.

## GPS + Odometry

In order to fit an 8-motor drivetrain into the 15" size requirement, the robots could not fit non-powered odometry wheels, leaving only the drive encoders to be used for position tracking. This isn't ideal, since sudden changes in acceleration and wheel slippage can easily cause the tracking to drift a substantial amount. To combat drifting, we looked to the GPS sensor for localization.

The GPS sensor uses a tag-based approach for localization, using a coded strip around the perimeter of the field to estimate position. Between pose estimates, the integrated IMU provides inertial information to estimate changes in position and heading for a constant flow of data, presumably using some sort of onboard Kalman filter. The pose (X, Y, Heading) data is sent back to the Brain over the smart port. In addition, the GPS provides a "quality" value, which is a percentage that increases when the camera can see a large amount of tape, and decreases when the camera is blocked and the IMU detects change in position over a period of time.

To properly characterize the GPS sensor, X/Y/Heading data points were gathered at different positions around the field, facing different headings. The following graphs show the data points on the 12' x 12' field grid. Distance error (in inches) to the actual measurements is shown by color.



Figure 7 - Raw Data Points



Figure 8 - Error Heat Map

There were some other errors with the GPS sensor, including issues localizing the robot when the sensor could not see enough of the coded tape. To take full advantage of the GPS sensor's localization capability, we'd need a way to perform sensor fusion alongside traditional ground-based odometry. To do this, a complementary filter was chosen - a filter that mixes two sets of data based on a proportional scalar *alpha* ( $\alpha$ ). The equation for a complementary filter is shown below:

$$out = \alpha * s_1 + (1 - \alpha) * s_2$$

where  $s_1$  is *sensor 1*,  $s_2$  is *sensor 2*, and *alpha* scales between the two.

To calculate *alpha*, first the X,Y position of the sensor and heading is taken into account. Since the robot will generally have a more accurate position when it's close to the wall and facing away from it, the following formula will report a score between 0 and 1 for the filter:

$$\alpha = \left( \frac{\vec{c} - \vec{p}}{\|\vec{c} - \vec{p}\|} \cdot \begin{bmatrix} \cos \theta \\ \sin \theta \end{bmatrix} \right) * \frac{\|\vec{c} - \vec{p}\|}{\|\vec{c}\|} * q$$

where  $\vec{c}$  is the constant vector of a point in the center of the field ( $x=72$ in,  $y=72$ in),  $\vec{p}$  is the robot's position as a vector ( $x, y$ ),  $\theta$  is the robot's heading, and  $x, y$  is again the robot's position (0 to 144 inches). The left side is the dot product of the normalized vector pointing from the robot to the center with the direction the robot is facing (gives 1 when the directions are aligned and -1 when opposite smoothly changing in between), and the right side is the sensor's distance to the center as a scalar percentage of the distance from corner to corner (between 0 and 1). Finally,  $q$  is the GPS's reported quality. We then remap this from the range [-1, 1] to [0, 1] when we do our mixing.

# Drivetrain

A drivetrain class has two functions: To control the robot remotely, and autonomously. In the Core API, the TankDrive class allows the operator to control the robot using Tank controls (Left stick controls the left drive wheels, right controls the right), and Arcade controls (Left stick is forward / backwards, right stick is turning). This means drivers can tailor their controls to whichever feels more natural.

## Tank Drivetrain

### Brake Mode

A VEX driver has many things to keep track of during a match. From game element position, match load status, and partner robot condition there is a great deal going on. Defense is another layer on top of the mental load of playing the game. To ease this burden, we implemented a brake mode on our drive train. It is a multi-modal system that can either bring the robot to a stop or hold the robot in a specific location on the field. We use the motion profiles we developed for auto programming to decelerate the robot when requested and use our auto driving functions to hold the robot's position. We implement a smarter form of position holding than just motor braking as we can return to the exact location on the field. Additionally, we combine our deceleration control with position holding such that we do not immediately "lock the brakes" and skid away thus losing the position we attempt to hold and making driving incredibly difficult.

### Autonomous Driving

For autonomous driving, the TankDrive class has multiple functions:

- `drive_forward()`:
  - Drive X inches forward/back from the current position
  - Signature: `drive_forward(double inches, directionType dir, double max_speed=1)`
- `turn_degrees()`:
  - Drive X degrees CW/CCW from the current rotation
  - Signature: `turn_degrees(double degrees, double max_speed=1)`
- `drive_to_point()`:
  - Drive to an absolute point on the field, using odometry
  - Signature: `drive_to_point(double x, double y, vex::directionType dir, double max_speed=1);`
- `turn_to_heading()`:
  - Turn to an absolute heading relative to the field, using odometry
  - Signature: `turn_to_heading(double heading_deg, double max_speed=1)`

Generally, it is better to use `drive_to_point` and `turn_to_heading` to avoid compounding errors in position over relative movements. These functions implement the `FeedbackBase` class, so any control loop can be used to control it.

## Drive To Point

The defining feature of a drive to point function is the ability for a robot to calculate a relative direction and distance between its own position and the target position, and navigate to it using tuned control loops. The steps taken for our implementation are listed below.

### 1 - Gather information

To drive towards a specific point, the robot must know the change in angle between the robot's heading and the target, and the distance to the target. To get this, we first grab the robot's current position and heading and create a positional difference vector between this and the new point.

```
pose_t current_pos = odometry->get_position();
pose_t end_pos = { .x = x, .y = y };

point_t pos_diff_pt =
{
    .x = x - current_pos.x,
    .y = y - current_pos.y
};

Vector2D point_vec(pos_diff_pt);
```

Using this information, grab the distance to the target (using a function in the Odometry subsystem). An issue with the pure distance between points is that it does not represent how far the robot has to travel to be considered "on target" in the control loop. In order to properly reach its target, the robot should report its "aligned distance", and ignore the lateral error, as per Figure 9. This should only hold true when the robot is close to the target, or inside a given radius that is tuned by the user.



Figure 9 - Distance Modification



Figure 10 - Correction Cutoff Circle

```

double dist_left = OdometryBase::pos_diff(current_pos, end_pos);

if (fabs(dist_left) < config.drive_correction_cutoff)
{
    dist_left *= fabs(cos(angle * PI / 180.0));
}

```

The next data needed is the difference in angle between the robot's current heading and the vector between the robot's position and the target. This is calculated by using the arctangent of the difference vector, and subtracting it from the robot's current heading. The angle is then wrapped around 360 degrees.

```

double angle_to_point = atan2(y - current_pos.y, x - current_pos.x)
                           * 180.0 / PI;
double angle = fmod(current_pos.rot - angle_to_point, 360.0);
if (angle > 360)
    angle -= 360;
if (angle < 0)
    angle += 360;

double heading = rad2deg(point_vec.get_dir());
double delta_heading = 0;
if (dir == directionType::fwd)
    delta_heading = OdometryBase::smallest_angle(current_pos.rot, heading);
else
    delta_heading = OdometryBase::smallest_angle(current_pos.rot
                                                - 180, heading);

```

The last piece of information needed is whether the robot should be moving forwards or backwards. Since the distance is calculated as  $\sqrt{x^2 + y^2}$ , the sign is lost when squaring. Re-implement the sign based on the angle and initial driving direction.

```

int sign = 1;
if (dir == directionType::fwd && angle > 90 && angle < 270)
    sign = -1;
else if (dir == directionType::rev && (angle < 90 || angle > 270))
    sign = -1;

```

## 2 - Setting Control Loops

In this section, the robot takes the above information and sets its feedback loops. Since the function takes in a FeedbackBase abstract class, any feedback can be used to drive the robot's correction and linear movements. The most common situation is a trapezoidal motion profile for linear distance with PD for heading correction. Once the robot is close enough to the target point, the correction feedback is ignored to avoid issues with last-minute heading changes.

```
correction_pid.update(delta_heading);
feedback.update(sign * -1 * dist_left);

double correction = 0;
if (is_pure_pursuit || fabs(dist_left) > config.drive_correction_cutoff)
{
    correction = correction_pid.get();
}

double drive_pid_rval;
if (dir == directionType::rev) {
    drive_pid_rval = feedback.get() * -1;
} else {
    drive_pid_rval = feedback.get();
}

double lside = drive_pid_rval + correction;
double rside = drive_pid_rval - correction;

lside = clamp(lside, -max_speed, max_speed);
rside = clamp(rside, -max_speed, max_speed);

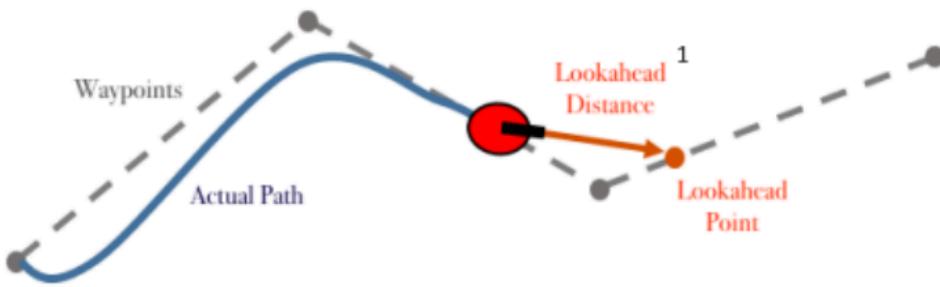
drive_tank(lside, rside);
```

Finally, when the linear feedback reports its on target, stop, return and report that the movement is over.

```
if (feedback.is_on_target())
{
    if (end_speed == 0) {
        stop();
    }
    func_initialized = false;
    return true;
}
```

## Pure Pursuit

Pure Pursuit is a method of autonomous robot driving that allows the robot to autonomously drive through a set of waypoints without stopping and turning.



*Figure 11 - Pure Pursuit Example*

This is accomplished by taking a list of points (x,y), connecting them, and then choosing a "lookahead point" along the lines that the robot will attempt to follow. This will inherently cause the robot to smooth out the point map, and follow without sudden changes in direction.

The lookahead point is chosen by iterating along the path created by connecting the points and finding the furthest point that intersects a circle centered on the robot, with a set radius tuned by the programmer. Increasing this radius smooths the path, while decreasing it ensures the robot more closely follows the path.

The pure pursuit implementation in Core can either use the Autonomous Command System (ACS), or be called directly through the TankDrive class. See the sample code below for examples.

```
// Autonomous Command Controller
CommandController cmd{
    drive_sys.PurePursuitCmd(PurePursuit::Path({
        {.x=19, .y=133},
        {.x=40, .y=136},
        {.x=92, .y=136},
    }, 8), directionType::rev, .5)->withTimeout(4),
};

cmd.run();

// Standalone
while(!drive_sys.pure_pursuit(PurePursuit::Path({
    {.x=19, .y=133},
    {.x=40, .y=136},
    {.x=92, .y=136}}, 8), directionType::fwd, 0.5))
{
    vexDelay(20);
}
```

# Control Loops

In order for the Autonomous Command Structure to function, we need a way to tell the robot how we want it to move. There are two broad categories of telling a robot to achieve a requested position - Feedback and Feedforward. Feedback relies on sensors and adjusts the output of the robot according to the error between where it is and where it wants to be. On the other hand, a feedforward controller takes a mathematical model of the system and creates outputs based on what it calculates to be the necessary output to achieve the goal. Additionally, there are simpler methods like Bang-Bang or Take Back Half. These adjust the outputs based on the current position relative to the target, where Take Back Half gradually refines the output until it settles at the desired position. These controller types work for many applications, but a combination of them can achieve an even better control over robot actuators.

## PID

A PID controller is perhaps the most common type of Feedback control. It uses measurements of the error at its current state (proportional), measurements of how the error was in the past (integral) and measurements of how the error changes over time(derivative). The controller acts accordingly to bring the errors towards 0. We implemented a standard PID controller but made some alterations to fit our needs. The most important of these are custom error calculations. The standard error calculation function (*target - measured*) works for many of our uses but causes problems when we use a PID controller to control angles. Since angles wrap around at 360 degrees or  $2\pi$  radians we wrote our own error calculation function that gives the error that accounts for this wrapping.

## Feedforward

A feedforward controller differs from a feedback controller in that it does not rely on any measurement of error to command a system. Instead, built into a feedforward controller is a mathematical model of the domain. When a target is requested by the controller, the model is queried to figure out what the robot actuators must output to achieve that target. A key advantage of this form of control is that instead of waiting for an error to build up in the system, the controller acts directly to achieve the target and can reach the target much faster.

## Bang-Bang

Bang-Bang control is a straightforward control methodology where the output to the system is either fully on or fully off, with no intermediate states. It's used for systems where fine control isn't necessary or possible. In this method, when the process variable is below the setpoint, the controller output is set to maximum; when above, it's set to minimum. This approach is simple and often used for systems with high inertia or where the precise control of the variable isn't critical. However, it can lead to oscillations around the setpoint and isn't suited for systems requiring precise regulation.

## Take Back Half (TBH)

The Take Back Half (TBH) method is an iterative approach used to refine control in systems where overshoot is a concern. This method adjusts the output by taking back half the value of the output each time the controlled variable overshoots the target. The adjustment continues until the system settles close to the desired setpoint. TBH is particularly useful in scenarios where a fine balance between responsiveness and stability is needed, as it reduces the oscillation or overshoot often seen in simpler control methods. It's a practical choice for systems where a PID controller might be too complex or unnecessary. TBH controllers only have one tuning parameter which allows for an incredibly easy tuning experience.

## Generic Feedback

Different control systems work best in different environments. Because of this, we found ourselves switching control schemes often enough that rewriting the code each time was time consuming and often led to rushed, worse quality code. To solve this problem we implemented a generic feedback interface so that none of our subsystem code needs to change when we use a different control scheme. Instead, the subsystem reports to the controller where it wants to be, measurements from its environment and some information about the system's capabilities and the controller will report back the actions needed to achieve that target. This allows for much faster prototyping as well as cleaner, less tightly coupled code.

## Motion Profile

As we learn from each event, our team has evolved our approach to robot control systems, transitioning from a simple PID controller to a more sophisticated Motion Profile controller. The PID system, while fundamental, had its drawbacks, such as limited speed specification, poor response to wheel slipping, and slower reaction times. These limitations highlighted the need for a more advanced control mechanism.

Our Motion Profile controller represents a significant upgrade. It integrates precise control over position, acceleration, and velocity, allowing for optimized performance of our robot's subsystems. Unlike the PID controller, which reacts only to discrepancies between actual and desired states, our Motion Profile controller proactively manages the robot's movements. It anticipates the required actions, thereby reducing response lags. Moreover, it avoids the rigidness of a pure feedforward controller by adapting dynamically to changing conditions in competition scenarios.



Figure 12: Trapezoidal motion profile

A key feature of the Motion Profile controller is its ability to handle varying accelerations. This functionality enables our robot to accelerate efficiently without wheel slipping, always maintaining optimal acceleration. This year, we've further refined our Motion Profile to accommodate non-zero starting and ending velocities. This enhancement allows for the seamless chaining of complex movements, ensuring smoother transitions and more fluid motion during competition tasks.

## Auto Command Structure (ACS)

### Principle

A recent addition to our core API was that of the Autonomous Command Structure. No more will our eyes glaze over staring at brackets as we trawl through an ocean of anonymous functions nor lose our way in a labyrinthine state machine constructed not of brick and stone but blocks of ifs and whiles. Instead, we provide named Commands for all the actions that our robot can execute and infrastructure to run them sequentially or concurrently. The API is written in a declarative way allowing even programmers unfamiliar with the code to see a step-by-step, annotated guide to our autonomous path while keeping the procedures of how to execute the actions from hurting the readability of the path.

```

CommandController auto_non_loader_side(){
    int non_loader_side_full_court_shot_rpm = 3000;
    CommandController non_loader_side_auto;

    non_loader_side_auto.add(new SpinRPMCommand(flywheel_sys, non_loader_side_full_court_shot_rpm));
    non_loader_side_auto.add(new WaitUntilUpToSpeedCommand(flywheel_sys, 10));
    non_loader_side_auto.add(new ShootCommand(intake, 2));
    non_loader_side_auto.add(new FlywheelStopCommand(flywheel_sys));
    non_loader_side_auto.add(new TurnDegreesCommand(drive_sys, turn_fast_mprofile, -60, 1));
    non_loader_side_auto.add(new DriveForwardCommand(drive_sys, drive_fast_mprofile, 20, fwd, 1));
    non_loader_side_auto.add(new TurnDegreesCommand(drive_sys, turn_fast_mprofile, -90, 1));
    non_loader_side_auto.add(new DriveForwardCommand(drive_sys, drive_fast_mprofile, 2, fwd, 1));
    non_loader_side_auto.add(new SpinRollerCommand(roller));

    return non_loader_side_auto;
}

```

*Figure 13: ACS code from the 2023 competition season*

## Updates

This season, we found ourselves annoyed with having to repeat basic things such as `path.add(...)` and having to write `new ThingCommand(...)` over and over again. Our first solution to this was “shortcuts”. These were member functions of subsystems that would allocate, initialize and return an auto command for that subsystem. So, instead of `path.add(new DriveForwardCommand(drive_sys, drive_fast_mprofile, 20, fwd))` we could simply write `path.add(drive_sys.DriveForwardCommand(20, fwd))`. This reduced a great deal of typing but still left us with some issues.

The most hazardous, rather than the simply annoying downside of last year's system, was the memory unsafety of this system. Since our auto commands must use virtual functions, they must be on the other end of a pointer. So, they must be allocated using `new` or they must be initialized statically before we write the path which is a terrible user experience (Though, if constrained by an embedded system where allocating on the heap was deemed dangerous, the system could work with this). This became a real issue when we began to write more complicated constructs such as branching, asynchronous, and repeated commands as it became dangerously unclear who was responsible for deallocating these objects. As a solution for this, we developed an RAI wrapper for the Auto Command Interface. Inspired by C++'s `std::unique_ptr`, this wrapper provides a memory safe, value based way of using auto commands while still maintaining their adaptability. We used C++'s ideas of move semantics and ‘Resource Allocation Is Initialization’ to practically solve memory management so programmers (and even non programmers) can focus on writing paths.

```

CommandController cmd{
    odom.SetPositionCmd({.x = 16.0, .y = 16.0, .rot = 225}),
    // 1 - Turn and shoot preload
    {
        cata_sys.Fire(),
        drive_sys.DriveForwardCmd(dist, REV),
        DelayCommand(300),
        cata_sys.StopFiring(),
        cata_sys.IntakeFully(),
    },
    // 2 - Turn to matchload zone & begin matchloading
    drive_sys.DriveForwardCmd(dist + 2, FWD, 0.5)
        .with_timeout(1.5),

    // Matchloading phase
    Repeat{
        odom.SetPositionCmd({.x = 16.0, .y = 16.0, .rot = 225}),
        intakeToCata.with_timeout(1.75),
        cata_sys.Fire(),
        drive_sys.DriveForwardCmd(10, REV, 0.5),
        cata_sys.StopFiring(),
        cata_sys.IntakeFully(),
        drive_sys.TurnToHeadingCmd(load_angle, 0.5),
        drive_sys.DriveForwardCmd(12, FWD, 0.2).with_timeout(1.7),
    }.until(TimeSinceStartExceeds(30))
};

}

```

*Figure 13: ACS code going into the 2024 competition season*

Now that we were free to use auto commands without fear for leaking memory or messing with currently running commands, we began to create more powerful constructs such as branching on runtime information, timeouts so the robot can decide what to do based on how much time is left in the auto or skills period, fearless concurrency (driving and reloading at the same time), and a much much nicer user interface. This declarative, safe, and straightforward method of writing auto paths lets us spend less time writing and debugging custom code and more time exploring and optimizing auto paths.

## Serializer

One pain point we found last year was configuring auto paths, color targets, path timeouts, and other parameters that changed often but for the most part should be persistent. Commonly, we found ourselves redeploying code at the last minute before a match. To solve this, we wrote a class that takes control of a file on the SD card to which users can read and write values at runtime using a simple key-value interface. This keeps us from having to change a value, redeploy, repeat which cost us valuable time in the past.

# Screen Subsystem

## Principle

One of the most powerful elements of the V5 Brain is the fairly substantial touch screen. However, its simple drawing API limits its utility as one person's part of the code will draw over another since there is no larger abstraction controlling who draws when. We have many different subsystems on our robot to observe and debug and many parameters that can be tuned at run time and the screen provides a way to do this. We provide an API that provides a 'page' interface that can be inserted into a slideshow-like interface. Each 'page' provides two functions, an update and a draw. The update runs more frequently allowing touch input and data collection at a reasonably fast rate while the draw function runs less frequently to not cause too much overhead on the system. At startup, users provide the screen subsystem a list of pages and the screen subsystem handles orchestration and input in a background thread while other robot code runs unaffected.

```
pages = {
    new AutoChooser({"Auto 1", "Auto 2", "Auto 3", "Auto 4"}),
    new screen::StatsPage(motor_names),
    new screen::OdometryPage(odom, 12, 12, true),
    cata_sys.Page(),
};

screen::start_screen(Brain.Screen, pages);
```

Figure 14: Configuration for the screen subsystem

## Pages

### Odometry Page

The odometry page has proved incredibly useful in writing and debugging auto and auto skills paths. It shows a picture of the robot on the field as well as a print out of the actual x,y coordinates and heading of the robot. Since we write our autos with respect to the coordinate system of the field, having a map to look at makes development much simpler.

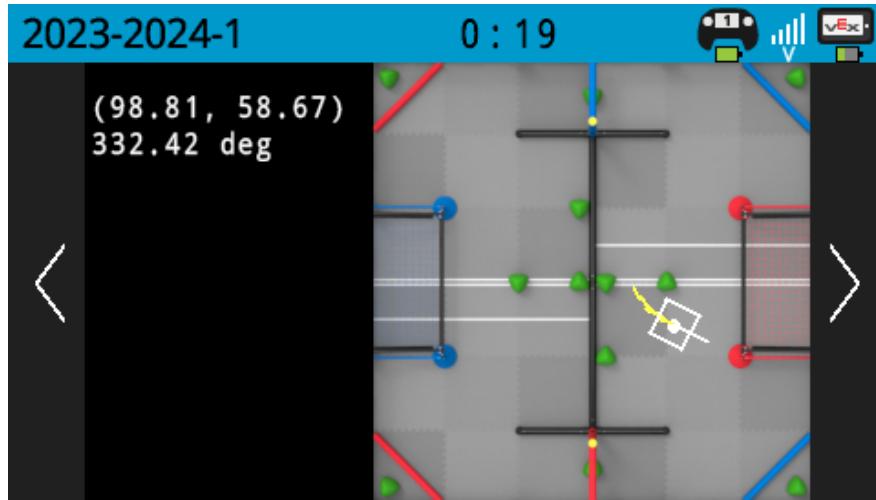


Figure 15: A field display for the Over Under season

## PID Tuner

PID controllers are integral to many subsystems on our robots. Our drive code uses them for turning and forward motion, our catapult uses them for reloading, and subsystems across seasons require them for precise control. Tuning them, however, can be incredibly tedious. Changing one value, redeploying, and repeating over and over again is time consuming and unnecessary. Since we have a wonderful touchscreen, we simply added a series of sliders for PID parameters and we can now easily adjust a PID tuning in seconds rather than minutes saving a great deal of time on an already time consuming part of robot development.

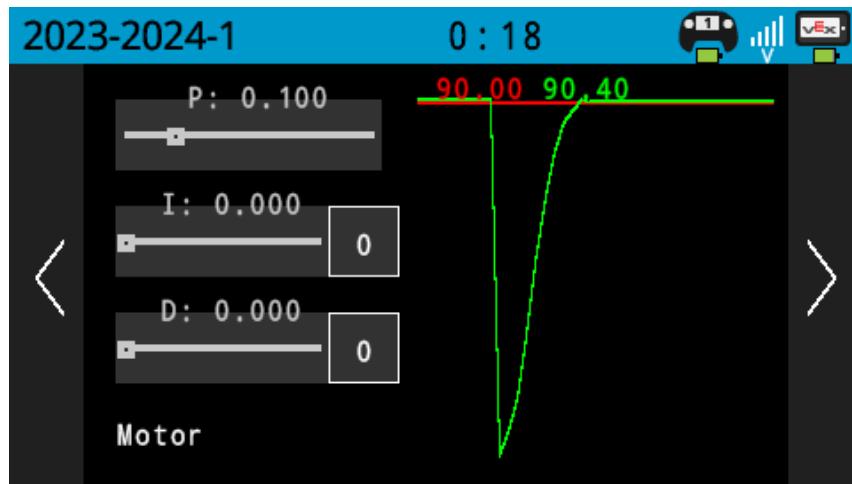


Figure 16: Tuning a motor for reaching an angle

## Motor Stats

One would think it an easy step to remember to plug motors in, and yet multiple times this season we have been bewildered and hindered by an unplugged motor. This page was written to continuously display that the motor had been unplugged and was not cancellable like the built-in VEX alert. This screen also displays what port to plug it into as well as a color coded

temperature displaying when the robot needs to cool down. This tool proved extremely useful as we discovered an alarmingly high number of dead or nonfunctioning ports on the brain.



Figure 17: Motor Stats screen from our 2023 robot

#### Cata System Page



Figure 18: The catapult status page. Includes a graph of Catapult PID values.

# Catapult System

## Motivation

Vex's Over Under game requires the effective utilization of the fascinatingly shaped triball. After much deliberation, our team decided on a catapult to launch the game element across the field and a reversible intake for picking up and scoring the triball. This system gives us a great deal of flexibility and power for strategy but does increase the system's complexity. This complexity mostly stems from the orchestration of intaking with catapult reloading such that we do not jam our catapult and never intake multiple game pieces leading to a disqualification.

## Initial Design

We implemented a state machine that receives inputs from the controller, a distance sensor in the intake, a distance sensor in the catapult, and a potentiometer for watching the catapult's position. The system runs the appropriate motors to either intake to hold the triball, reset the catapult, intake into the catapult, or shoot depending on its state. Because we have so many sensors, we can determine when intaking would lead to disqualification and simply not honor the intaking command.

These messages are a simple enum that one passes to `CataSys::send_command()`. This was originally intended to make writing multi-threaded code less error-prone as there was one thread-safe and simple way to interact with the subsystem, rather than many disparate methods some of which are meant for internal usage of the class on the running thread and some accessors and setters meant to be used from the user thread. Although it started for implementation ease, it naturally brought about a very simple interface for auto. Instead of sending a command on a button press, we simply send a command at a certain point in our auto path and the system reacts accordingly.

## Successor

Though the idea of the state machine modeled the intake and catapult system well, our haphazard implementation (very large and complicated switch statement on a worker thread) made changes exceedingly difficult. As we began competing, we identified changes we wished we could make to make driver and autonomous control easier and handle unforeseen hardware faults. However, our system was hard to read, modify, and all but impossible to prove correct.

Inspired by TinyFSM and other off the shelf C++ libraries for this problem, we created a generic state machine class that handles state transitions, background thread execution, and observability. While this tradeoff led to more code overall, its explicitness and separation of concerns allowed members to make changes in the behavior of the system without fear of deadlocking the threads or unknowingly modifying other states. The generic StateMachine class will remain in our Core library and can be reused year to year to achieve these benefits for any other stateful subsystem.

```

struct Reloading : public CataOnlySys::State {
    void entry(CataOnlySys &sys) override {
        sys.pid.update(sys.pot.angle(vex::deg));
        sys.pid.set_target(cata_target_charge);
    }

    CataOnlySys::MaybeMessage work(CataOnlySys &sys) override {
        // work on motor
        double cata_deg = sys.pot.angle(vex::deg);
        if (cata_deg == 0.0) {
            // adc hasn't warmed up yet, we're getting zero results
            return {};
        }
        sys.pid.update(cata_deg);
        sys.mot.spin(vex::fwd, sys.pid.get(), vex::volt);

        // are we there yettt
        if (sys.pid.is_on_target()) {
            return CataOnlyMessage::DoneReloading;
        }
        // otherwise keep chugging
        return {};
    }

    CataOnlyState id() const override { return CataOnlyState::Reloading; }
    State *respond(CataOnlySys &sys, CataOnlyMessage m) override;
};

```

Explicit separation of states allows simpler, more readable code

Due to the message passing interface to the catapult and intake system, this change was able to be made with very few modifications to the external interface of the system meaning driver code and autonomous paths did not have to be rewritten to use the advantages of the new system - a saving grace as we made this modification in the middle of competition season.

## Vision

With the unpredictable way triballs roll across the field, our robots need a way to repeatedly track the game objects during the autonomous period. And so, a vision sensor is placed inside the intake subsystem on the front of the robot.

The Vex Vision sensor is notorious among teams for being unreliable, being highly dependent on field lighting conditions and often sensing random objects, sending the robot off course. Our team explored different methods of filtering and lighting to combat these issues, and are now successfully tracking triballs in our autonomous programs.

## Filtering Vision Objects

The first issue to address was filtering - making sure the robot tracks the correct objects. Currently, we run a filtering algorithm that removes all vision objects that don't follow a strict criteria:

- Minimum area (object width \* height)
- Maximum area
- Minimum aspect ratio (object width / height)
- Maximum aspect ratio
- Min / Max X value
- Min / Max Y value

Finally, the filtered objects array is sorted by area, so that the largest objects are easily accessible at the start of the array. Here's an example of how it's used:

```
vision_filter_s filter{
    .min_area = 2000,
    .max_area = 100000,
    .aspect_low = 0.5,
    .aspect_high = 2,
    .min_x = 0,
    .max_x = 320,
    .min_y = 0,
    .max_y = 240,
};

vector<vision::object> obj_list = vision_run_filter(filter);
```

## Standardizing Lighting

In past competitions, we've found differing lighting conditions can spell an unfortunate end for autonomous programs using vision. Spotlights, windows and even the color temperature of the overhead lights caused slight differences which would cause the color profile to be off. We were able to completely eliminate this by adding a custom light to the robot - a board that uses two high-powered LEDs switched with a MOSFET over the three wire ports. Here's the schematic:



Figure 19 - LED Board schematic

The low-side FET switches power via the signal pin, allowing the programmer to use PWM to dim the lights as needed.

Here's the final PCB built for competition:



Figure 20 - LED Board PCB design

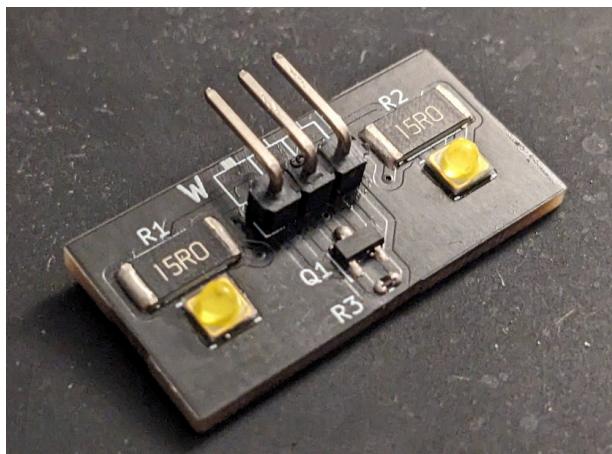


Figure 21 - LED Board, Front

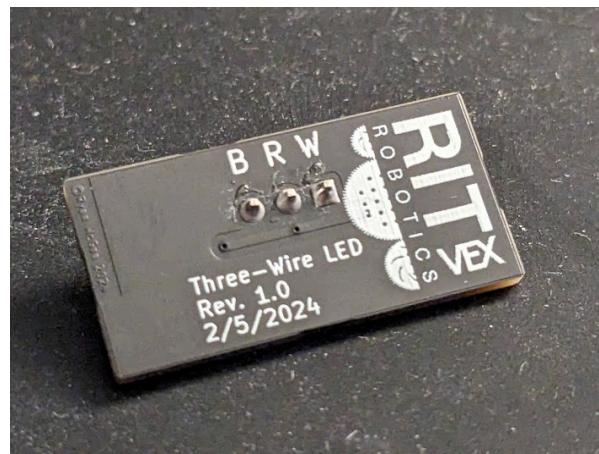


Figure 22 - LED Board, Back

The lighting system was tested and successfully used at the West Virginia tournament, where the robot was able to score five triballs in one autonomous program using this vision system.



Figure 23 - Vision Tracking in Auto



Figure 24 - LED board at full power (~2 Watts)

## Core: Ongoing Projects

### Rust

Over the course of the year, we have experimented with rewriting our Core API in Rust, a multi-paradigm programming language focused on performance and safety. Rust offers several potential advantages over C++:

#### Motivation

#### Memory Safety

One of the primary benefits of Rust is its emphasis on memory safety without sacrificing performance. Rust's ownership model ensures that memory is managed correctly at compile time, reducing the risk of memory leaks and buffer overflows which are common issues in C++. This is especially crucial in robotics, where memory management errors can lead to system crashes or unpredictable behavior in real-time operations.

#### Concurrency

Rust's approach to concurrency is another major advantage. Concurrency errors, like race conditions, are hard to debug and can be catastrophic in robotics, leading to inconsistent states and erratic behavior. Rust's type system and ownership model prevent data races at compile time, making concurrent programming more reliable and easier to reason about.

## Performance

In terms of performance, Rust is comparable to C++, which is essential in robotics where processing speed and response time are critical. Rust's zero-cost abstractions mean that high-level constructs do not add overhead at runtime. This allows developers to write high-level code without compromising on performance, an important consideration in robotics where every millisecond can count.

## Improved Code Maintenance and Readability

Rust also offers improved code maintainability and readability. Its modern syntax and language features make it easier to write clear and concise code. This reduces the cognitive load on developers, making it easier to develop and maintain complex robotic systems. The compiler's strictness also ensures that many potential bugs are caught early in the development cycle, reducing the time spent on debugging.

## Growing Ecosystem and Community

The Rust ecosystem is rapidly growing, with a strong focus on safety and performance. There are increasing numbers of libraries and tools being developed for Rust, including those specifically for robotics. The Rust community is known for its dedication to improving code quality and security, which aligns well with the needs of robotics development.

## Overall

While the transition from C++ to Rust in a robotics context requires investment in terms of learning and codebase modification, the benefits in memory safety, concurrency handling, performance, and maintainability make it a compelling choice. The modern features of Rust, combined with its growing ecosystem and community support, position it well for developing robust, efficient, and safe robotic systems.

## Progress

Though progress slowed as competition season began, our rust build system is moving out of the proof of concept stage and into something useful. We setup a cargo (rust's build system manager) target and can cargo build a vex project into an architecture-correct .elf file linked according to vexcode's standard library version and linker configurations. We then created a simple python script to convert the .elf file into the stripped binary file that the vex brain expects and call the vexcom tool provided by the vscode extension to send binaries to the brain.

## Findings

Though we did not have much time before our small software team's resources were needed elsewhere, our experiments with Rust programming for VEX found many interesting things.

A surprise we came across is that for proper and safe rust environments one must provide a panic handler. This will be called whenever an error occurs or the programmer signals that the specified behavior is invalid. Though rust does many things to insure 'if it compiles

correctly it runs correctly' there is still behavior that should be signaled to be an error at run time. With the custom panic handler we are able to provide detailed error messages including line numbers and function names - a feature that is sorely missed when programming with the C/C++ API.

Though Rust does come with many benefits, we did find a blocker that is limiting more widespread adoption on the team. The C/C++ API dynamically links the C and C++ standard library after deploying such that a much smaller binary must be transferred to the brain, a life saver when wirelessly uploading. Even with aggressive minimal size optimizations, the requirement to statically link rust core library functions means even simple rust binaries would match the size of our largest C/C++ projects. The PROS ecosystem ran into a similar problem and did work with hot/cold linking in order to not deploy non-changing code each time and we are looking to explore a similar solution. However, most of our research is into undocumented areas of the VEX ecosystem and this feature is still in the early phase of development.

The work on the rust port was split between two members: one of whom ported the API of core and modified it to fit into the rust programming style and safety model and one who set up the compiler toolchain and low level system for interfacing with the vex C/C++ library. Though this was originally an organizational decision, we realized that much of core could be completely abstracted away from dealing with VEX specific components and could operate on hardware that fulfills specific interface requirements. For example, as long as we can send a voltage to a motor and read a position our drivetrain and flywheel subsystems would work no matter the actual hardware. Thanks to rust's powerful generic programming features, this flexibility can be used without sacrificing helpful compiler errors (a common C++ issue) and without sacrificing performance using runtime polymorphism.

## N-Pod Odometry

### Motivation

Although we have been working on the GPS odometry system, wheel odometry is still vital. It provides great small-scale, quickly updating positions as well as having near-perfect, continuous, local velocity which a GPS system can not achieve. We use odometry in two ways; either tank or differential odometry where there is one wheel on either side of the drivetrain alongside the drive wheels and 3-wheel odometry where we have 3 wheels at ninety degrees to each other. Tank odometry is limited as it can not track horizontal movement and we simply hope that we never move sideways, though it is easiest to implement in the robot so it is our most commonly used system. 3-wheel odometry solves the side-to-side problem but is much harder to implement in hardware owing to the extra wheel where other subsystems would need space.

In a plea for mercy from the hardware team, we agreed that we would take tracking wheels wherever and we could make do. Though we once again got stuck with a tank system, if our dream of more tracking wheels ever comes true we would need code to handle such a system. Also, since tank and 3 wheel odometry are special cases of an n-pod system, we could reduce code duplication.



Figure 25: 2 pod, 3 pod, and arbitrary pods such a system could handle.

## Syntax

After much brainstorming and many mad scientist whiteboard drawings, we believe that we have the fundamentals of a system figured out. Unfortunately, other responsibilities to the team came up so we do not yet have a functioning implementation of the system.

Imagine a robot with  $n$  number of tracking omni wheels. We could read encoder values  $E_1, E_2, \dots, E_n$  from the system in radians from the initial position. As well, each encoder has a configuration  $(x_1, y_1, \theta_1, r_1), \dots, (x_n, y_n, \theta_n, r_n)$  describing its position ( $x, y$ ) relative to the center of rotation, an angle describing its orientation relative to the robot frame ( $\theta$ ), and a radius of the wheel ( $r$ ).



Figure 26: The configuration of a tracking wheel on the robot.  $(e_x, e_y)$  are the basis vectors of our coordinate system - the X and Y axes of the robot coordinate frame.  $d_i$  is the direction vector of the tracking wheel.

Now, if we pretend that these wheels are powered and we wish to translate and rotate the robot according to some controller input  $(x, y, \theta)$  we can develop a formula for how much each wheel needs to rotate to move the robot in that direction with that rotation. Luckily, since the tracking wheels are omni wheels that roll freely in the axis against their “forward” direction, we do not need to worry about dragging a wheel so long as it is spinning the correct amount in its “forward” direction. For a desired  $(x, y, \theta)$  (in the robots reference frame), for the  $i$ -th encoder, we say  $E_i = xF_{xi}$ . That is, for a movement in the x-axis the rotations of the  $i$ -th encoder, are the desired  $x$  movement times some scalar factor ( $F$ ) for how far this specific wheel would rotate. Similarly, for a  $y$  only and  $\theta$  only movement,  $E_i = yF_{yi}$  and  $E_i = \theta F_{\theta i}$  respectively.

## Deriving Factors

$F_x$

$F_x$  depends on the direction vector  $\vec{d}$  of the omni-wheel. If the omni-wheel is facing along the x-axis,  $F_x$  will be higher whereas if the omni-wheel is directly perpendicular to the x-axis, it will not spin when you move only in the x-direction. Since  $\vec{e}_x$  and  $\vec{d}$  are unit vectors, how closely they are related is given by  $\vec{e}_x \cdot \vec{d} = \cos(\text{angle between } x \text{ axis and wheel})$

$F_x$  also depends on the radius of the wheel  $r$ . One full rotation of the wheel moves a distance of  $C = 2\pi r$ . If we drive in the direction of the wheel  $i$  inches, the wheel will complete  $\frac{i}{2\pi r}$  revolutions. If we measure the rotations in radians, the wheel will travel  $\frac{i}{r}$  radians. That is, if the encoder wheel travels  $E$  radians, we will have traveled  $Er$  inches in that direction.

So, the distance traveled in the x direction of a wheel pointing in the direction  $\vec{d}$ , rotating  $E$  radians is  $x = Er(\vec{e}_x \cdot \vec{d})$ . This gives since  $F_x$  as how many inches per radian turned,

$$F_x = \frac{x}{E} = r(\vec{e}_x \cdot \vec{d})$$

$F_y$

$F_y$  is derived almost identically as  $F_x$  just instead of testing against  $\vec{e}_x$  we test against  $\vec{e}_y$ . So,

$$F_y = \frac{y}{E} = r(\vec{e}_y \cdot \vec{d})$$

$F_\theta$

$F_\theta$  is a little more complicated since it is determined by the position of the wheel  $\vec{v}$  as well as the orientation of the wheel  $\vec{v}$

Imagine that the robot turns an angle of  $\theta_r$  measured in radians. A wheel that is perfectly perpendicular to the rotation will travel an arc with distance  $S = ||\vec{v}|| \theta_r$  by the arc length formula where the 'radius' of the arc is defined by the length of the vector  $\vec{v}$ .



Figure 27: A conceptual perfectly perpendicular wheel

So, if we have a wheel that is always tangent to the rotation, it will travel

$$E_t r = S = \vec{v} \cdot \vec{t}$$

Since our wheel isn't guaranteed to be perfectly tangent to the arc, we have to use our dot product trick to get the component of its motion that is tangent to the turning circle. That is, instead of comparing to  $\vec{e}_x$  or  $\vec{e}_y$  we compare to the normalized vector  $\vec{t}$  tangent to the turning circle.



$$E_t r = Er(\vec{t} \cdot \vec{d})$$

So

$$Er(\vec{t} \cdot \vec{d}) = S = ||\vec{v}||\theta_t$$

Since  $\vec{t}$  is just a unit vector 90 degrees counterclockwise of  $\vec{v}$ , We can find it by multiplying  $\vec{v}$  by the rotation matrix for 90 degrees and normalizing giving

$$\vec{t} = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} norm(\vec{v}) = \begin{bmatrix} -norm(\vec{v}).y \\ norm(\vec{v}).x \end{bmatrix}$$

So

$$F_\theta = \frac{\theta_r}{E} = \frac{r(\vec{t} \cdot \vec{d})}{||\vec{v}||} = \frac{r(\begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} norm(\vec{v}) \cdot \vec{d})}{||\vec{v}||} = \frac{r(\begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \vec{v} \cdot \vec{d})}{||\vec{v}||^2}$$

## Why factors

These factors make solving this problem much simpler. For the forward case, for some wheel  $i$ , its rotation is the sum of all the motions applied to it. So  $E_i = F_{xi}x + F_{yi}y + F_{\theta i}\theta$ . So, for all the wheels, we plug in the commanded  $(x, y, \theta)$  to each wheel's factors to get its necessary rotation. Since the factors depend only on the wheel's pose in the frame, these can be calculated once at the start of the program and are constant (unless the frame breaks apart, in which case the robot has other problems).

## Now Do It Backwards

We have now solved the forward system for when we have a delta of our pose and want our wheel deltas. Now we must take our wheel deltas and solve for our pose delta. We have our formulas for each wheel's encoder motion and can consider this as a system of linear equations. At runtime, we have our wheel encoder deltas we can plug in and then we can solve the system of linear equations. This requires that we have enough data to satisfy the equations. That is, we need at least 3 separate wheels with at least some angle between them, or else the system will be not fully constrained. In the case of tank odometry, we only have two wheels but as outside observers we know we can not measure change in one dimension. So, we know one variable is zero and then have two remaining free variables and two equations to satisfy the system. For robots with greater than three encoders, we have an over-constrained system of equations but this is not an issue. Since all the encoders are modeled on a physical system, they should agree on what the solution is. Using the technique of least squares regression, we can find our  $(x, y, \theta)$  to solve the over-constrained system that minimizes the error between equations. This

also gives us a way to detect errors in our drive train. If a wheel gets jammed, its encoder reading will disagree with the rest of the system, and the error value will measurably increase. If we monitor this error value we can diagnose mechanical or electrical issues from the code.

$$T = \begin{bmatrix} F_{x1} & F_{y1} & F_{\theta 1} \\ \vdots & \vdots & \vdots \\ F_{xn} & F_{yn} & F_{\theta n} \end{bmatrix}$$

$$\vec{X} = \begin{bmatrix} \frac{dx_{robot}}{dt} \\ \frac{dy_{robot}}{dt} \\ \frac{d\theta_{robot}}{dt} \end{bmatrix}$$

$$\vec{E} = \begin{bmatrix} E_1 \\ \vdots \\ E_n \end{bmatrix}$$

$$\begin{bmatrix} \text{Length} & \text{Length} & \text{Angle} \\ \text{Angle} & \text{Angle} & \text{Angle} \\ \vdots & \vdots & \vdots \end{bmatrix}$$

transfer matrix  
from robot velocity  
to encoder velocities  
(f for factor)

$$\begin{bmatrix} \frac{\text{Distance}}{\text{Time}} \\ \frac{\text{Distance}}{\text{Time}} \\ \frac{\text{Angle}}{\text{Time}} \end{bmatrix}$$

pose velocity

$$\begin{bmatrix} \frac{\text{Angle}}{\text{Time}} \\ \vdots \\ \frac{\text{Angle}}{\text{Time}} \end{bmatrix}$$

encoder wheel  
velocities

$$T\vec{X} = \vec{E}$$

$$\vec{X} = T^{-1}\vec{E}$$

or in the case where the matrix is not invertible, find the best solution

The linear algebra behind the solution

## V5 Debug Board

The large number of features added to core, while extremely useful, are also very difficult to debug. Without a proper real-time c++ debugger and one stream serial data for print statements, data parsing can get very messy. The improvements to the Screen subsystem have helped, but a remote solution is needed to avoid chasing after the robot to get visual data.



Figure 28 - Debug Board (Back)

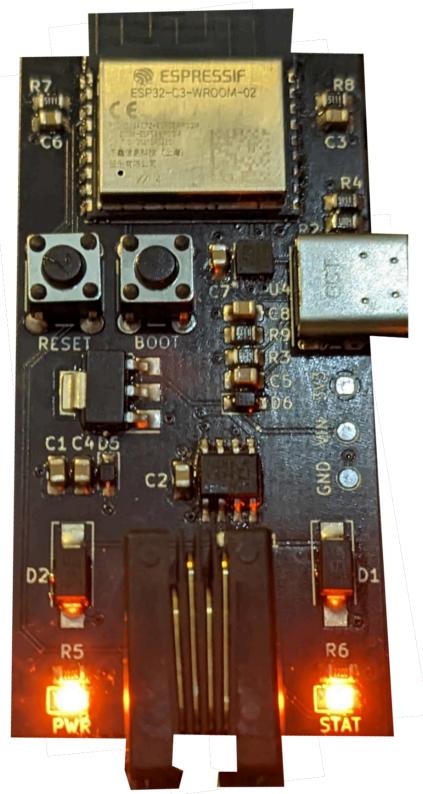


Figure 29 - Debug Board (Front)

The V5 Debug Board is a custom PCB designed by our team specifically to interface with the V5 Smart Ports, host a ROS2 node and a WiFi access point for programmers to connect to with laptops. This board is designed to ingest any kind of data and use it for graphs, real-time tuning and even displaying a 3D model of the robot on a virtual field using odometry data. This data can be viewed using either ROS' RViz or Foxglove visualization software.



*Figure 30 - Debug Board PCB Layout*

Hardware design is nearing completion, with 3 revisions built and tested. Revision 3.0 is powered by an ESP32-C3-WROOM2 microcontroller, and uses an RS-485 transceiver to communicate with the Brain over a smart-port. The new addition of a Micro-SD card allows users to upload their own 3D model of the robot, and provides data logging capabilities.

As of now, the hardware design is nearly complete. Software has achieved WiFi AP broadcasting, TCP communications and work is starting on the Micro-ROS implementation. The design is fully open source under the GPL-3 license, and is hosted at [github.com/superrm11/VexDebugBoard](https://github.com/superrm11/VexDebugBoard) and [github.com/superrm11/VexDebugBoard\\_PCB](https://github.com/superrm11/VexDebugBoard_PCB).

# RIT VEXU Core API

Generated by Doxygen 1.10.0



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<b>1 Core</b>	<b>1</b>
1.1 Getting Started . . . . .	1
1.2 Features . . . . .	1
<b>2 Hierarchical Index</b>	<b>3</b>
2.1 Class Hierarchy . . . . .	3
<b>3 Class Index</b>	<b>7</b>
3.1 Class List . . . . .	7
<b>4 File Index</b>	<b>11</b>
4.1 File List . . . . .	11
<b>5 Class Documentation</b>	<b>13</b>
5.1 AndCondition Class Reference . . . . .	13
5.1.1 Member Function Documentation . . . . .	13
5.1.1.1 test() . . . . .	13
5.2 Async Class Reference . . . . .	14
5.2.1 Detailed Description . . . . .	14
5.2.2 Member Function Documentation . . . . .	15
5.2.2.1 run() . . . . .	15
5.3 AutoChooser Class Reference . . . . .	15
5.3.1 Detailed Description . . . . .	16
5.3.2 Constructor & Destructor Documentation . . . . .	16
5.3.2.1 AutoChooser() . . . . .	16
5.3.3 Member Function Documentation . . . . .	16
5.3.3.1 draw() . . . . .	16
5.3.3.2 get_choice() . . . . .	17
5.3.3.3 update() . . . . .	17
5.3.4 Member Data Documentation . . . . .	17
5.3.4.1 choice . . . . .	17
5.3.4.2 list . . . . .	17
5.4 AutoCommand Class Reference . . . . .	18
5.4.1 Member Function Documentation . . . . .	19
5.4.1.1 on_timeout() . . . . .	19
5.4.1.2 run() . . . . .	19
5.4.2 Member Data Documentation . . . . .	19
5.4.2.1 timeout_seconds . . . . .	19
5.5 BangBang Class Reference . . . . .	20
5.5.1 Member Function Documentation . . . . .	20
5.5.1.1 get() . . . . .	20
5.5.1.2 init() . . . . .	20
5.5.1.3 is_on_target() . . . . .	21
5.5.1.4 set_limits() . . . . .	21

---

5.5.1.5 update()	21
5.6 BasicSolenoidSet Class Reference	22
5.6.1 Detailed Description	22
5.6.2 Constructor & Destructor Documentation	22
5.6.2.1 BasicSolenoidSet()	22
5.6.3 Member Function Documentation	23
5.6.3.1 run()	23
5.7 BasicSpinCommand Class Reference	23
5.7.1 Detailed Description	24
5.7.2 Constructor & Destructor Documentation	24
5.7.2.1 BasicSpinCommand()	24
5.7.3 Member Function Documentation	25
5.7.3.1 run()	25
5.8 BasicStopCommand Class Reference	25
5.8.1 Detailed Description	26
5.8.2 Constructor & Destructor Documentation	26
5.8.2.1 BasicStopCommand()	26
5.8.3 Member Function Documentation	26
5.8.3.1 run()	26
5.9 Branch Class Reference	27
5.9.1 Detailed Description	28
5.9.2 Member Function Documentation	28
5.9.2.1 on_timeout()	28
5.9.2.2 run()	28
5.10 screen::ButtonConfig Struct Reference	28
5.11 screen::ButtonWidget Class Reference	28
5.11.1 Detailed Description	29
5.11.2 Constructor & Destructor Documentation	29
5.11.2.1 ButtonWidget() [1/2]	29
5.11.2.2 ButtonWidget() [2/2]	29
5.11.3 Member Function Documentation	30
5.11.3.1 update()	30
5.12 screen::CheckboxConfig Struct Reference	30
5.13 CommandController Class Reference	30
5.13.1 Detailed Description	31
5.13.2 Constructor & Destructor Documentation	31
5.13.2.1 CommandController()	31
5.13.3 Member Function Documentation	31
5.13.3.1 add() [1/3]	31
5.13.3.2 add() [2/3]	32
5.13.3.3 add() [3/3]	32
5.13.3.4 add_cancel_func()	32

---

5.13.3.5 add_delay()	33
5.13.3.6 last_command_timed_out()	33
5.13.3.7 run()	33
5.14 Condition Class Reference	33
5.14.1 Detailed Description	34
5.15 CustomEncoder Class Reference	34
5.15.1 Detailed Description	34
5.15.2 Constructor & Destructor Documentation	34
5.15.2.1 CustomEncoder()	34
5.15.3 Member Function Documentation	35
5.15.3.1 position()	35
5.15.3.2 rotation()	35
5.15.3.3 setPosition()	35
5.15.3.4 setRotation()	36
5.15.3.5 velocity()	36
5.16 DelayCommand Class Reference	36
5.16.1 Detailed Description	37
5.16.2 Constructor & Destructor Documentation	37
5.16.2.1 DelayCommand()	37
5.16.3 Member Function Documentation	37
5.16.3.1 run()	37
5.17 DriveForwardCommand Class Reference	38
5.17.1 Detailed Description	39
5.17.2 Constructor & Destructor Documentation	39
5.17.2.1 DriveForwardCommand()	39
5.17.3 Member Function Documentation	39
5.17.3.1 on_timeout()	39
5.17.3.2 run()	40
5.18 DriveStopCommand Class Reference	40
5.18.1 Detailed Description	41
5.18.2 Constructor & Destructor Documentation	41
5.18.2.1 DriveStopCommand()	41
5.18.3 Member Function Documentation	41
5.18.3.1 on_timeout()	41
5.18.3.2 run()	41
5.19 DriveToPointCommand Class Reference	42
5.19.1 Detailed Description	43
5.19.2 Constructor & Destructor Documentation	43
5.19.2.1 DriveToPointCommand() [1/2]	43
5.19.2.2 DriveToPointCommand() [2/2]	43
5.19.3 Member Function Documentation	44
5.19.3.1 run()	44

5.20 AutoChooser::entry_t Struct Reference . . . . .	44
5.20.1 Detailed Description . . . . .	44
5.20.2 Member Data Documentation . . . . .	44
5.20.2.1 name . . . . .	44
5.21 ExponentialMovingAverage Class Reference . . . . .	45
5.21.1 Detailed Description . . . . .	45
5.21.2 Constructor & Destructor Documentation . . . . .	45
5.21.2.1 ExponentialMovingAverage() [1/2] . . . . .	45
5.21.2.2 ExponentialMovingAverage() [2/2] . . . . .	46
5.21.3 Member Function Documentation . . . . .	46
5.21.3.1 add_entry() . . . . .	46
5.21.3.2 get_size() . . . . .	46
5.21.3.3 get_value() . . . . .	46
5.22 Feedback Class Reference . . . . .	47
5.22.1 Detailed Description . . . . .	47
5.22.2 Member Function Documentation . . . . .	48
5.22.2.1 get() . . . . .	48
5.22.2.2 init() . . . . .	48
5.22.2.3 is_on_target() . . . . .	48
5.22.2.4 set_limits() . . . . .	48
5.22.2.5 update() . . . . .	49
5.23 FeedForward Class Reference . . . . .	49
5.23.1 Detailed Description . . . . .	50
5.23.2 Constructor & Destructor Documentation . . . . .	50
5.23.2.1 FeedForward() . . . . .	50
5.23.3 Member Function Documentation . . . . .	50
5.23.3.1 calculate() . . . . .	50
5.24 FeedForward::ff_config_t Struct Reference . . . . .	51
5.24.1 Detailed Description . . . . .	51
5.24.2 Member Data Documentation . . . . .	51
5.24.2.1 kA . . . . .	51
5.24.2.2 kG . . . . .	52
5.24.2.3 kS . . . . .	52
5.24.2.4 kV . . . . .	52
5.25 Filter Class Reference . . . . .	52
5.25.1 Detailed Description . . . . .	52
5.25.2 Member Function Documentation . . . . .	53
5.25.2.1 add_entry() . . . . .	53
5.25.2.2 get_value() . . . . .	53
5.26 Flywheel Class Reference . . . . .	53
5.26.1 Detailed Description . . . . .	54
5.26.2 Constructor & Destructor Documentation . . . . .	54

---

5.26.2.1 Flywheel()	54
5.26.3 Member Function Documentation	54
5.26.3.1 get_motors()	54
5.26.3.2 get_target()	54
5.26.3.3 getRPM()	55
5.26.3.4 is_on_target()	55
5.26.3.5 Page()	55
5.26.3.6 spin_manual()	55
5.26.3.7 spin_rpm()	56
5.26.3.8 SpinRpmCmd()	56
5.26.3.9 stop()	56
5.26.3.10 WaitUntilUpToSpeedCmd()	56
5.26.4 Friends And Related Symbol Documentation	57
5.26.4.1 spinRPMTask	57
5.27 FlywheelPage Class Reference	57
5.27.1 Member Function Documentation	57
5.27.1.1 draw()	57
5.27.1.2 update()	58
5.28 FlywheelStopCommand Class Reference	58
5.28.1 Detailed Description	59
5.28.2 Constructor & Destructor Documentation	59
5.28.2.1 FlywheelStopCommand()	59
5.28.3 Member Function Documentation	59
5.28.3.1 run()	59
5.29 FlywheelStopMotorsCommand Class Reference	59
5.29.1 Detailed Description	60
5.29.2 Constructor & Destructor Documentation	60
5.29.2.1 FlywheelStopMotorsCommand()	60
5.29.3 Member Function Documentation	60
5.29.3.1 run()	60
5.30 FlywheelStopNonTasksCommand Class Reference	61
5.30.1 Detailed Description	61
5.31 FunctionCommand Class Reference	62
5.31.1 Detailed Description	62
5.31.2 Member Function Documentation	63
5.31.2.1 run()	63
5.32 FunctionCondition Class Reference	63
5.32.1 Detailed Description	63
5.32.2 Member Function Documentation	64
5.32.2.1 test()	64
5.33 screen::FunctionPage Class Reference	64
5.33.1 Detailed Description	64

5.33.2 Constructor & Destructor Documentation . . . . .	64
5.33.2.1 FunctionPage() . . . . .	64
5.33.3 Member Function Documentation . . . . .	65
5.33.3.1 draw() . . . . .	65
5.33.3.2 update() . . . . .	65
5.34 GenericAuto Class Reference . . . . .	65
5.34.1 Detailed Description . . . . .	66
5.34.2 Member Function Documentation . . . . .	66
5.34.2.1 add() . . . . .	66
5.34.2.2 add_async() . . . . .	66
5.34.2.3 add_delay() . . . . .	66
5.34.2.4 run() . . . . .	67
5.35 GraphDrawer Class Reference . . . . .	67
5.35.1 Constructor & Destructor Documentation . . . . .	67
5.35.1.1 GraphDrawer() . . . . .	67
5.35.2 Member Function Documentation . . . . .	68
5.35.2.1 add_samples() [1/2] . . . . .	68
5.35.2.2 add_samples() [2/2] . . . . .	68
5.35.2.3 draw() . . . . .	68
5.36 PurePursuit::hermite_point Struct Reference . . . . .	69
5.36.1 Detailed Description . . . . .	69
5.37 IfTimePassed Class Reference . . . . .	69
5.37.1 Detailed Description . . . . .	70
5.37.2 Member Function Documentation . . . . .	70
5.37.2.1 test() . . . . .	70
5.38 InOrder Class Reference . . . . .	70
5.38.1 Detailed Description . . . . .	71
5.38.2 Member Function Documentation . . . . .	71
5.38.2.1 on_timeout() . . . . .	71
5.38.2.2 run() . . . . .	71
5.39 screen::LabelConfig Struct Reference . . . . .	72
5.40 Lift< T > Class Template Reference . . . . .	72
5.40.1 Detailed Description . . . . .	72
5.40.2 Constructor & Destructor Documentation . . . . .	73
5.40.2.1 Lift() . . . . .	73
5.40.3 Member Function Documentation . . . . .	73
5.40.3.1 control_continuous() . . . . .	73
5.40.3.2 control_manual() . . . . .	73
5.40.3.3 control_setpoints() . . . . .	74
5.40.3.4 get_async() . . . . .	74
5.40.3.5 get_setpoint() . . . . .	74
5.40.3.6 hold() . . . . .	74

---

5.40.3.7 <code>home()</code>	75
5.40.3.8 <code>set_async()</code>	75
5.40.3.9 <code>set_position()</code>	75
5.40.3.10 <code>set_sensor_function()</code>	75
5.40.3.11 <code>set_sensor_reset()</code>	76
5.40.3.12 <code>set_setpoint()</code>	76
5.41 <code>Lift&lt; T &gt;::lift_cfg_t</code> Struct Reference	76
5.41.1 Detailed Description	76
5.42 Logger Class Reference	77
5.42.1 Detailed Description	77
5.42.2 Constructor & Destructor Documentation	77
5.42.2.1 <code>Logger()</code>	77
5.42.3 Member Function Documentation	78
5.42.3.1 <code>Log()</code> [1/2]	78
5.42.3.2 <code>Log()</code> [2/2]	78
5.42.3.3 <code>Logf()</code> [1/2]	78
5.42.3.4 <code>Logf()</code> [2/2]	79
5.42.3.5 <code>LogIn()</code> [1/2]	79
5.42.3.6 <code>LogIn()</code> [2/2]	79
5.43 <code>MotionController::m_profile_cfg_t</code> Struct Reference	79
5.43.1 Detailed Description	80
5.44 <code>Mat2</code> Struct Reference	80
5.45 <code>StateMachine&lt; System, IDType, Message, delay_ms, do_log &gt;::MaybeMessage</code> Class Reference	80
5.45.1 Detailed Description	81
5.45.2 Constructor & Destructor Documentation	81
5.45.2.1 <code>MaybeMessage()</code>	81
5.45.3 Member Function Documentation	81
5.45.3.1 <code>has_message()</code>	81
5.45.3.2 <code>message()</code>	82
5.46 MecanumDrive Class Reference	82
5.46.1 Detailed Description	82
5.46.2 Constructor & Destructor Documentation	82
5.46.2.1 <code>MecanumDrive()</code>	82
5.46.3 Member Function Documentation	83
5.46.3.1 <code>auto_drive()</code>	83
5.46.3.2 <code>auto_turn()</code>	83
5.46.3.3 <code>drive()</code>	84
5.46.3.4 <code>drive_raw()</code>	85
5.47 <code>MecanumDrive::mecanumdrive_config_t</code> Struct Reference	85
5.47.1 Detailed Description	85
5.48 <code>motion_t</code> Struct Reference	85
5.48.1 Detailed Description	86

5.49 MotionController Class Reference . . . . .	86
5.49.1 Detailed Description . . . . .	87
5.49.2 Constructor & Destructor Documentation . . . . .	87
5.49.2.1 MotionController() . . . . .	87
5.49.3 Member Function Documentation . . . . .	88
5.49.3.1 get() . . . . .	88
5.49.3.2 get_motion() . . . . .	88
5.49.3.3 init() . . . . .	88
5.49.3.4 is_on_target() . . . . .	88
5.49.3.5 set_limits() . . . . .	89
5.49.3.6 tune_feedforward() . . . . .	89
5.49.3.7 update() . . . . .	90
5.50 MotionControllerPage Class Reference . . . . .	90
5.50.1 Member Function Documentation . . . . .	90
5.50.1.1 draw() . . . . .	90
5.50.1.2 update() . . . . .	91
5.51 MovingAverage Class Reference . . . . .	91
5.51.1 Detailed Description . . . . .	92
5.51.2 Constructor & Destructor Documentation . . . . .	92
5.51.2.1 MovingAverage() [1/2] . . . . .	92
5.51.2.2 MovingAverage() [2/2] . . . . .	92
5.51.3 Member Function Documentation . . . . .	92
5.51.3.1 add_entry() . . . . .	92
5.51.3.2 get_size() . . . . .	93
5.51.3.3 get_value() . . . . .	93
5.52 Odometry3Wheel Class Reference . . . . .	93
5.52.1 Detailed Description . . . . .	95
5.52.2 Constructor & Destructor Documentation . . . . .	95
5.52.2.1 Odometry3Wheel() . . . . .	95
5.52.3 Member Function Documentation . . . . .	95
5.52.3.1 tune() . . . . .	95
5.52.3.2 update() . . . . .	96
5.53 Odometry3Wheel::odometry3wheel_cfg_t Struct Reference . . . . .	96
5.53.1 Detailed Description . . . . .	96
5.53.2 Member Data Documentation . . . . .	97
5.53.2.1 off_axis_center_dist . . . . .	97
5.53.2.2 wheel_diam . . . . .	97
5.53.2.3 wheelbase_dist . . . . .	97
5.54 OdometryBase Class Reference . . . . .	97
5.54.1 Detailed Description . . . . .	98
5.54.2 Constructor & Destructor Documentation . . . . .	98
5.54.2.1 OdometryBase() . . . . .	98

---

5.54.3 Member Function Documentation . . . . .	99
5.54.3.1 background_task() . . . . .	99
5.54.3.2 end_async() . . . . .	99
5.54.3.3 get_accel() . . . . .	99
5.54.3.4 get_angular_accel_deg() . . . . .	99
5.54.3.5 get_angular_speed_deg() . . . . .	100
5.54.3.6 get_position() . . . . .	100
5.54.3.7 get_speed() . . . . .	100
5.54.3.8 pos_diff() . . . . .	100
5.54.3.9 rot_diff() . . . . .	101
5.54.3.10 set_position() . . . . .	101
5.54.3.11 smallest_angle() . . . . .	101
5.54.3.12 update() . . . . .	102
5.54.4 Member Data Documentation . . . . .	102
5.54.4.1 accel . . . . .	102
5.54.4.2 ang_accel_deg . . . . .	102
5.54.4.3 ang_speed_deg . . . . .	102
5.54.4.4 current_pos . . . . .	103
5.54.4.5 handle . . . . .	103
5.54.4.6 mut . . . . .	103
5.54.4.7 speed . . . . .	103
5.54.4.8 zero_pos . . . . .	103
5.55 screen::OdometryPage Class Reference . . . . .	103
5.55.1 Detailed Description . . . . .	104
5.55.2 Constructor & Destructor Documentation . . . . .	104
5.55.2.1 OdometryPage() . . . . .	104
5.55.3 Member Function Documentation . . . . .	104
5.55.3.1 draw() . . . . .	104
5.55.3.2 update() . . . . .	105
5.56 OdometryTank Class Reference . . . . .	105
5.56.1 Detailed Description . . . . .	106
5.56.2 Constructor & Destructor Documentation . . . . .	106
5.56.2.1 OdometryTank() [1/3] . . . . .	106
5.56.2.2 OdometryTank() [2/3] . . . . .	107
5.56.2.3 OdometryTank() [3/3] . . . . .	107
5.56.3 Member Function Documentation . . . . .	108
5.56.3.1 set_position() . . . . .	108
5.56.3.2 update() . . . . .	108
5.57 OdomSetPosition Class Reference . . . . .	108
5.57.1 Detailed Description . . . . .	109
5.57.2 Constructor & Destructor Documentation . . . . .	109
5.57.2.1 OdomSetPosition() . . . . .	109

---

5.57.3 Member Function Documentation . . . . .	110
5.57.3.1 run() . . . . .	110
5.58 OrCondition Class Reference . . . . .	110
5.58.1 Member Function Documentation . . . . .	110
5.58.1.1 test() . . . . .	110
5.59 screen::Page Class Reference . . . . .	111
5.59.1 Detailed Description . . . . .	111
5.59.2 Member Function Documentation . . . . .	111
5.59.2.1 draw() . . . . .	111
5.59.2.2 update() . . . . .	112
5.60 Parallel Class Reference . . . . .	112
5.60.1 Detailed Description . . . . .	113
5.60.2 Member Function Documentation . . . . .	113
5.60.2.1 on_timeout() . . . . .	113
5.60.2.2 run() . . . . .	113
5.61 parallel_runner_info Struct Reference . . . . .	114
5.62 PurePursuit::Path Class Reference . . . . .	114
5.62.1 Detailed Description . . . . .	114
5.62.2 Constructor & Destructor Documentation . . . . .	114
5.62.2.1 Path() . . . . .	114
5.62.3 Member Function Documentation . . . . .	115
5.62.3.1 get_points() . . . . .	115
5.62.3.2 get_radius() . . . . .	115
5.62.3.3 is_valid() . . . . .	115
5.63 PID Class Reference . . . . .	115
5.63.1 Detailed Description . . . . .	116
5.63.2 Member Enumeration Documentation . . . . .	116
5.63.2.1 ERROR_TYPE . . . . .	116
5.63.3 Constructor & Destructor Documentation . . . . .	116
5.63.3.1 PID() . . . . .	116
5.63.4 Member Function Documentation . . . . .	117
5.63.4.1 get() . . . . .	117
5.63.4.2 get_error() . . . . .	117
5.63.4.3 get_sensor_val() . . . . .	117
5.63.4.4 get_target() . . . . .	118
5.63.4.5 init() . . . . .	118
5.63.4.6 is_on_target() . . . . .	118
5.63.4.7 reset() . . . . .	118
5.63.4.8 set_limits() . . . . .	119
5.63.4.9 set_target() . . . . .	119
5.63.4.10 update() . . . . .	119
5.63.5 Member Data Documentation . . . . .	120

---

5.63.5.1 config . . . . .	120
5.64 PID::pid_config_t Struct Reference . . . . .	120
5.64.1 Detailed Description . . . . .	120
5.64.2 Member Data Documentation . . . . .	120
5.64.2.1 error_method . . . . .	120
5.64.2.2 on_target_time . . . . .	121
5.65 PIDFF Class Reference . . . . .	121
5.65.1 Member Function Documentation . . . . .	121
5.65.1.1 get() . . . . .	121
5.65.1.2 init() . . . . .	122
5.65.1.3 is_on_target() . . . . .	123
5.65.1.4 set_limits() . . . . .	123
5.65.1.5 set_target() . . . . .	123
5.65.1.6 update() [1/2] . . . . .	124
5.65.1.7 update() [2/2] . . . . .	124
5.66 screen::PIDPage Class Reference . . . . .	125
5.66.1 Detailed Description . . . . .	125
5.66.2 Constructor & Destructor Documentation . . . . .	125
5.66.2.1 PIDPage() . . . . .	125
5.66.3 Member Function Documentation . . . . .	126
5.66.3.1 draw() . . . . .	126
5.66.3.2 update() . . . . .	126
5.67 plm_frame_t Struct Reference . . . . .	126
5.68 plm_packet_t Struct Reference . . . . .	127
5.69 plm_plane_t Struct Reference . . . . .	127
5.70 plm_samples_t Struct Reference . . . . .	127
5.71 point_t Struct Reference . . . . .	127
5.71.1 Detailed Description . . . . .	128
5.71.2 Member Function Documentation . . . . .	128
5.71.2.1 dist() . . . . .	128
5.71.2.2 operator+() . . . . .	128
5.71.2.3 operator-() . . . . .	129
5.72 pose_t Struct Reference . . . . .	129
5.72.1 Detailed Description . . . . .	130
5.73 PurePursuitCommand Class Reference . . . . .	130
5.73.1 Detailed Description . . . . .	130
5.73.2 Constructor & Destructor Documentation . . . . .	131
5.73.2.1 PurePursuitCommand() . . . . .	131
5.73.3 Member Function Documentation . . . . .	131
5.73.3.1 on_timeout() . . . . .	131
5.73.3.2 run() . . . . .	131
5.74 Rect Struct Reference . . . . .	131

5.75 RepeatUntil Class Reference . . . . .	132
5.75.1 Constructor & Destructor Documentation . . . . .	133
5.75.1.1 RepeatUntil() [1/2] . . . . .	133
5.75.1.2 RepeatUntil() [2/2] . . . . .	134
5.75.2 Member Function Documentation . . . . .	134
5.75.2.1 on_timeout() . . . . .	134
5.75.2.2 run() . . . . .	134
5.76 robot_specs_t Struct Reference . . . . .	135
5.76.1 Detailed Description . . . . .	135
5.76.2 Member Data Documentation . . . . .	135
5.76.2.1 correction_pid . . . . .	135
5.76.2.2 dist_between_wheels . . . . .	135
5.76.2.3 drive_correction_cutoff . . . . .	135
5.76.2.4 odom_gear_ratio . . . . .	136
5.76.2.5 robot_radius . . . . .	136
5.77 screen::ScreenData Struct Reference . . . . .	136
5.77.1 Detailed Description . . . . .	136
5.78 screen::ScreenRect Struct Reference . . . . .	136
5.79 Serializer Class Reference . . . . .	137
5.79.1 Detailed Description . . . . .	137
5.79.2 Constructor & Destructor Documentation . . . . .	137
5.79.2.1 Serializer() . . . . .	137
5.79.3 Member Function Documentation . . . . .	138
5.79.3.1 bool_or() . . . . .	138
5.79.3.2 double_or() . . . . .	138
5.79.3.3 int_or() . . . . .	138
5.79.3.4 save_to_disk() . . . . .	140
5.79.3.5 set_bool() . . . . .	140
5.79.3.6 set_double() . . . . .	140
5.79.3.7 set_int() . . . . .	140
5.79.3.8 set_string() . . . . .	141
5.79.3.9 string_or() . . . . .	141
5.80 screen::SizedWidget Struct Reference . . . . .	142
5.81 SliderCfg Struct Reference . . . . .	142
5.82 screen::SliderConfig Struct Reference . . . . .	142
5.83 screen::SliderWidget Class Reference . . . . .	142
5.83.1 Detailed Description . . . . .	143
5.83.2 Constructor & Destructor Documentation . . . . .	143
5.83.2.1 SliderWidget() . . . . .	143
5.83.3 Member Function Documentation . . . . .	143
5.83.3.1 update() . . . . .	143
5.84 SpinRPMCommand Class Reference . . . . .	144

---

5.84.1 Detailed Description . . . . .	145
5.84.2 Constructor & Destructor Documentation . . . . .	145
5.84.2.1 SpinRPMCommand() . . . . .	145
5.84.3 Member Function Documentation . . . . .	145
5.84.3.1 run() . . . . .	145
5.85 PurePursuit::spline Struct Reference . . . . .	146
5.85.1 Detailed Description . . . . .	146
5.86 StateMachine< System, IDType, Message, delay_ms, do_log >::State Struct Reference . . . . .	146
5.86.1 Detailed Description . . . . .	146
5.87 StateMachine< System, IDType, Message, delay_ms, do_log > Class Template Reference . . . . .	147
5.87.1 Detailed Description . . . . .	147
5.87.2 Constructor & Destructor Documentation . . . . .	148
5.87.2.1 StateMachine() . . . . .	148
5.87.3 Member Function Documentation . . . . .	148
5.87.3.1 current_state() . . . . .	148
5.87.3.2 send_message() . . . . .	148
5.88 screen::StatsPage Class Reference . . . . .	149
5.88.1 Detailed Description . . . . .	149
5.88.2 Constructor & Destructor Documentation . . . . .	149
5.88.2.1 StatsPage() . . . . .	149
5.88.3 Member Function Documentation . . . . .	149
5.88.3.1 draw() . . . . .	149
5.88.3.2 update() . . . . .	150
5.89 TakeBackHalf Class Reference . . . . .	150
5.89.1 Detailed Description . . . . .	151
5.89.2 Member Function Documentation . . . . .	151
5.89.2.1 get() . . . . .	151
5.89.2.2 init() . . . . .	151
5.89.2.3 is_on_target() . . . . .	151
5.89.2.4 set_limits() . . . . .	152
5.89.2.5 update() . . . . .	152
5.90 TankDrive Class Reference . . . . .	152
5.90.1 Detailed Description . . . . .	154
5.90.2 Member Enumeration Documentation . . . . .	154
5.90.2.1 BrakeType . . . . .	154
5.90.3 Constructor & Destructor Documentation . . . . .	154
5.90.3.1 TankDrive() . . . . .	154
5.90.4 Member Function Documentation . . . . .	154
5.90.4.1 drive_arcade() . . . . .	154
5.90.4.2 drive_forward() [1/2] . . . . .	155
5.90.4.3 drive_forward() [2/2] . . . . .	156
5.90.4.4 drive_tank() . . . . .	156

5.90.4.5 drive_tank_raw()	157
5.90.4.6 drive_to_point() [1/2]	157
5.90.4.7 drive_to_point() [2/2]	158
5.90.4.8 modify_inputs()	159
5.90.4.9 pure_pursuit() [1/2]	159
5.90.4.10 pure_pursuit() [2/2]	160
5.90.4.11 reset_auto()	161
5.90.4.12 stop()	161
5.90.4.13 turn_degrees() [1/2]	161
5.90.4.14 turn_degrees() [2/2]	162
5.90.4.15 turn_to_heading() [1/2]	162
5.90.4.16 turn_to_heading() [2/2]	163
5.91 screen::TextConfig Struct Reference	164
5.92 TimesTestedCondition Class Reference	164
5.92.1 Member Function Documentation	164
5.92.1.1 test()	164
5.93 trapezoid_profile_segment_t Struct Reference	164
5.93.1 Detailed Description	165
5.94 TrapezoidProfile Class Reference	165
5.94.1 Detailed Description	166
5.94.2 Constructor & Destructor Documentation	166
5.94.2.1 TrapezoidProfile()	166
5.94.3 Member Function Documentation	167
5.94.3.1 calculate()	167
5.94.3.2 calculate_time_based()	167
5.94.3.3 get_movement_time()	167
5.94.3.4 set_accel()	168
5.94.3.5 set_endpts()	168
5.94.3.6 set_max_v()	168
5.94.3.7 set_vel_endpts()	168
5.95 TurnDegreesCommand Class Reference	169
5.95.1 Detailed Description	170
5.95.2 Constructor & Destructor Documentation	170
5.95.2.1 TurnDegreesCommand()	170
5.95.3 Member Function Documentation	170
5.95.3.1 on_timeout()	170
5.95.3.2 run()	170
5.96 TurnToHeadingCommand Class Reference	171
5.96.1 Detailed Description	171
5.96.2 Constructor & Destructor Documentation	171
5.96.2.1 TurnToHeadingCommand()	171
5.96.3 Member Function Documentation	172

---

5.96.3.1 <code>on_timeout()</code>	172
5.96.3.2 <code>run()</code>	172
5.97 Vector2D Class Reference	172
5.97.1 Detailed Description	173
5.97.2 Constructor & Destructor Documentation	173
5.97.2.1 <code>Vector2D() [1/2]</code>	173
5.97.2.2 <code>Vector2D() [2/2]</code>	173
5.97.3 Member Function Documentation	174
5.97.3.1 <code>get_dir()</code>	174
5.97.3.2 <code>get_mag()</code>	174
5.97.3.3 <code>get_x()</code>	174
5.97.3.4 <code>get_y()</code>	174
5.97.3.5 <code>normalize()</code>	175
5.97.3.6 <code>operator*()</code>	175
5.97.3.7 <code>operator+()</code>	175
5.97.3.8 <code>operator-()</code>	175
5.97.3.9 <code>point()</code>	176
5.98 VideoPlayer Class Reference	176
5.98.1 Member Function Documentation	176
5.98.1.1 <code>draw()</code>	176
5.98.1.2 <code>update()</code>	177
5.99 WaitUntilCondition Class Reference	177
5.99.1 Detailed Description	178
5.99.2 Member Function Documentation	178
5.99.2.1 <code>run()</code>	178
5.100 WaitUntilUpToSpeedCommand Class Reference	178
5.100.1 Detailed Description	179
5.100.2 Constructor & Destructor Documentation	179
5.100.2.1 <code>WaitUntilUpToSpeedCommand()</code>	179
5.100.3 Member Function Documentation	180
5.100.3.1 <code>run()</code>	180
5.101 <code>screen::WidgetConfig</code> Struct Reference	180
5.102 <code>screen::WidgetPage</code> Class Reference	181
5.102.1 Member Function Documentation	181
5.102.1.1 <code>draw()</code>	181
5.102.1.2 <code>update()</code>	181
<b>6 File Documentation</b>	<b>183</b>
6.1 <code>robot_specs.h</code>	183
6.2 <code>custom_encoder.h</code>	183
6.3 <code>flywheel.h</code>	183
6.4 <code>pl_mpeg.h</code>	184

---

6.5 video.h . . . . .	232
6.6 layout.h . . . . .	232
6.7 lift.h . . . . .	232
6.8 mecanum_drive.h . . . . .	235
6.9 odometry_3wheel.h . . . . .	235
6.10 odometry_base.h . . . . .	236
6.11 odometry_tank.h . . . . .	237
6.12 screen.h . . . . .	237
6.13 tank_drive.h . . . . .	240
6.14 auto_chooser.h . . . . .	241
6.15 auto_command.h . . . . .	241
6.16 basic_command.h . . . . .	243
6.17 command_controller.h . . . . .	244
6.18 delay_command.h . . . . .	244
6.19 drive_commands.h . . . . .	245
6.20 flywheel_commands.h . . . . .	247
6.21 bang_bang.h . . . . .	247
6.22 feedback_base.h . . . . .	248
6.23 feedforward.h . . . . .	248
6.24 motion_controller.h . . . . .	248
6.25 pid.h . . . . .	249
6.26 pidff.h . . . . .	250
6.27 take_back_half.h . . . . .	250
6.28 trapezoid_profile.h . . . . .	251
6.29 generic_auto.h . . . . .	252
6.30 geometry.h . . . . .	252
6.31 graph_drawer.h . . . . .	253
6.32 logger.h . . . . .	253
6.33 math_util.h . . . . .	254
6.34 moving_average.h . . . . .	254
6.35 pure_pursuit.h . . . . .	255
6.36 serializer.h . . . . .	256
6.37 state_machine.h . . . . .	257
6.38 vector2d.h . . . . .	258
<b>Index</b>	<b>261</b>

# Chapter 1

## Core

This is the host repository for the custom VEX libraries used by the RIT VEXU team

Automatically updated documentation is available at [here](#). There is also a downloadable [reference manual](#).

### 1.1 Getting Started

In order to simply use this repo, you can either clone it into your VEXcode project folder, or download the .zip and place it into a core/ subfolder. Then follow the instructions for setting up compilation at [Wiki/BuildSystem](#)

If you wish to contribute, follow the instructions at [Wiki/ProjectSetup](#)

### 1.2 Features

Here is the current feature list this repo provides:

Subsystems (See [Wiki/Subsystems](#)):

- Tank drivetrain (user control / autonomous)
- Mecanum drivetrain (user control / autonomous)
- Odometry
- [Flywheel](#)
- [Lift](#)
- Custom encoders

Utilities (See [Wiki/Utilites](#)):

- [PID](#) controller
- [FeedForward](#) controller
- Trapezoidal motion profile controller
- Pure Pursuit
- Generic auto program builder
- Auto program UI selector
- Mathematical classes ([Vector2D](#), Moving Average)



# Chapter 2

## Hierarchical Index

### 2.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

AutoCommand . . . . .	18
Async . . . . .	14
BasicSolenoidSet . . . . .	22
BasicSpinCommand . . . . .	23
BasicStopCommand . . . . .	25
Branch . . . . .	27
DelayCommand . . . . .	36
DriveForwardCommand . . . . .	38
DriveStopCommand . . . . .	40
DriveToPointCommand . . . . .	42
FlywheelStopCommand . . . . .	58
FlywheelStopMotorsCommand . . . . .	59
FlywheelStopNonTasksCommand . . . . .	61
FunctionCommand . . . . .	62
InOrder . . . . .	70
OdomSetPosition . . . . .	108
Parallel . . . . .	112
PurePursuitCommand . . . . .	130
RepeatUntil . . . . .	132
SpinRPMCommand . . . . .	144
TurnDegreesCommand . . . . .	169
TurnToHeadingCommand . . . . .	171
WaitUntilCondition . . . . .	177
WaitUntilUpToSpeedCommand . . . . .	178
screen::ButtonConfig . . . . .	28
screen::ButtonWidget . . . . .	28
screen::CheckboxConfig . . . . .	30
CommandController . . . . .	30
Condition . . . . .	33
AndCondition . . . . .	13
FunctionCondition . . . . .	63
IfTimePassed . . . . .	69
OrCondition . . . . .	110
TimesTestedCondition . . . . .	164
vex::encoder	

CustomEncoder . . . . .	34
AutoChooser::entry_t . . . . .	44
Feedback . . . . .	47
BangBang . . . . .	20
MotionController . . . . .	86
PID . . . . .	115
PIDFF . . . . .	121
TakeBackHalf . . . . .	150
FeedForward . . . . .	49
FeedForward::ff_config_t . . . . .	51
Filter . . . . .	52
ExponentialMovingAverage . . . . .	45
MovingAverage . . . . .	91
Flywheel . . . . .	53
GenericAuto . . . . .	65
GraphDrawer . . . . .	67
PurePursuit::hermite_point . . . . .	69
screen::LabelConfig . . . . .	72
Lift< T > . . . . .	72
Lift< T >::lift_cfg_t . . . . .	76
Logger . . . . .	77
MotionController::m_profile_cfg_t . . . . .	79
Mat2 . . . . .	80
StateMachine< System, IDType, Message, delay_ms, do_log >::MaybeMessage . . . . .	80
MecanumDrive . . . . .	82
MecanumDrive::mecanumdrive_config_t . . . . .	85
motion_t . . . . .	85
Odometry3Wheel::odometry3wheel_cfg_t . . . . .	96
OdometryBase . . . . .	97
Odometry3Wheel . . . . .	93
OdometryTank . . . . .	105
screen::Page . . . . .	111
AutoChooser . . . . .	15
FlywheelPage . . . . .	57
MotionControllerPage . . . . .	90
VideoPlayer . . . . .	176
screen::FunctionPage . . . . .	64
screen::OdometryPage . . . . .	103
screen::PIDPage . . . . .	125
screen::StatsPage . . . . .	149
screen::WidgetPage . . . . .	181
parallel_runner_info . . . . .	114
PurePursuit::Path . . . . .	114
PID::pid_config_t . . . . .	120
plm_frame_t . . . . .	126
plm_packet_t . . . . .	127
plm_plane_t . . . . .	127
plm_samples_t . . . . .	127
point_t . . . . .	127
pose_t . . . . .	129
Rect . . . . .	131
robot_specs_t . . . . .	135
screen::ScreenData . . . . .	136
screen::ScreenRect . . . . .	136
Serializer . . . . .	137
screen::SizedWidget . . . . .	142
SliderCfg . . . . .	142

screen::SliderConfig . . . . .	142
screen::SliderWidget . . . . .	142
PurePursuit::spline . . . . .	146
StateMachine< System, IDType, Message, delay_ms, do_log >::State . . . . .	146
StateMachine< System, IDType, Message, delay_ms, do_log > . . . . .	147
TankDrive . . . . .	152
screen::TextConfig . . . . .	164
trapezoid_profile_segment_t . . . . .	164
TrapezoidProfile . . . . .	165
Vector2D . . . . .	172
screen::WidgetConfig . . . . .	180



# Chapter 3

## Class Index

### 3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

AndCondition . . . . .	13
Async	
<b>Async</b> runs a command asynchronously will simply let it go and never look back THIS HAS A VERY NICHE USE CASE. THINK ABOUT IF YOU REALLY NEED IT . . . . .	14
AutoChooser . . . . .	15
AutoCommand . . . . .	18
BangBang . . . . .	20
BasicSolenoidSet . . . . .	22
BasicSpinCommand . . . . .	23
BasicStopCommand . . . . .	25
Branch	
<b>Branch</b> chooses from multiple options at runtime. the function decider returns an index into the choices vector If you wish to make no choice and skip this section, return NO_CHOICE; any choice that is out of bounds set to NO_CHOICE . . . . .	27
screen::ButtonConfig . . . . .	28
screen::ButtonWidget	
Widget that does something when you tap it. The function is only called once when you first tap it	28
screen::CheckboxConfig . . . . .	30
CommandController . . . . .	30
Condition . . . . .	33
CustomEncoder . . . . .	34
DelayCommand . . . . .	36
DriveForwardCommand . . . . .	38
DriveStopCommand . . . . .	40
DriveToPointCommand . . . . .	42
AutoChooser::entry_t . . . . .	44
ExponentialMovingAverage . . . . .	45
Feedback . . . . .	47
FeedForward . . . . .	49
FeedForward::ff_config_t . . . . .	51
Filter . . . . .	52
Flywheel . . . . .	53
FlywheelPage . . . . .	57
FlywheelStopCommand . . . . .	58
FlywheelStopMotorsCommand . . . . .	59

FlywheelStopNonTasksCommand	61
FunctionCommand	62
FunctionCondition	
FunctionCondition	is a quick and dirty <a href="#">Condition</a> to wrap some expression that should be evaluated at runtime
	63
screen::FunctionPage	
Simple page that stores no internal data. the draw and update functions use only global data rather than storing anything	64
GenericAuto	65
GraphDrawer	67
PurePursuit::hermite_point	69
IfTimePassed	
IfTimePassed	tests based on time since the command controller was constructed. Returns true if elapsed time > time_s
	69
InOrder	
InOrder	runs its commands sequentially then continues. How to handle timeout in this case.
Automatically set it to sum of commands timeouts?	70
screen::LabelConfig	72
Lift< T >	72
Lift< T >::lift_cfg_t	76
Logger	
Class to simplify writing to files	77
MotionController::m_profile_cfg_t	79
Mat2	80
StateMachine< System, IDType, Message, delay_ms, do_log >::MaybeMessage	
MaybeMessage	a message of Message type or nothing
MaybeMessage	m = {}; // empty
MaybeMessage	m = Message::EnumField1
MecanumDrive	82
MecanumDrive::mecanumdrive_config_t	85
motion_t	85
MotionController	86
MotionControllerPage	90
MovingAverage	91
Odometry3Wheel	93
Odometry3Wheel::odometry3wheel_cfg_t	96
OdometryBase	97
screen::OdometryPage	
Page	that shows odometry position and rotation and a map (if an sd card with the file is on)
	103
OdometryTank	105
OdomSetPosition	108
OrCondition	110
screen::Page	
Page	describes one part of the screen slideshow
	111
Parallel	
Parallel	runs multiple commands in parallel and waits for all to finish before continuing. if none finish before this command's timeout, it will call on_timeout on all children continue
	112
parallel_runner_info	114
PurePursuit::Path	114
PID	115
PID::pid_config_t	120
PIDFF	121
screen::PIDPage	
PIDPage	provides a way to tune a pid controller on the screen
	125
plm_frame_t	126
plm_packet_t	127
plm_plane_t	127
plm_samples_t	127
point_t	127

pose_t . . . . .	129
PurePursuitCommand . . . . .	130
Rect . . . . .	131
RepeatUntil . . . . .	132
robot_specs_t . . . . .	135
screen::ScreenData Holds the data that will be passed to the screen thread you probably shouldnt have to use it . . . . .	136
screen::ScreenRect . . . . .	136
Serializer Serializes Arbitrary data to a file on the SD Card . . . . .	137
screen::SizedWidget . . . . .	142
SliderCfg . . . . .	142
screen::SliderConfig . . . . .	142
screen::SliderWidget Widget that updates a double value. Updates by reference so watch out for race conditions cuz the screen stuff lives on another thread . . . . .	142
SpinRPMCommand . . . . .	144
PurePursuit::spline . . . . .	146
StateMachine< System, IDType, Message, delay_ms, do_log >::State . . . . .	146
StateMachine< System, IDType, Message, delay_ms, do_log > State Machine :)))))) A fun fun way of controlling stateful subsystems - used in the 2023-2024 Over Under game for our overly complex intake-cata subsystem (see there for an example) The statemachine runs in a background thread and a user thread can interact with it through current_state and send_message . . . . .	147
screen::StatsPage Draws motor stats and battery stats to the screen . . . . .	149
TakeBackHalf A velocity controller . . . . .	150
TankDrive . . . . .	152
screen::TextConfig . . . . .	164
TimesTestedCondition . . . . .	164
trapezoid_profile_segment_t . . . . .	164
TrapezoidProfile . . . . .	165
TurnDegreesCommand . . . . .	169
TurnToHeadingCommand . . . . .	171
Vector2D . . . . .	172
VideoPlayer . . . . .	176
WaitUntilCondition Waits until the condition is true . . . . .	177
WaitUntilUpToSpeedCommand . . . . .	178
screen::WidgetConfig . . . . .	180
screen::WidgetPage . . . . .	181



# Chapter 4

## File Index

### 4.1 File List

Here is a list of all documented files with brief descriptions:

include/robot_specs.h . . . . .	183
include/subsystems/custom_encoder.h . . . . .	183
include/subsystems/flywheel.h . . . . .	183
include/subsystems/layout.h . . . . .	232
include/subsystems/lift.h . . . . .	232
include/subsystems/mecanum_drive.h . . . . .	235
include/subsystems/screen.h . . . . .	237
include/subsystems/tank_drive.h . . . . .	240
include/subsystems/fun/pl_mpeg.h . . . . .	184
include/subsystems/fun/video.h . . . . .	232
include/subsystems/odometry/odometry_3wheel.h . . . . .	235
include/subsystems/odometry/odometry_base.h . . . . .	236
include/subsystems/odometry/odometry_tank.h . . . . .	237
include/utils/auto_chooser.h . . . . .	241
include/utils/generic_auto.h . . . . .	252
include/utils/geometry.h . . . . .	252
include/utils/graph_drawer.h . . . . .	253
include/utils/logger.h . . . . .	253
include/utils/math_util.h . . . . .	254
include/utils/moving_average.h . . . . .	254
include/utils/pure_pursuit.h . . . . .	255
include/utils/serializer.h . . . . .	256
include/utils/state_machine.h . . . . .	257
include/utils/vector2d.h . . . . .	258
include/utils/command_structure/auto_command.h . . . . .	241
include/utils/command_structure/basic_command.h . . . . .	243
include/utils/command_structure/command_controller.h . . . . .	244
include/utils/command_structure/delay_command.h . . . . .	244
include/utils/command_structure/drive_commands.h . . . . .	245
include/utils/command_structure/flywheel_commands.h . . . . .	247
include/utils/controls/bang_bang.h . . . . .	247
include/utils/controls/feedback_base.h . . . . .	248
include/utils/controls/feedforward.h . . . . .	248
include/utils/controls/motion_controller.h . . . . .	248
include/utils/controls/pid.h . . . . .	249
include/utils/controls/pidff.h . . . . .	250
include/utils/controls/take_back_half.h . . . . .	250
include/utils/controls/trapezoid_profile.h . . . . .	251

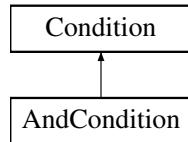


# Chapter 5

## Class Documentation

### 5.1 AndCondition Class Reference

Inheritance diagram for AndCondition:



#### Public Member Functions

- **AndCondition** ([Condition](#) \*A, [Condition](#) \*B)
- bool [test](#) () override

#### Public Member Functions inherited from [Condition](#)

- [Condition](#) \* **Or** ([Condition](#) \*b)
- [Condition](#) \* **And** ([Condition](#) \*b)

#### 5.1.1 Member Function Documentation

##### 5.1.1.1 [test\(\)](#)

```
bool AndCondition::test ( ) [inline], [override], [virtual]
```

Implements [Condition](#).

The documentation for this class was generated from the following file:

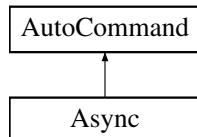
- src/utils/command\_structure/auto\_command.cpp

## 5.2 Async Class Reference

[Async](#) runs a command asynchronously will simply let it go and never look back THIS HAS A VERY NICHE USE CASE. THINK ABOUT IF YOU REALLY NEED IT.

```
#include <auto_command.h>
```

Inheritance diagram for Async:



### Public Member Functions

- [Async \(AutoCommand \\*cmd\)](#)
- bool [run \(\)](#) override

### Public Member Functions inherited from [AutoCommand](#)

- virtual void [on\\_timeout \(\)](#)
- [AutoCommand \\* withTimeout \(double t\\_seconds\)](#)
- [AutoCommand \\* withCancelCondition \(Condition \\*true\\_to\\_end\)](#)

### Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition \\* true\\_to\\_end](#) = nullptr

### Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double [default\\_timeout](#) = 10.0

#### 5.2.1 Detailed Description

[Async](#) runs a command asynchronously will simply let it go and never look back THIS HAS A VERY NICHE USE CASE. THINK ABOUT IF YOU REALLY NEED IT.

## 5.2.2 Member Function Documentation

### 5.2.2.1 run()

```
bool Async::run ( ) [override], [virtual]
```

Executes the command Overridden by child classes

Returns

true when the command is finished, false otherwise

Reimplemented from [AutoCommand](#).

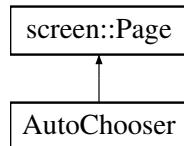
The documentation for this class was generated from the following files:

- [include/utils/command\\_structure/auto\\_command.h](#)
- [src/utils/command\\_structure/auto\\_command.cpp](#)

## 5.3 AutoChooser Class Reference

```
#include <auto_chooser.h>
```

Inheritance diagram for AutoChooser:



### Classes

- struct [entry\\_t](#)

### Public Member Functions

- [AutoChooser](#) (`std::vector< std::string > paths, size_t def=0)`
- void [update](#) (`bool was_pressed, int x, int y)`  
*collect data, respond to screen input, do fast things (runs at 50hz even if you're not focused on this Page (only drawn page gets touch updates))*
- void [draw](#) (`vex::brain::lcd &, bool first_draw, unsigned int frame_number)`  
*draw stored data to the screen (runs at 10 hz and only runs if this page is in front)*
- `size_t get\_choice ()`

### Protected Attributes

- `size_t choice`
- `std::vector< entry\_t > list`

## Static Protected Attributes

- static const size\_t **width** = 380
- static const size\_t **height** = 220

### 5.3.1 Detailed Description

Autochooser is a utility to make selecting robot autonomous programs easier source: RIT VexU Wiki During a season, we usually code between 4 and 6 autonomous programs. Most teams will change their entire robot program as a way of choosing autonomy but this may cause issues if you have an emergency patch to upload during a competition. This class was built as a way of using the robot screen to list autonomous programs, and the touchscreen to select them.

### 5.3.2 Constructor & Destructor Documentation

#### 5.3.2.1 AutoChooser()

```
AutoChooser::AutoChooser (
    std::vector< std::string > paths,
    size_t def = 0 )
```

Initialize the auto-chooser. This class places a choice menu on the brain screen, so the driver can choose which autonomous to run.

#### Parameters

<i>brain</i>	the brain on which to draw the selection boxes
--------------	------------------------------------------------

### 5.3.3 Member Function Documentation

#### 5.3.3.1 draw()

```
void AutoChooser::draw (
    vex::brain::lcd & screen,
    bool first_draw,
    unsigned int frame_number ) [virtual]
```

draw stored data to the screen (runs at 10 hz and only runs if this page is in front)

#### Parameters

<i>first_draw</i>	true if we just switched to this page
<i>frame_number</i>	frame of drawing we are on (basically an animation tick)

Reimplemented from [screen::Page](#).

### 5.3.3.2 get\_choice()

```
size_t AutoChooser::get_choice ( )
```

Get the currently selected auto choice

#### Returns

the identifier to the auto path

Return the selected autonomous

### 5.3.3.3 update()

```
void AutoChooser::update (
    bool was_pressed,
    int x,
    int y ) [virtual]
```

collect data, respond to screen input, do fast things (runs at 50hz even if you're not focused on this Page (only drawn page gets touch updates))

#### Parameters

<i>was_pressed</i>	true if the screen has been pressed
<i>x</i>	x position of screen press (if the screen was pressed)
<i>y</i>	y position of screen press (if the screen was pressed)

Reimplemented from [screen::Page](#).

## 5.3.4 Member Data Documentation

### 5.3.4.1 choice

```
size_t AutoChooser::choice [protected]
```

the current choice of auto

### 5.3.4.2 list

```
std::vector<entry\_t> AutoChooser::list [protected]
```

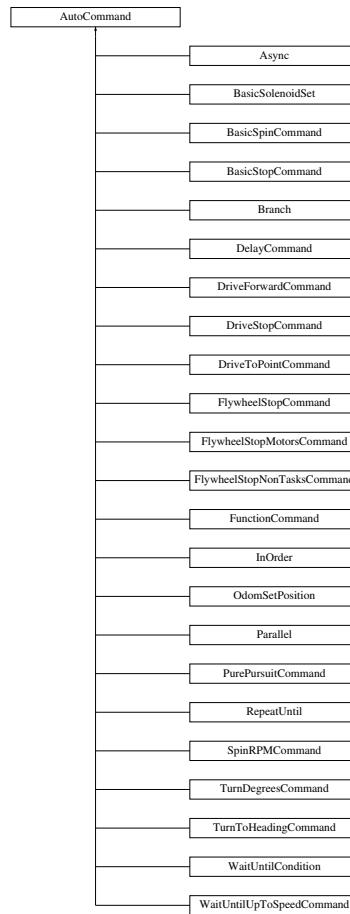
< a list of all possible auto choices

The documentation for this class was generated from the following files:

- [include/utils/auto\\_chooser.h](#)
- [src/utils/auto\\_chooser.cpp](#)

## 5.4 AutoCommand Class Reference

Inheritance diagram for AutoCommand:



### Public Member Functions

- virtual bool `run ()`
- virtual void `on_timeout ()`
- `AutoCommand * withTimeout (double t_seconds)`
- `AutoCommand * withCancelCondition (Condition *true_to_end)`

### Public Attributes

- double `timeout_seconds` = `default_timeout`
- `Condition * true_to_end` = `nullptr`

### Static Public Attributes

- static constexpr double `default_timeout` = 10.0

## 5.4.1 Member Function Documentation

### 5.4.1.1 on\_timeout()

```
virtual void AutoCommand::on_timeout ( ) [inline], [virtual]
```

What to do if we timeout instead of finishing. timeout is specified by the timeout seconds in the constructor

Reimplemented in [InOrder](#), [Parallel](#), [Branch](#), [RepeatUntil](#), [DriveForwardCommand](#), [TurnDegreesCommand](#), [TurnToHeadingCommand](#), [PurePursuitCommand](#), and [DriveStopCommand](#).

### 5.4.1.2 run()

```
virtual bool AutoCommand::run ( ) [inline], [virtual]
```

Executes the command Overridden by child classes

#### Returns

true when the command is finished, false otherwise

Reimplemented in [FunctionCommand](#), [WaitUntilCondition](#), [InOrder](#), [Parallel](#), [Branch](#), [Async](#), [RepeatUntil](#), [BasicSpinCommand](#), [BasicStopCommand](#), [BasicSolenoidSet](#), [DelayCommand](#), [DriveForwardCommand](#), [TurnDegreesCommand](#), [DriveToPointCommand](#), [TurnToHeadingCommand](#), [PurePursuitCommand](#), [DriveStopCommand](#), [OdomSetPosition](#), [SpinRPMCommand](#), [WaitUntilUpToSpeedCommand](#), [FlywheelStopCommand](#), and [FlywheelStopMotorsCommand](#)

## 5.4.2 Member Data Documentation

### 5.4.2.1 timeout\_seconds

```
double AutoCommand::timeout_seconds = default_timeout
```

How long to run until we cancel this command. If the command is cancelled, [on\\_timeout\(\)](#) is called to allow any cleanup from the function. If the timeout\_seconds <= 0, no timeout will be applied and this command will run forever. A timeout can come in handy for some commands that can not reach the end due to some physical limitation such as

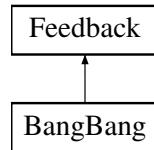
- a drive command hitting a wall and not being able to reach its target
- a command that waits until something is up to speed that never gets up to speed because of battery voltage
- something else...

The documentation for this class was generated from the following file:

- include/utils/command\_structure/auto\_command.h

## 5.5 BangBang Class Reference

Inheritance diagram for BangBang:



### Public Member Functions

- **BangBang** (double threshold, double low, double high)
- void **init** (double start\_pt, double set\_pt, double start\_vel=0.0, double end\_vel=0.0) override
- double **update** (double val) override
- double **get** () override
- void **set\_limits** (double lower, double upper) override
- bool **is\_on\_target** () override

### 5.5.1 Member Function Documentation

#### 5.5.1.1 get()

```
double BangBang::get () [override], [virtual]
```

##### Returns

the last saved result from the feedback controller

Implements [Feedback](#).

#### 5.5.1.2 init()

```
void BangBang::init (
    double start_pt,
    double set_pt,
    double start_vel = 0.0,
    double end_vel = 0.0 ) [override], [virtual]
```

Initialize the feedback controller for a movement

##### Parameters

<i>start_pt</i>	the current sensor value
<i>set_pt</i>	where the sensor value should be
<i>start_vel</i>	Movement starting velocity
<i>end_vel</i>	Movement ending velocity

Implements [Feedback](#).

#### 5.5.1.3 `is_on_target()`

```
bool BangBang::is_on_target ( ) [override], [virtual]
```

##### Returns

true if the feedback controller has reached it's setpoint

Implements [Feedback](#).

#### 5.5.1.4 `set_limits()`

```
void BangBang::set_limits (
    double lower,
    double upper ) [override], [virtual]
```

Clamp the upper and lower limits of the output. If both are 0, no limits should be applied.

##### Parameters

<i>lower</i>	Upper limit
<i>upper</i>	Lower limit

Implements [Feedback](#).

#### 5.5.1.5 `update()`

```
double BangBang::update (
    double val ) [override], [virtual]
```

Iterate the feedback loop once with an updated sensor value

##### Parameters

<i>val</i>	value from the sensor
------------	-----------------------

##### Returns

feedback loop result

Implements [Feedback](#).

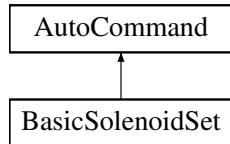
The documentation for this class was generated from the following files:

- include/utils/controls/bang\_bang.h
- src/utils/controls/bang\_bang.cpp

## 5.6 BasicSolenoidSet Class Reference

```
#include <basic_command.h>
```

Inheritance diagram for BasicSolenoidSet:



### Public Member Functions

- **BasicSolenoidSet** (vex::pneumatics &solenoid, bool setting)  
*Construct a new BasicSolenoidSet Command.*
- bool **run** () override  
*Runs the BasicSolenoidSet Overrides run command from AutoCommand.*

### Public Member Functions inherited from AutoCommand

- virtual void **on\_timeout** ()
- **AutoCommand** \* **withTimeout** (double t\_seconds)
- **AutoCommand** \* **withCancelCondition** (**Condition** \*true\_to\_end)

### Additional Inherited Members

#### Public Attributes inherited from AutoCommand

- double **timeout\_seconds** = default\_timeout
- **Condition** \* **true\_to\_end** = nullptr

#### Static Public Attributes inherited from AutoCommand

- static constexpr double **default\_timeout** = 10.0

### 5.6.1 Detailed Description

[AutoCommand](#) wrapper class for [BasicSolenoidSet](#) Using the Vex hardware functions

### 5.6.2 Constructor & Destructor Documentation

#### 5.6.2.1 BasicSolenoidSet()

```
BasicSolenoidSet::BasicSolenoidSet (
    vex::pneumatics & solenoid,
    bool setting )
```

Construct a new [BasicSolenoidSet](#) Command.

**Parameters**

<i>solenoid</i>	Solenoid being set
<i>setting</i>	Setting of the solenoid in boolean (true,false)

**5.6.3 Member Function Documentation****5.6.3.1 run()**

```
bool BasicSolenoidSet::run ( ) [override], [virtual]
```

Runs the [BasicSolenoidSet](#) Overrides run command from [AutoCommand](#).

**Returns**

True Command runs once

Reimplemented from [AutoCommand](#).

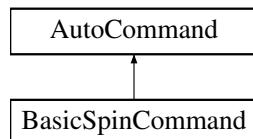
The documentation for this class was generated from the following files:

- include/utils/command\_structure/basic\_command.h
- src/utils/command\_structure/basic\_command.cpp

**5.7 BasicSpinCommand Class Reference**

```
#include <basic_command.h>
```

Inheritance diagram for BasicSpinCommand:

**Public Types**

- enum **type** { **percent** , **voltage** , **veocity** }

**Public Member Functions**

- [\*\*BasicSpinCommand\*\*](#) (vex::motor &motor, vex::directionType dir, BasicSpinCommand::type setting, double power)

*Construct a new BasicSpinCommand.*

- bool [\*\*run\*\*](#) () override

*Runs the BasicSpinCommand Overrides run from Auto Command.*

## Public Member Functions inherited from [AutoCommand](#)

- virtual void [on\\_timeout \(\)](#)
- [AutoCommand \\* withTimeout](#) (double t\_seconds)
- [AutoCommand \\* withCancelCondition](#) ([Condition](#) \*true\_to\_end)

## Additional Inherited Members

## Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition \\* true\\_to\\_end](#) = nullptr

## Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double [default\\_timeout](#) = 10.0

### 5.7.1 Detailed Description

[AutoCommand](#) wrapper class for [BasicSpinCommand](#) using the vex hardware functions

### 5.7.2 Constructor & Destructor Documentation

#### 5.7.2.1 [BasicSpinCommand\(\)](#)

```
BasicSpinCommand::BasicSpinCommand (
    vex::motor & motor,
    vex::directionType dir,
    BasicSpinCommand::type setting,
    double power )
```

Construct a new [BasicSpinCommand](#).

a BasicMotorSpin Command

#### Parameters

<i>motor</i>	Motor to spin
<i>direc</i>	Direction of motor spin
<i>setting</i>	Power setting in volts,percentage,velocity
<i>power</i>	Value of desired power
<i>motor</i>	Motor port to spin
<i>dir</i>	Direction for spinning
<i>setting</i>	Power setting in volts,percentage,velocity
<i>power</i>	Value of desired power

### 5.7.3 Member Function Documentation

#### 5.7.3.1 run()

```
bool BasicSpinCommand::run ( ) [override], [virtual]
```

Runs the [BasicSpinCommand](#) Overrides run from Auto Command.

Run the [BasicSpinCommand](#) Overrides run from Auto Command.

##### Returns

True [Async](#) running command

True Command runs once

Reimplemented from [AutoCommand](#).

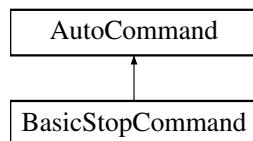
The documentation for this class was generated from the following files:

- include/utils/command\_structure/basic\_command.h
- src/utils/command\_structure/basic\_command.cpp

## 5.8 BasicStopCommand Class Reference

```
#include <basic_command.h>
```

Inheritance diagram for BasicStopCommand:



### Public Member Functions

- [BasicStopCommand](#) (vex::motor &motor, vex::brakeType setting)  
*Construct a new BasicMotorStop Command.*
- bool [run \(\)](#) override  
*Runs the BasicMotorStop Command Overrides run command from [AutoCommand](#).*

### Public Member Functions inherited from [AutoCommand](#)

- virtual void [on\\_timeout \(\)](#)
- [AutoCommand \\* withTimeout](#) (double t\_seconds)
- [AutoCommand \\* withCancelCondition](#) ([Condition](#) \*true\_to\_end)

## Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- double `timeout_seconds` = `default_timeout`
- `Condition * true_to_end` = `nullptr`

### Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double `default_timeout` = 10.0

## 5.8.1 Detailed Description

[AutoCommand](#) wrapper class for [BasicStopCommand](#) Using the Vex hardware functions

## 5.8.2 Constructor & Destructor Documentation

### 5.8.2.1 [BasicStopCommand\(\)](#)

```
BasicStopCommand::BasicStopCommand (
    vex::motor & motor,
    vex::brakeType setting )
```

Construct a new BasicMotorStop Command.

Construct a BasicMotorStop Command.

#### Parameters

<code>motor</code>	The motor to stop
<code>setting</code>	The brake setting for the motor
<code>motor</code>	Motor to stop
<code>setting</code>	Braketype setting brake,coast,hold

## 5.8.3 Member Function Documentation

### 5.8.3.1 [run\(\)](#)

```
bool BasicStopCommand::run ( ) [override], [virtual]
```

Runs the BasicMotorStop Command Overrides run command from [AutoCommand](#).

Runs the BasicMotorStop command Ovverides run command from [AutoCommand](#).

**Returns**

True Command runs once

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

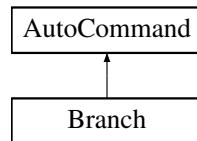
- include/utils/command\_structure/basic\_command.h
- src/utils/command\_structure/basic\_command.cpp

## 5.9 Branch Class Reference

[Branch](#) chooses from multiple options at runtime. the function decider returns an index into the choices vector If you wish to make no choice and skip this section, return NO\_CHOICE; any choice that is out of bounds set to NO\_CHOICE.

```
#include <auto_command.h>
```

Inheritance diagram for Branch:



### Public Member Functions

- **Branch** ([Condition](#) \*cond, [AutoCommand](#) \*false\_choice, [AutoCommand](#) \*true\_choice)
- bool [run](#) () override
- void [on\\_timeout](#) () override

### Public Member Functions inherited from [AutoCommand](#)

- [AutoCommand](#) \* [withTimeout](#) (double t\_seconds)
- [AutoCommand](#) \* [withCancelCondition](#) ([Condition](#) \*true\_to\_end)

### Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition](#) \* [true\\_to\\_end](#) = nullptr

### Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double [default\\_timeout](#) = 10.0

### 5.9.1 Detailed Description

[Branch](#) chooses from multiple options at runtime. the function decider returns an index into the choices vector If you wish to make no choice and skip this section, return NO\_CHOICE; any choice that is out of bounds set to NO\_CHOICE.

### 5.9.2 Member Function Documentation

#### 5.9.2.1 on\_timeout()

```
void Branch::on_timeout ( ) [override], [virtual]
```

What to do if we timeout instead of finishing. timeout is specified by the timeout seconds in the constructor

Reimplemented from [AutoCommand](#).

#### 5.9.2.2 run()

```
bool Branch::run ( ) [override], [virtual]
```

Executes the command Overridden by child classes

Returns

true when the command is finished, false otherwise

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

- include/utils/command\_structure/auto\_command.h
- src/utils/command\_structure/auto\_command.cpp

## 5.10 screen::ButtonConfig Struct Reference

### Public Attributes

- std::function< void()> **onclick**

The documentation for this struct was generated from the following file:

- include/subsystems/screen.h

## 5.11 screen::ButtonWidget Class Reference

Widget that does something when you tap it. The function is only called once when you first tap it.

```
#include <screen.h>
```

## Public Member Functions

- **ButtonWidget** (std::function< void(void)> onpress, `Rect` rect, std::string name)  
*Create a Button widget.*
- **ButtonWidget** (void(\*onpress)(), `Rect` rect, std::string name)  
*Create a Button widget.*
- bool **update** (bool was\_pressed, int x, int y)  
*responds to user input*
- void **draw** (vex::brain::lcd &, bool first\_draw, unsigned int frame\_number)  
*draws the button to the screen*

### 5.11.1 Detailed Description

Widget that does something when you tap it. The function is only called once when you first tap it.

### 5.11.2 Constructor & Destructor Documentation

#### 5.11.2.1 **ButtonWidget()** [1/2]

```
screen::ButtonWidget::ButtonWidget (
    std::function< void(void)> onpress,
    Rect rect,
    std::string name ) [inline]
```

Create a Button widget.

##### Parameters

<i>onpress</i>	the function to be called when the button is tapped
<i>rect</i>	the area the button should take up on the screen
<i>name</i>	the label put on the button

#### 5.11.2.2 **ButtonWidget()** [2/2]

```
screen::ButtonWidget::ButtonWidget (
    void(*)() onpress,
    Rect rect,
    std::string name ) [inline]
```

Create a Button widget.

##### Parameters

<i>onpress</i>	the function to be called when the button is tapped
<i>rect</i>	the area the button should take up on the screen
<i>name</i>	the label put on the button

### 5.11.3 Member Function Documentation

#### 5.11.3.1 update()

```
bool screen::ButtonWidget::update (
    bool was_pressed,
    int x,
    int y )
```

responds to user input

##### Parameters

<i>was_pressed</i>	if the screen is pressed
<i>x</i>	x position if the screen was pressed
<i>y</i>	y position if the screen was pressed

##### Returns

true if the button was pressed

The documentation for this class was generated from the following files:

- include/subsystems/screen.h
- src/subsystems/screen.cpp

## 5.12 screen::CheckboxConfig Struct Reference

### Public Attributes

- std::function< void(bool)> **onupdate**

The documentation for this struct was generated from the following file:

- include/subsystems/screen.h

## 5.13 CommandController Class Reference

```
#include <command_controller.h>
```

## Public Member Functions

- **CommandController ()**  
*Create an empty [CommandController](#). Add Command with [CommandController::add\(\)](#)*
- **CommandController (std::initializer\_list< [AutoCommand](#) \* > cmd)**  
*Create a [CommandController](#) with commands pre added. More can be added with [CommandController::add\(\)](#)*
- void **add (std::vector< [AutoCommand](#) \* > cmd)**
- void **add ([AutoCommand](#) \*cmd, double timeout\_seconds=10.0)**
- void **add (std::vector< [AutoCommand](#) \* > cmd, double timeout\_sec)**
- void **add\_delay (int ms)**
- void **add\_cancel\_func (std::function< bool(void)> true\_if\_cancel)**  
*add\_cancel\_func specifies that when this func evaluates to true, to cancel the command controller*
- void **run ()**
- bool **last\_command\_timed\_out ()**

### 5.13.1 Detailed Description

File: [command\\_controller.h](#) Desc: A [CommandController](#) manages the AutoCommands that make up an autonomous route. The AutoCommands are kept in a queue and get executed and removed from the queue in FIFO order.

### 5.13.2 Constructor & Destructor Documentation

#### 5.13.2.1 CommandController()

```
CommandController::CommandController (
    std::initializer_list< AutoCommand * > cmd ) [inline]
```

Create a [CommandController](#) with commands pre added. More can be added with [CommandController::add\(\)](#)

##### Parameters

<i>cmd</i>	
------------	--

### 5.13.3 Member Function Documentation

#### 5.13.3.1 add() [1/3]

```
void CommandController::add (
    AutoCommand * cmd,
    double timeout_seconds = 10.0 )
```

File: [command\\_controller.cpp](#) Desc: A [CommandController](#) manages the AutoCommands that make up an autonomous route. The AutoCommands are kept in a queue and get executed and removed from the queue in FIFO order. Adds a command to the queue

##### Parameters

<i>cmd</i>	the <a href="#">AutoCommand</a> we want to add to our list
<i>timeout_seconds</i> Generated by Doxygen	the number of seconds we will let the command run for. If it exceeds this, we cancel it and run on_timeout

### 5.13.3.2 add() [2/3]

```
void CommandController::add (
    std::vector< AutoCommand * > cmds )
```

Adds a command to the queue

#### Parameters

<i>cmd</i>	the <a href="#">AutoCommand</a> we want to add to our list
<i>timeout_seconds</i>	the number of seconds we will let the command run for. If it exceeds this, we cancel it and run on_timeout. if it is $\leq 0$ no time out will be applied

Add multiple commands to the queue. No timeout here.

#### Parameters

<i>cmds</i>	the AutoCommands we want to add to our list
-------------	---------------------------------------------

### 5.13.3.3 add() [3/3]

```
void CommandController::add (
    std::vector< AutoCommand * > cmds,
    double timeout_sec )
```

Add multiple commands to the queue. No timeout here.

#### Parameters

<i>cmds</i>	the AutoCommands we want to add to our list Add multiple commands to the queue. No timeout here.
<i>cmds</i>	the AutoCommands we want to add to our list
<i>timeout_sec</i>	timeout in seconds to apply to all commands if they are still the default

Add multiple commands to the queue. No timeout here.

#### Parameters

<i>cmds</i>	the AutoCommands we want to add to our list
<i>timeout</i>	timeout in seconds to apply to all commands if they are still the default

### 5.13.3.4 add\_cancel\_func()

```
void CommandController::add_cancel_func (
    std::function< bool(void)> true_if_cancel )
```

`add_cancel_func` specifies that when this func evaluates to true, to cancel the command controller

**Parameters**

<i>true_if_cancel</i>	a function that returns true when we want to cancel the command controller
-----------------------	----------------------------------------------------------------------------

**5.13.3.5 add\_delay()**

```
void CommandController::add_delay (
    int ms )
```

Adds a command that will delay progression of the queue

**Parameters**

<i>ms</i>	- number of milliseconds to wait before continuing execution of autonomous
-----------	----------------------------------------------------------------------------

**5.13.3.6 last\_command\_timed\_out()**

```
bool CommandController::last_command_timed_out ( )
```

`last_command_timed_out` tells how the last command ended. Use this if you want to make decisions based on the end of the last command

**Returns**

true if the last command timed out. false if it finished regularly

**5.13.3.7 run()**

```
void CommandController::run ( )
```

Begin execution of the queue. Execute and remove commands in FIFO order

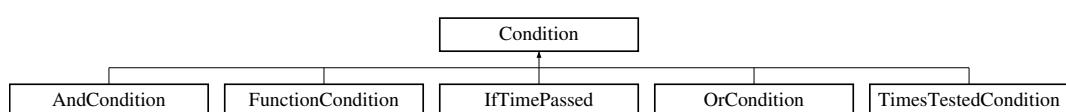
The documentation for this class was generated from the following files:

- include/utils/command\_structure/command\_controller.h
- src/utils/command\_structure/command\_controller.cpp

**5.14 Condition Class Reference**

```
#include <auto_command.h>
```

Inheritance diagram for Condition:



## Public Member Functions

- `Condition * Or (Condition *b)`
- `Condition * And (Condition *b)`
- virtual bool `test ()=0`

### 5.14.1 Detailed Description

File: `auto_command.h` Desc: Interface for module-specific commands A `Condition` is a function that returns true or false `is_even` is a predicate that would return true if a number is even For our purposes, a `Condition` is a choice to be made at runtime `drive_sys.reached_point(10, 30)` is a predicate `time.has_elapsed(10, vex::seconds)` is a predicate extend this class for different choices you wish to make

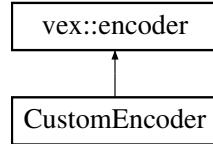
The documentation for this class was generated from the following files:

- `include/utils/command_structure/auto_command.h`
- `src/utils/command_structure/auto_command.cpp`

## 5.15 CustomEncoder Class Reference

```
#include <custom_encoder.h>
```

Inheritance diagram for CustomEncoder:



## Public Member Functions

- `CustomEncoder (vex::triport::port &port, double ticks_per_rev)`
- void `setRotation (double val, vex::rotationUnits units)`
- void `setPosition (double val, vex::rotationUnits units)`
- double `rotation (vex::rotationUnits units)`
- double `position (vex::rotationUnits units)`
- double `velocity (vex::velocityUnits units)`

### 5.15.1 Detailed Description

A wrapper class for the vex encoder that allows the use of 3rd party encoders with different tick-per-revolution values.

## 5.15.2 Constructor & Destructor Documentation

### 5.15.2.1 CustomEncoder()

```
CustomEncoder::CustomEncoder (
    vex::triport::port & port,
    double ticks_per_rev )
```

Construct an encoder with a custom number of ticks

**Parameters**

<i>port</i>	the triport port on the brain the encoder is plugged into
<i>ticks_per_rev</i>	the number of ticks the encoder will report for one revolution

## 5.15.3 Member Function Documentation

### 5.15.3.1 position()

```
double CustomEncoder::position (
    vex::rotationUnits units )
```

get the position that the encoder is at

**Parameters**

<i>units</i>	the unit we want the return value to be in
--------------	--------------------------------------------

**Returns**

the position of the encoder in the units specified

### 5.15.3.2 rotation()

```
double CustomEncoder::rotation (
    vex::rotationUnits units )
```

get the rotation that the encoder is at

**Parameters**

<i>units</i>	the unit we want the return value to be in
--------------	--------------------------------------------

**Returns**

the rotation of the encoder in the units specified

### 5.15.3.3 setPosition()

```
void CustomEncoder::setPosition (
    double val,
    vex::rotationUnits units )
```

sets the stored position of the encoder. Any further movements will be from this value

**Parameters**

<i>val</i>	the numerical value of the position we are setting to
<i>units</i>	the unit of val

**5.15.3.4 setRotation()**

```
void CustomEncoder::setRotation (
    double val,
    vex::rotationUnits units )
```

sets the stored rotation of the encoder. Any further movements will be from this value

**Parameters**

<i>val</i>	the numerical value of the angle we are setting to
<i>units</i>	the unit of val

**5.15.3.5 velocity()**

```
double CustomEncoder::velocity (
    vex::velocityUnits units )
```

get the velocity that the encoder is moving at

**Parameters**

<i>units</i>	the unit we want the return value to be in
--------------	--------------------------------------------

**Returns**

the velocity of the encoder in the units specified

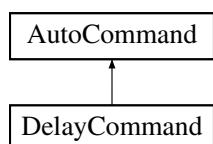
The documentation for this class was generated from the following files:

- include/subsystems/custom\_encoder.h
- src/subsystems/custom\_encoder.cpp

**5.16 DelayCommand Class Reference**

```
#include <delay_command.h>
```

Inheritance diagram for DelayCommand:



## Public Member Functions

- [DelayCommand \(int ms\)](#)
- bool [run \(\) override](#)

## Public Member Functions inherited from [AutoCommand](#)

- virtual void [on\\_timeout \(\)](#)
- [AutoCommand \\* withTimeout \(double t\\_seconds\)](#)
- [AutoCommand \\* withCancelCondition \(Condition \\*true\\_to\\_end\)](#)

## Additional Inherited Members

## Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- Condition \* [true\\_to\\_end](#) = nullptr

## Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double [default\\_timeout](#) = 10.0

## 5.16.1 Detailed Description

File: [delay\\_command.h](#) Desc: A [DelayCommand](#) will make the robot wait the set amount of milliseconds before continuing execution of the autonomous route

## 5.16.2 Constructor & Destructor Documentation

### 5.16.2.1 [DelayCommand\(\)](#)

```
DelayCommand::DelayCommand (
    int ms ) [inline]
```

Construct a delay command

#### Parameters

<i>ms</i>	the number of milliseconds to delay for
-----------	-----------------------------------------

## 5.16.3 Member Function Documentation

### 5.16.3.1 [run\(\)](#)

```
bool DelayCommand::run ( ) [inline], [override], [virtual]
```

Delays for the amount of milliseconds stored in the command Overrides run from [AutoCommand](#)

#### Returns

- true when complete

Reimplemented from [AutoCommand](#).

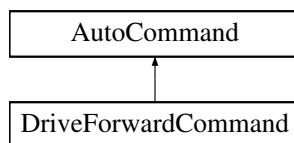
The documentation for this class was generated from the following file:

- include/utils/command\_structure/delay\_command.h

## 5.17 DriveForwardCommand Class Reference

```
#include <drive_commands.h>
```

Inheritance diagram for DriveForwardCommand:



#### Public Member Functions

- [DriveForwardCommand](#) ([TankDrive](#) &drive\_sys, [Feedback](#) &feedback, double inches, directionType dir, double max\_speed=1, double end\_speed=0)
- bool [run](#) () override
- void [on\\_timeout](#) () override

#### Public Member Functions inherited from [AutoCommand](#)

- [AutoCommand](#) \* [withTimeout](#) (double t\_seconds)
- [AutoCommand](#) \* [withCancelCondition](#) ([Condition](#) \*true\_to\_end)

#### Additional Inherited Members

#### Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition](#) \* [true\\_to\\_end](#) = nullptr

#### Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double [default\\_timeout](#) = 10.0

### 5.17.1 Detailed Description

[AutoCommand](#) wrapper class for the drive\_forward function in the [TankDrive](#) class

### 5.17.2 Constructor & Destructor Documentation

#### 5.17.2.1 DriveForwardCommand()

```
DriveForwardCommand::DriveForwardCommand (
    TankDrive & drive_sys,
    Feedback & feedback,
    double inches,
    directionType dir,
    double max_speed = 1,
    double end_speed = 0 )
```

File: [drive\\_commands.h](#) Desc: Holds all the [AutoCommand](#) subclasses that wrap (currently) [TankDrive](#) functions

Currently includes:

- [drive\\_forward](#)
- [turn\\_degrees](#)
- [drive\\_to\\_point](#)
- [turn\\_to\\_heading](#)
- [stop](#)

Also holds [AutoCommand](#) subclasses that wrap [OdometryBase](#) functions

Currently includes:

- [set\\_position](#) Construct a DriveForward Command

#### Parameters

<i>drive_sys</i>	the drive system we are commanding
<i>feedback</i>	the feedback controller we are using to execute the drive
<i>inches</i>	how far forward to drive
<i>dir</i>	the direction to drive
<i>max_speed</i>	0 -> 1 percentage of the drive systems speed to drive at

### 5.17.3 Member Function Documentation

#### 5.17.3.1 on\_timeout()

```
void DriveForwardCommand::on_timeout ( ) [override], [virtual]
```

Cleans up drive system if we time out before finishing

reset the drive system if we timeout

Reimplemented from [AutoCommand](#).

### 5.17.3.2 run()

```
bool DriveForwardCommand::run ( ) [override], [virtual]
```

Run drive\_forward Overrides run from [AutoCommand](#)

Returns

true when execution is complete, false otherwise

Reimplemented from [AutoCommand](#).

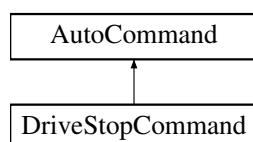
The documentation for this class was generated from the following files:

- include/utils/command\_structure/drive\_commands.h
- src/utils/command\_structure/drive\_commands.cpp

## 5.18 DriveStopCommand Class Reference

```
#include <drive_commands.h>
```

Inheritance diagram for DriveStopCommand:



### Public Member Functions

- [DriveStopCommand \(TankDrive &drive\\_sys\)](#)
- [bool run \(\) override](#)
- [void on\\_timeout \(\) override](#)

### Public Member Functions inherited from [AutoCommand](#)

- [AutoCommand \\* withTimeout \(double t\\_seconds\)](#)
- [AutoCommand \\* withCancelCondition \(Condition \\*true\\_to\\_end\)](#)

## Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- double `timeout_seconds` = `default_timeout`
- `Condition * true_to_end` = `nullptr`

### Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double `default_timeout` = 10.0

## 5.18.1 Detailed Description

[AutoCommand](#) wrapper class for the stop() function in the [TankDrive](#) class

## 5.18.2 Constructor & Destructor Documentation

### 5.18.2.1 [DriveStopCommand\(\)](#)

```
DriveStopCommand::DriveStopCommand (   
    TankDrive & drive_sys )
```

Construct a DriveStop Command

#### Parameters

<code>drive_sys</code>	the drive system we are commanding
------------------------	------------------------------------

## 5.18.3 Member Function Documentation

### 5.18.3.1 [on\\_timeout\(\)](#)

```
void DriveStopCommand::on_timeout ( ) [override], [virtual]
```

What to do if we timeout instead of finishing. timeout is specified by the timeout seconds in the constructor

Reimplemented from [AutoCommand](#).

### 5.18.3.2 [run\(\)](#)

```
bool DriveStopCommand::run ( ) [override], [virtual]
```

Stop the drive system Overrides run from [AutoCommand](#)

**Returns**

true when execution is complete, false otherwise

Stop the drive train Overrides run from [AutoCommand](#)

**Returns**

true when execution is complete, false otherwise

Reimplemented from [AutoCommand](#).

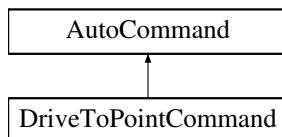
The documentation for this class was generated from the following files:

- include/utils/command\_structure/drive\_commands.h
- src/utils/command\_structure/drive\_commands.cpp

## 5.19 DriveToPointCommand Class Reference

```
#include <drive_commands.h>
```

Inheritance diagram for DriveToPointCommand:



### Public Member Functions

- [DriveToPointCommand \(TankDrive &drive\\_sys, Feedback &feedback, double x, double y, directionType dir, double max\\_speed=1, double end\\_speed=0\)](#)
- [DriveToPointCommand \(TankDrive &drive\\_sys, Feedback &feedback, point\\_t point, directionType dir, double max\\_speed=1, double end\\_speed=0\)](#)
- bool [run \(\) override](#)

### Public Member Functions inherited from [AutoCommand](#)

- [AutoCommand \\* withTimeout \(double t\\_seconds\)](#)
- [AutoCommand \\* withCancelCondition \(Condition \\*true\\_to\\_end\)](#)

### Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition \\* true\\_to\\_end](#) = nullptr

## Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double **default\_timeout** = 10.0

### 5.19.1 Detailed Description

[AutoCommand](#) wrapper class for the drive\_to\_point function in the [TankDrive](#) class

### 5.19.2 Constructor & Destructor Documentation

#### 5.19.2.1 DriveToPointCommand() [1/2]

```
DriveToPointCommand::DriveToPointCommand (
    TankDrive & drive_sys,
    Feedback & feedback,
    double x,
    double y,
    directionType dir,
    double max_speed = 1,
    double end_speed = 0 )
```

Construct a DriveForward Command

##### Parameters

<i>drive_sys</i>	the drive system we are commanding
<i>feedback</i>	the feedback controller we are using to execute the drive
<i>x</i>	where to drive in the x dimension
<i>y</i>	where to drive in the y dimension
<i>dir</i>	the direction to drive
<i>max_speed</i>	0 -> 1 percentage of the drive systems speed to drive at

#### 5.19.2.2 DriveToPointCommand() [2/2]

```
DriveToPointCommand::DriveToPointCommand (
    TankDrive & drive_sys,
    Feedback & feedback,
    point_t point,
    directionType dir,
    double max_speed = 1,
    double end_speed = 0 )
```

Construct a DriveForward Command

##### Parameters

<i>drive_sys</i>	the drive system we are commanding
<i>feedback</i>	the feedback controller we are using to execute the drive
<i>point</i>	the point to drive to
<i>dir</i>	the direction to drive
<i>max_speed</i>	0 -> 1 percentage of the drive systems speed to drive at

### 5.19.3 Member Function Documentation

#### 5.19.3.1 run()

```
bool DriveToPointCommand::run ( ) [override], [virtual]
```

Run drive\_to\_point Overrides run from [AutoCommand](#)

##### Returns

true when execution is complete, false otherwise

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

- include/utils/command\_structure/drive\_commands.h
- src/utils/command\_structure/drive\_commands.cpp

## 5.20 AutoChooser::entry\_t Struct Reference

```
#include <auto_chooser.h>
```

### Public Attributes

- [Rect rect](#)
- std::string [name](#)

#### 5.20.1 Detailed Description

[entry\\_t](#) is a datatype used to store information that the chooser knows about an auto selection button

#### 5.20.2 Member Data Documentation

##### 5.20.2.1 name

```
std::string AutoChooser::entry_t::name
```

name of the auto repretsented by the block

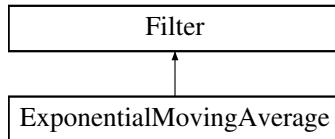
The documentation for this struct was generated from the following file:

- include/utils/auto\_chooser.h

## 5.21 ExponentialMovingAverage Class Reference

```
#include <moving_average.h>
```

Inheritance diagram for ExponentialMovingAverage:



### Public Member Functions

- [ExponentialMovingAverage \(int buffer\\_size\)](#)
- [ExponentialMovingAverage \(int buffer\\_size, double starting\\_value\)](#)
- void [add\\_entry \(double n\)](#) override
- double [get\\_value \(\) const](#) override
- int [get\\_size \(\)](#)

### 5.21.1 Detailed Description

#### [ExponentialMovingAverage](#)

An exponential moving average is a way of smoothing out noisy data. For many sensor readings, the noise is roughly symmetric around the actual value. This means that if you collect enough samples those that are too high are cancelled out by the samples that are too low leaving the real value.

A simple moving average lags significantly with time as it has to counteract old samples. An exponential moving average keeps more up to date by weighting newer readings higher than older readings so it is more up to date while also still smoothed.

The [ExponentialMovingAverage](#) class provides a simple interface to do this smoothing from our noisy sensor values.

### 5.21.2 Constructor & Destructor Documentation

#### 5.21.2.1 [ExponentialMovingAverage\(\) \[1/2\]](#)

```
ExponentialMovingAverage::ExponentialMovingAverage (
    int buffer_size )
```

Create a moving average calculator with 0 as the default value

##### Parameters

<i>buffer_size</i>	The size of the buffer. The number of samples that constitute a valid reading
--------------------	-------------------------------------------------------------------------------

### 5.21.2.2 ExponentialMovingAverage() [2/2]

```
ExponentialMovingAverage::ExponentialMovingAverage (
    int buffer_size,
    double starting_value )
```

Create a moving average calculator with a specified default value

#### Parameters

<i>buffer_size</i>	The size of the buffer. The number of samples that constitute a valid reading
<i>starting_value</i>	The value that the average will be before any data is added

## 5.21.3 Member Function Documentation

### 5.21.3.1 add\_entry()

```
void ExponentialMovingAverage::add_entry (
    double n ) [override], [virtual]
```

Add a reading to the buffer Before: [ 1 1 2 2 3 3 ] => 2 ^ After: [ 2 1 2 2 3 3 ] => 2.16 ^

#### Parameters

<i>n</i>	the sample that will be added to the moving average.
----------	------------------------------------------------------

Implements [Filter](#).

### 5.21.3.2 get\_size()

```
int ExponentialMovingAverage::get_size ( )
```

How many samples the average is made from

#### Returns

the number of samples used to calculate this average

### 5.21.3.3 get\_value()

```
double ExponentialMovingAverage::get_value ( ) const [override], [virtual]
```

Returns the average based off of all the samples collected so far

**Returns**

the calculated average.  $\text{sum}(\text{samples})/\text{numsamples}$

How many samples the average is made from

**Returns**

the number of samples used to calculate this average

Implements [Filter](#).

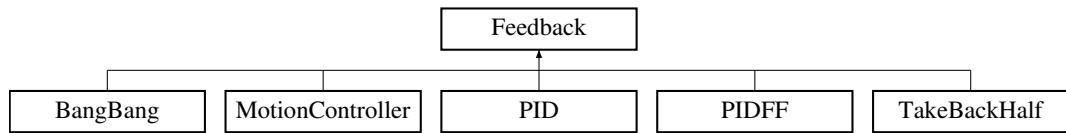
The documentation for this class was generated from the following files:

- include/utils/moving\_average.h
- src/utils/moving\_average.cpp

## 5.22 Feedback Class Reference

```
#include <feedback_base.h>
```

Inheritance diagram for Feedback:



### Public Member Functions

- virtual void [init](#) (double start\_pt, double set\_pt, double start\_vel=0.0, double end\_vel=0.0)=0
- virtual double [update](#) (double val)=0
- virtual double [get](#) ()=0
- virtual void [set\\_limits](#) (double lower, double upper)=0
- virtual bool [is\\_on\\_target](#) ()=0

### 5.22.1 Detailed Description

Interface so that subsystems can easily switch between feedback loops

**Author**

Ryan McGee

**Date**

9/25/2022

## 5.22.2 Member Function Documentation

### 5.22.2.1 get()

```
virtual double Feedback::get ( ) [pure virtual]
```

#### Returns

the last saved result from the feedback controller

Implemented in [BangBang](#), [MotionController](#), [PID](#), [PIDFF](#), and [TakeBackHalf](#).

### 5.22.2.2 init()

```
virtual void Feedback::init (
    double start_pt,
    double set_pt,
    double start_vel = 0.0,
    double end_vel = 0.0 ) [pure virtual]
```

Initialize the feedback controller for a movement

#### Parameters

<i>start_pt</i>	the current sensor value
<i>set_pt</i>	where the sensor value should be
<i>start_vel</i>	Movement starting velocity
<i>end_vel</i>	Movement ending velocity

Implemented in [MotionController](#), [PIDFF](#), [PID](#), [BangBang](#), and [TakeBackHalf](#).

### 5.22.2.3 is\_on\_target()

```
virtual bool Feedback::is_on_target ( ) [pure virtual]
```

#### Returns

true if the feedback controller has reached it's setpoint

Implemented in [BangBang](#), [MotionController](#), [PID](#), [PIDFF](#), and [TakeBackHalf](#).

### 5.22.2.4 set\_limits()

```
virtual void Feedback::set_limits (
    double lower,
    double upper ) [pure virtual]
```

Clamp the upper and lower limits of the output. If both are 0, no limits should be applied.

**Parameters**

<i>lower</i>	Upper limit
<i>upper</i>	Lower limit

Implemented in [BangBang](#), [MotionController](#), [PID](#), [PIDFF](#), and [TakeBackHalf](#).

### 5.22.2.5 update()

```
virtual double Feedback::update (
    double val ) [pure virtual]
```

Iterate the feedback loop once with an updated sensor value

**Parameters**

<i>val</i>	value from the sensor
------------	-----------------------

**Returns**

feedback loop result

Implemented in [MotionController](#), [PID](#), [BangBang](#), [PIDFF](#), and [TakeBackHalf](#).

The documentation for this class was generated from the following file:

- include/utils/controls/feedback\_base.h

## 5.23 FeedForward Class Reference

```
#include <feedforward.h>
```

**Classes**

- struct [ff\\_config\\_t](#)

**Public Member Functions**

- [FeedForward \(ff\\_config\\_t &cfg\)](#)
- double [calculate](#) (double v, double a, double pid\_ref=0.0)  
*Perform the feedforward calculation.*

### 5.23.1 Detailed Description

#### FeedForward

Stores the feedforward constants, and allows for quick computation. Feedforward should be used in systems that require smooth precise movements and have high inertia, such as drivetrains and lifts.

This is best used alongside a **PID** loop, with the form: `output = pid.get() + feedforward.calculate(v, a);`

In this case, the feedforward does the majority of the heavy lifting, and the pid loop only corrects for inconsistencies

For information about tuning feedforward, I recommend looking at this post: <https://www.chiefdelphi.com/t/paper-frc-drivetrain-characterization/160915> (yes I know it's for FRC but trust me, it's useful)

#### Author

Ryan McGee

#### Date

6/13/2022

### 5.23.2 Constructor & Destructor Documentation

#### 5.23.2.1 FeedForward()

```
FeedForward::FeedForward (
    ff_config_t & cfg ) [inline]
```

Creates a **FeedForward** object.

#### Parameters

<code>cfg</code>	Configuration Struct for tuning
------------------	---------------------------------

### 5.23.3 Member Function Documentation

#### 5.23.3.1 calculate()

```
double FeedForward::calculate (
    double v,
    double a,
    double pid_ref = 0.0 ) [inline]
```

Perform the feedforward calculation.

This calculation is the equation:  $F = kG + kS * \text{sgn}(v) + kV * v + kA * a$

**Parameters**

<i>v</i>	Requested velocity of system
<i>a</i>	Requested acceleration of system

**Returns**

A feedforward that should closely represent the system if tuned correctly

The documentation for this class was generated from the following file:

- include/utils/controls/feedforward.h

## 5.24 FeedForward::ff\_config\_t Struct Reference

```
#include <feedforward.h>
```

**Public Attributes**

- double kS
- double kV
- double kA
- double kG

### 5.24.1 Detailed Description

`ff_config_t` holds the parameters to make the theoretical model of a real world system equation is of the form `kS` if the system is not stopped, 0 otherwise

- `kV * desired velocity`
- `kA * desired acceleration`
- `kG`

### 5.24.2 Member Data Documentation

#### 5.24.2.1 kA

```
double FeedForward::ff_config_t::kA
```

`kA` - Acceleration coefficient: the power required to change the mechanism's speed. Multiplied by the requested acceleration.

### 5.24.2.2 kG

```
double FeedForward::ff_config_t::kG
```

kG - Gravity coefficient: only needed for lifts. The power required to overcome gravity and stay at steady state.

### 5.24.2.3 kS

```
double FeedForward::ff_config_t::kS
```

Coefficient to overcome static friction: the point at which the motor *starts* to move.

### 5.24.2.4 kV

```
double FeedForward::ff_config_t::kV
```

Velocity coefficient: the power required to keep the mechanism in motion. Multiplied by the requested velocity.

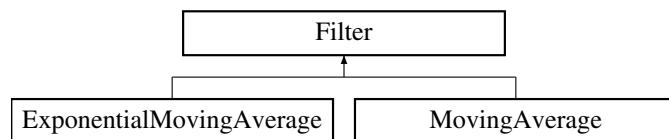
The documentation for this struct was generated from the following file:

- include/utils/controls/feedforward.h

## 5.25 Filter Class Reference

```
#include <moving_average.h>
```

Inheritance diagram for Filter:



### Public Member Functions

- virtual void [add\\_entry](#) (double n)=0
- virtual double [get\\_value](#) () const =0

### 5.25.1 Detailed Description

Interface for filters Use add\_entry to supply data and get\_value to retrieve the filtered value

## 5.25.2 Member Function Documentation

### 5.25.2.1 add\_entry()

```
virtual void Filter::add_entry (
    double n ) [pure virtual]
```

Implemented in [MovingAverage](#), and [ExponentialMovingAverage](#).

### 5.25.2.2 get\_value()

```
virtual double Filter::get_value ( ) const [pure virtual]
```

Implemented in [MovingAverage](#), and [ExponentialMovingAverage](#).

The documentation for this class was generated from the following file:

- include/utils/moving\_average.h

## 5.26 Flywheel Class Reference

```
#include <flywheel.h>
```

### Public Member Functions

- [Flywheel](#) (vex::motor\_group &motors, [Feedback](#) &feedback, [FeedForward](#) &helper, const double ratio, [Filter](#) &filt)
- double [get\\_target](#) () const
- double [getRPM](#) () const
- vex::motor\_group & [get\\_motors](#) () const
- void [spin\\_manual](#) (double speed, directionType dir=fwd)
- void [spin\\_rpm](#) (double rpm)
- void [stop](#) ()
- bool [is\\_on\\_target](#) ()
 

*check if the feedback controller thinks the flywheel is on target*
- [screen::Page](#) \* [Page](#) () const
 

*Creates a page displaying info about the flywheel.*
- [AutoCommand](#) \* [SpinRpmCmd](#) (int rpm)
 

*Creates a new auto command to spin the flywheel at the desired velocity.*
- [AutoCommand](#) \* [WaitUntilUpToSpeedCmd](#) ()
 

*Creates a new auto command that will hold until the flywheel has its target as defined by its feedback controller.*

### Friends

- class [FlywheelPage](#)
- int [spinRPMTask](#) (void \*wheelPointer)

### 5.26.1 Detailed Description

a [Flywheel](#) class that handles all control of a high inertia spinning disk. It gives multiple options for what control system to use in order to control wheel velocity and functions alerting the user when the flywheel is up to speed. [Flywheel](#) is a set and forget class. Once you create it you can call `spin_rpm` or `stop` on it at any time and it will take all necessary steps to accomplish this.

### 5.26.2 Constructor & Destructor Documentation

#### 5.26.2.1 Flywheel()

```
Flywheel::Flywheel (
    vex::motor_group & motors,
    Feedback & feedback,
    FeedForward & helper,
    const double ratio,
    Filter & filt )
```

Create the [Flywheel](#) object using [PID](#) + feedforward for control.

#### Parameters

<i>motors</i>	pointer to the motors on the fly wheel
<i>feedback</i>	a feedback controller
<i>helper</i>	a feedforward config (only kV is used) to help the feedback controller along
<i>ratio</i>	ratio of the gears from the motor to the flywheel just multiplies the velocity
<i>filter</i>	the filter to use to smooth noisy motor readings

### 5.26.3 Member Function Documentation

#### 5.26.3.1 get\_motors()

```
motor_group & Flywheel::get_motors ( ) const
```

Returns the motors

#### Returns

the motors used to run the flywheel

#### 5.26.3.2 get\_target()

```
double Flywheel::get_target ( ) const
```

Return the target\_rpm that the flywheel is currently trying to achieve

#### Returns

target\_rpm the target rpm

Return the current value that the target\_rpm should be set to

### 5.26.3.3 getRPM()

```
double Flywheel::getRPM ( ) const
```

return the velocity of the flywheel

### 5.26.3.4 is\_on\_target()

```
bool Flywheel::is_on_target ( ) [inline]
```

check if the feedback controller thinks the flywheel is on target

#### Returns

true if on target

### 5.26.3.5 Page()

```
screen::Page * Flywheel::Page ( ) const
```

Creates a page displaying info about the flywheel.

#### Returns

the page should be used for `screen::start\_screen(screen, {fw.Page()});`

### 5.26.3.6 spin\_manual()

```
void Flywheel::spin_manual (
    double speed,
    directionType dir = fwd )
```

Spin motors using voltage; defaults forward at 12 volts FOR USE BY OPCONTROL AND AUTONOMOUS - this only applies if the target\_rpm thread is not running

#### Parameters

<i>speed</i>	- speed (between -1 and 1) to set the motor
<i>dir</i>	- direction that the motor moves in; defaults to forward

Spin motors using voltage; defaults forward at 12 volts FOR USE BY OPCONTROL AND AUTONOMOUS - this only applies if the RPM thread is not running

#### Parameters

<i>speed</i>	- speed (between -1 and 1) to set the motor
<i>dir</i>	- direction that the motor moves in; defaults to forward

### 5.26.3.7 spin\_rpm()

```
void Flywheel::spin_rpm (
    double input_rpm )
```

starts or sets the target\_rpm thread at new value what control scheme is dependent on control\_style

#### Parameters

<i>rpm</i>	- the target_rpm we want to spin at
------------	-------------------------------------

starts or sets the RPM thread at new value what control scheme is dependent on control\_style

#### Parameters

<i>input_rpm</i>	- set the current RPM
------------------	-----------------------

### 5.26.3.8 SpinRpmCmd()

```
AutoCommand * Flywheel::SpinRpmCmd (
    int rpm ) [inline]
```

Creates a new auto command to spin the flywheel at the desired velocity.

#### Parameters

<i>rpm</i>	the rpm to spin at
------------	--------------------

#### Returns

an auto command to add to a command controller

### 5.26.3.9 stop()

```
void Flywheel::stop ( )
```

Stops the motors. If manually spinning, this will do nothing just call spin\_mainual(0.0) to send 0 volts

stop the RPM thread and the wheel

### 5.26.3.10 WaitUntilUpToSpeedCmd()

```
AutoCommand * Flywheel::WaitUntilUpToSpeedCmd ( ) [inline]
```

Creates a new auto command that will hold until the flywheel has its target as defined by its feedback controller.

#### Returns

an auto command to add to a command controller

## 5.26.4 Friends And Related Symbol Documentation

### 5.26.4.1 spinRPMTask

```
int spinRPMTask (
    void * wheelPointer ) [friend]
```

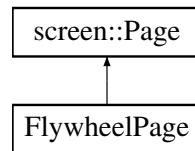
Runs a thread that keeps track of updating flywheel RPM and controlling it accordingly

The documentation for this class was generated from the following files:

- include/subsystems/flywheel.h
- src/subsystems/flywheel.cpp

## 5.27 FlywheelPage Class Reference

Inheritance diagram for FlywheelPage:



### Public Member Functions

- **FlywheelPage** (const [Flywheel](#) &fw)
- void [update](#) (bool, int, int) override
- void [draw](#) (vex::brain::lcd &screen, bool, unsigned int) override

### Static Public Attributes

- static const size\_t [window\\_size](#) = 40

## 5.27.1 Member Function Documentation

### 5.27.1.1 draw()

```
void FlywheelPage::draw (
    vex::brain::lcd & screen,
    bool ,
    unsigned int ) [inline], [override], [virtual]
```

See also

[Page::draw](#)

Reimplemented from [screen::Page](#).

### 5.27.1.2 update()

```
void FlywheelPage::update (
    bool ,
    int ,
    int ) [inline], [override], [virtual]
```

#### See also

[Page::update](#)

Reimplemented from [screen::Page](#).

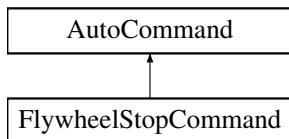
The documentation for this class was generated from the following file:

- [src/subsystems/flywheel.cpp](#)

## 5.28 FlywheelStopCommand Class Reference

```
#include <flywheel_commands.h>
```

Inheritance diagram for FlywheelStopCommand:



#### Public Member Functions

- [FlywheelStopCommand \(Flywheel &flywheel\)](#)
- bool [run \(\) override](#)

#### Public Member Functions inherited from [AutoCommand](#)

- virtual void [on\\_timeout \(\)](#)
- [AutoCommand \\* withTimeout \(double t\\_seconds\)](#)
- [AutoCommand \\* withCancelCondition \(Condition \\*true\\_to\\_end\)](#)

#### Additional Inherited Members

#### Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition \\* true\\_to\\_end](#) = nullptr

## Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double **default\_timeout** = 10.0

### 5.28.1 Detailed Description

[AutoCommand](#) wrapper class for the stop function in the [Flywheel](#) class

### 5.28.2 Constructor & Destructor Documentation

#### 5.28.2.1 FlywheelStopCommand()

```
FlywheelStopCommand::FlywheelStopCommand (
    Flywheel & flywheel )
```

Construct a [FlywheelStopCommand](#)

##### Parameters

<i>flywheel</i>	the flywheel system we are commanding
-----------------	---------------------------------------

### 5.28.3 Member Function Documentation

#### 5.28.3.1 run()

```
bool FlywheelStopCommand::run ( ) [override], [virtual]
```

Run stop Overrides run from [AutoCommand](#)

##### Returns

true when execution is complete, false otherwise

Reimplemented from [AutoCommand](#).

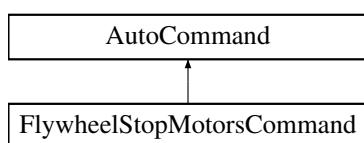
The documentation for this class was generated from the following files:

- include/utils/command\_structure/flywheel\_commands.h
- src/utils/command\_structure/flywheel\_commands.cpp

## 5.29 FlywheelStopMotorsCommand Class Reference

```
#include <flywheel_commands.h>
```

Inheritance diagram for FlywheelStopMotorsCommand:



## Public Member Functions

- `FlywheelStopMotorsCommand (Flywheel &flywheel)`
- `bool run () override`

## Public Member Functions inherited from `AutoCommand`

- `virtual void on_timeout ()`
- `AutoCommand * withTimeout (double t_seconds)`
- `AutoCommand * withCancelCondition (Condition *true_to_end)`

## Additional Inherited Members

## Public Attributes inherited from `AutoCommand`

- `double timeout_seconds = default_timeout`
- `Condition * true_to_end = nullptr`

## Static Public Attributes inherited from `AutoCommand`

- `static constexpr double default_timeout = 10.0`

### 5.29.1 Detailed Description

`AutoCommand` wrapper class for the stopMotors function in the `Flywheel` class

### 5.29.2 Constructor & Destructor Documentation

#### 5.29.2.1 `FlywheelStopMotorsCommand()`

```
FlywheelStopMotorsCommand::FlywheelStopMotorsCommand (
    Flywheel & flywheel )
```

Construct a FlywheelStopMotors Command

#### Parameters

<code>flywheel</code>	the flywheel system we are commanding
-----------------------	---------------------------------------

### 5.29.3 Member Function Documentation

#### 5.29.3.1 `run()`

```
bool FlywheelStopMotorsCommand::run ( ) [override], [virtual]
```

Run stop Overrides run from `AutoCommand`

**Returns**

true when execution is complete, false otherwise

Reimplemented from [AutoCommand](#).

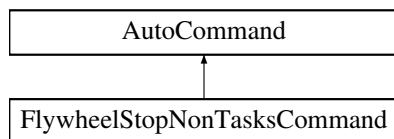
The documentation for this class was generated from the following files:

- include/utils/command\_structure/flywheel\_commands.h
- src/utils/command\_structure/flywheel\_commands.cpp

## 5.30 FlywheelStopNonTasksCommand Class Reference

```
#include <flywheel_commands.h>
```

Inheritance diagram for FlywheelStopNonTasksCommand:



### Additional Inherited Members

#### Public Member Functions inherited from [AutoCommand](#)

- virtual void [on\\_timeout \(\)](#)
- [AutoCommand \\* withTimeout](#) (double t\_seconds)
- [AutoCommand \\* withCancelCondition](#) ([Condition](#) \*true\_to\_end)

#### Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition](#) \* [true\\_to\\_end](#) = nullptr

#### Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double [default\\_timeout](#) = 10.0

### 5.30.1 Detailed Description

[AutoCommand](#) wrapper class for the stopNonTasks function in the [Flywheel](#) class

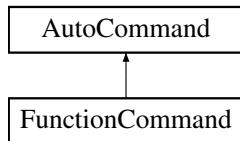
The documentation for this class was generated from the following files:

- include/utils/command\_structure/flywheel\_commands.h
- src/utils/command\_structure/flywheel\_commands.cpp

## 5.31 FunctionCommand Class Reference

```
#include <auto_command.h>
```

Inheritance diagram for FunctionCommand:



### Public Member Functions

- **FunctionCommand** (std::function< bool(void)> f)
- bool **run** ()

### Public Member Functions inherited from [AutoCommand](#)

- virtual void [on\\_timeout](#) ()
- [AutoCommand](#) \* [withTimeout](#) (double t\_seconds)
- [AutoCommand](#) \* [withCancelCondition](#) ([Condition](#) \*true\_to\_end)

### Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition](#) \* [true\\_to\\_end](#) = nullptr

### Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double [default\\_timeout](#) = 10.0

### 5.31.1 Detailed Description

[FunctionCommand](#) is fun and good way to do simple things Printing, launching nukes, and other quick and dirty one time things

### 5.31.2 Member Function Documentation

#### 5.31.2.1 run()

```
bool FunctionCommand::run ( ) [inline], [virtual]
```

Executes the command Overridden by child classes

##### Returns

true when the command is finished, false otherwise

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following file:

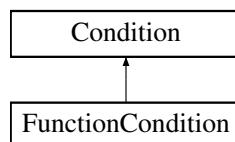
- include/utils/command\_structure/auto\_command.h

## 5.32 FunctionCondition Class Reference

[FunctionCondition](#) is a quick and dirty [Condition](#) to wrap some expression that should be evaluated at runtime.

```
#include <auto_command.h>
```

Inheritance diagram for FunctionCondition:



### Public Member Functions

- **FunctionCondition** (std::function< bool()> cond, std::function< void(void)> timeout=[ ]() {})
- bool [test](#) () override

### Public Member Functions inherited from [Condition](#)

- [Condition \\* Or](#) ([Condition](#) \*b)
- [Condition \\* And](#) ([Condition](#) \*b)

### 5.32.1 Detailed Description

[FunctionCondition](#) is a quick and dirty [Condition](#) to wrap some expression that should be evaluated at runtime.

## 5.32.2 Member Function Documentation

### 5.32.2.1 test()

```
bool FunctionCondition::test ( ) [override], [virtual]
```

Implements [Condition](#).

The documentation for this class was generated from the following files:

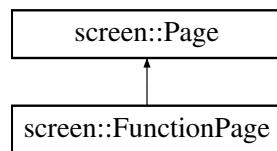
- include/utils/command\_structure/auto\_command.h
- src/utils/command\_structure/auto\_command.cpp

## 5.33 screen::FunctionPage Class Reference

Simple page that stores no internal data. the draw and update functions use only global data rather than storing anything.

```
#include <screen.h>
```

Inheritance diagram for screen::FunctionPage:



### Public Member Functions

- [FunctionPage](#) (update\_func\_t update\_f, draw\_func\_t draw\_t)  
*Creates a function page.*
- void [update](#) (bool was\_pressed, int x, int y) override  
*update uses the supplied update function to update this page*
- void [draw](#) (vex::brain::lcd &, bool first\_draw, unsigned int frame\_number) override  
*draw uses the supplied draw function to draw to the screen*

### 5.33.1 Detailed Description

Simple page that stores no internal data. the draw and update functions use only global data rather than storing anything.

## 5.33.2 Constructor & Destructor Documentation

### 5.33.2.1 FunctionPage()

```
screen::FunctionPage::FunctionPage (
    update_func_t update_f,
    draw_func_t draw_f )
```

Creates a function page.

[FunctionPage](#).

**Parameters**

<i>update_f</i>	the function called every tick to respond to user input or do data collection
<i>draw_t</i>	the function called to draw to the screen
<i>update_f</i>	drawing function
<i>draw_f</i>	drawing function

**5.33.3 Member Function Documentation****5.33.3.1 draw()**

```
void screen::FunctionPage::draw (
    vex::brain::lcd & screen,
    bool first_draw,
    unsigned int frame_number ) [override], [virtual]
```

draw uses the supplied draw function to draw to the screen

**See also**

[Page::draw](#)

Reimplemented from [screen::Page](#).

**5.33.3.2 update()**

```
void screen::FunctionPage::update (
    bool was_pressed,
    int x,
    int y ) [override], [virtual]
```

update uses the supplied update function to update this page

**See also**

[Page::update](#)

Reimplemented from [screen::Page](#).

The documentation for this class was generated from the following files:

- include/subsystems/screen.h
- src/subsystems/screen.cpp

**5.34 GenericAuto Class Reference**

```
#include <generic_auto.h>
```

## Public Member Functions

- bool `run` (bool blocking)
- void `add` (state\_ptr new\_state)
- void `add_async` (state\_ptr async\_state)
- void `add_delay` (int ms)

### 5.34.1 Detailed Description

`GenericAuto` provides a pleasant interface for organizing an auto path steps of the path can be added with `add()` and when ready, calling `run()` will begin executing the path

### 5.34.2 Member Function Documentation

#### 5.34.2.1 add()

```
void GenericAuto::add (
    state_ptr new_state )
```

Add a new state to the autonomous via function point of type "bool (ptr\*)()"

Parameters

<code>new_state</code>	the function to run
------------------------	---------------------

#### 5.34.2.2 add\_async()

```
void GenericAuto::add_async (
    state_ptr async_state )
```

Add a new state to the autonomous via function point of type "bool (ptr\*)()" that will run asynchronously

Parameters

<code>async_state</code>	the function to run
--------------------------	---------------------

#### 5.34.2.3 add\_delay()

```
void GenericAuto::add_delay (
    int ms )
```

`add_delay` adds a period where the auto system will simply wait for the specified time

Parameters

<code>ms</code>	how long to wait in milliseconds
-----------------	----------------------------------

### 5.34.2.4 run()

```
bool GenericAuto::run (
    bool blocking )
```

The method that runs the autonomous. If 'blocking' is true, then this method will run through every state until it finished.

If blocking is false, then assuming every state is also non-blocking, the method will run through the current state in the list and return immediately.

#### Parameters

<i>blocking</i>	Whether or not to block the thread until all states have run
-----------------	--------------------------------------------------------------

#### Returns

true after all states have finished.

The documentation for this class was generated from the following files:

- include/utils/generic\_auto.h
- src/utils/generic\_auto.cpp

## 5.35 GraphDrawer Class Reference

### Public Member Functions

- [GraphDrawer](#) (int num\_samples, double lower\_bound, double upper\_bound, std::vector< vex::color > colors, size\_t num\_series=1)
   
*Creates a graph drawer with the specified number of series (each series is a separate line)*
- void [add\\_samples](#) (std::vector< point\_t > sample)
- void [add\\_samples](#) (std::vector< double > sample)
- void [draw](#) (vex::brain::lcd &screen, int x, int y, int width, int height)

### 5.35.1 Constructor & Destructor Documentation

#### 5.35.1.1 GraphDrawer()

```
GraphDrawer::GraphDrawer (
    int num_samples,
    double lower_bound,
    double upper_bound,
    std::vector< vex::color > colors,
    size_t num_series = 1 )
```

Creates a graph drawer with the specified number of series (each series is a separate line)

**Parameters**

<i>num_samples</i>	the number of samples to graph at a time (40 will graph the last 40 data points)
<i>lower_bound</i>	the bottom of the window when displaying (if <i>upper_bound</i> = <i>lower_bound</i> , auto calculate bounds)
<i>upper_bound</i>	the top of the window when displaying (if <i>upper_bound</i> = <i>lower_bound</i> , auto calculate bounds)
<i>colors</i>	the colors of the series. must be of size <i>num_series</i>
<i>num_series</i>	the number of series to graph

**5.35.2 Member Function Documentation****5.35.2.1 add\_samples() [1/2]**

```
void GraphDrawer::add_samples (
    std::vector< double > sample )
```

*add\_samples* adds a point to the graph, removing one from the back

**Parameters**

<i>sample</i>	a y coordinate of the next point to graph, the x coordinate is gotten from vex::timer::system(); (time in ms)
---------------	---------------------------------------------------------------------------------------------------------------

**5.35.2.2 add\_samples() [2/2]**

```
void GraphDrawer::add_samples (
    std::vector< point_t > new_samples )
```

*add\_samples* adds a point to the graph, removing one from the back

**Parameters**

<i>sample</i>	an x, y coordinate of the next point to graph
---------------	-----------------------------------------------

**5.35.2.3 draw()**

```
void GraphDrawer::draw (
    vex::brain::lcd & screen,
    int x,
    int y,
    int width,
    int height )
```

draws the graph to the screen in the constructor

**Parameters**

<i>x</i>	x position of the top left of the graphed region
----------	--------------------------------------------------

**Parameters**

<i>y</i>	y position of the top left of the graphed region
<i>width</i>	the width of the graphed region
<i>height</i>	the height of the graphed region

The documentation for this class was generated from the following files:

- include/utils/graph\_drawer.h
- src/utils/graph\_drawer.cpp

## 5.36 PurePursuit::hermite\_point Struct Reference

```
#include <pure_pursuit.h>
```

**Public Member Functions**

- `point_t getPoint () const`
- `Vector2D getTangent () const`

**Public Attributes**

- `double x`
- `double y`
- `double dir`
- `double mag`

### 5.36.1 Detailed Description

a position along the hermite path contains a position and orientation information that the robot would be at at this point

The documentation for this struct was generated from the following file:

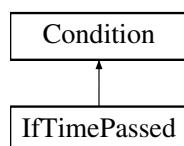
- include/utils/pure\_pursuit.h

## 5.37 IfTimePassed Class Reference

`IfTimePassed` tests based on time since the command controller was constructed. Returns true if elapsed time > time\_s.

```
#include <auto_command.h>
```

Inheritance diagram for IfTimePassed:



## Public Member Functions

- **IfTimePassed** (double time\_s)
- bool **test** () override

## Public Member Functions inherited from [Condition](#)

- [Condition \\* Or](#) ([Condition \\*b](#))
- [Condition \\* And](#) ([Condition \\*b](#))

### 5.37.1 Detailed Description

[IfTimePassed](#) tests based on time since the command controller was constructed. Returns true if elapsed time > time\_s.

### 5.37.2 Member Function Documentation

#### 5.37.2.1 test()

```
bool IfTimePassed::test ( ) [override], [virtual]
```

Implements [Condition](#).

The documentation for this class was generated from the following files:

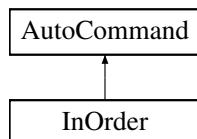
- include/utils/command\_structure/auto\_command.h
- src/utils/command\_structure/auto\_command.cpp

## 5.38 InOrder Class Reference

[InOrder](#) runs its commands sequentially then continues. How to handle timeout in this case. Automatically set it to sum of commands timeouts?

```
#include <auto_command.h>
```

Inheritance diagram for InOrder:



## Public Member Functions

- **InOrder** (const [InOrder](#) &other)=default
- **InOrder** (std::queue<[AutoCommand](#) \*> cmdqs)
- **InOrder** (std::initializer\_list<[AutoCommand](#) \*> cmdqs)
- bool **run** () override
- void **on\_timeout** () override

## Public Member Functions inherited from [AutoCommand](#)

- [AutoCommand \\* withTimeout](#) (double t\_seconds)
- [AutoCommand \\* withCancelCondition](#) ([Condition](#) \*true\_to\_end)

## Additional Inherited Members

## Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition](#) \* [true\\_to\\_end](#) = nullptr

## Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double [default\\_timeout](#) = 10.0

### 5.38.1 Detailed Description

[InOrder](#) runs its commands sequentially then continues. How to handle timeout in this case. Automatically set it to sum of commands timeouts?

[InOrder](#) runs its commands sequentially then continues. How to handle timeout in this case. Automatically set it to sum of commands timeouts?

### 5.38.2 Member Function Documentation

#### 5.38.2.1 [on\\_timeout\(\)](#)

```
void InOrder::on_timeout ( ) [override], [virtual]
```

What to do if we timeout instead of finishing. timeout is specified by the timeout seconds in the constructor

Reimplemented from [AutoCommand](#).

#### 5.38.2.2 [run\(\)](#)

```
bool InOrder::run ( ) [override], [virtual]
```

Executes the command Overridden by child classes

Returns

    true when the command is finished, false otherwise

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

- [include/utils/command\\_structure/auto\\_command.h](#)
- [src/utils/command\\_structure/auto\\_command.cpp](#)

## 5.39 screen::LabelConfig Struct Reference

### Public Attributes

- std::string **label**

The documentation for this struct was generated from the following file:

- include/subsystems/screen.h

## 5.40 Lift< T > Class Template Reference

```
#include <lift.h>
```

### Classes

- struct [lift\\_cfg\\_t](#)

### Public Member Functions

- [Lift](#) (motor\_group &lift\_motors, [lift\\_cfg\\_t](#) &lift\_cfg, map< T, double > &setpoint\_map, limit \*homing\_switch=NULL)
- void [control\\_continuous](#) (bool up\_ctrl, bool down\_ctrl)
- void [control\\_manual](#) (bool up\_btn, bool down\_btn, int volt\_up, int volt\_down)
- void [control\\_setpoints](#) (bool up\_step, bool down\_step, vector< T > pos\_list)
- bool [set\\_position](#) (T pos)
- bool [set\\_setpoint](#) (double val)
- double [get\\_setpoint](#) ()
- void [hold](#) ()
- void [home](#) ()
- bool [get\\_async](#) ()
- void [set\\_async](#) (bool val)
- void [set\\_sensor\\_function](#) (double(\*fn\_ptr)(void))
- void [set\\_sensor\\_reset](#) (void(\*fn\_ptr)(void))

### 5.40.1 Detailed Description

```
template<typename T>
class Lift< T >
```

LIFT A general class for lifts (e.g. 4bar, dr4bar, linear, etc) Uses a [PID](#) to hold the lift at a certain height under load, and to move the lift to different heights

#### Author

Ryan McGee

## 5.40.2 Constructor & Destructor Documentation

### 5.40.2.1 Lift()

```
template<typename T >
Lift< T >::Lift (
    motor_group & lift_motors,
    lift_cfg_t & lift_cfg,
    map< T, double > & setpoint_map,
    limit * homing_switch = NULL ) [inline]
```

Construct the `Lift` object and begin the background task that controls the lift.

Usage example: /code{.cpp} enum Positions {UP, MID, DOWN}; map<Positions, double> setpt\_map { {DOWN, 0.0}, {MID, 0.5}, {UP, 1.0} }; Lift<Positions> my\_lift(motors, lift\_cfg, setpt\_map); /endcode

#### Parameters

<code>lift_motors</code>	A set of motors, all set that positive rotation correlates with the lift going up
<code>lift_cfg</code>	<code>Lift</code> characterization information; PID tunings and movement speeds
<code>setpoint_map</code>	A map of enum type T, in which each enum entry corresponds to a different lift height

## 5.40.3 Member Function Documentation

### 5.40.3.1 control\_continuous()

```
template<typename T >
void Lift< T >::control_continuous (
    bool up_ctrl,
    bool down_ctrl ) [inline]
```

Control the lift with an "up" button and a "down" button. Use `PID` to hold the lift when letting go.

#### Parameters

<code>up_ctrl</code>	Button controlling the "UP" motion
<code>down_ctrl</code>	Button controlling the "DOWN" motion

### 5.40.3.2 control\_manual()

```
template<typename T >
void Lift< T >::control_manual (
    bool up_btn,
    bool down_btn,
    int volt_up,
    int volt_down ) [inline]
```

Control the lift with manual controls (no holding voltage)

**Parameters**

<i>up_btn</i>	Raise the lift when true
<i>down_btn</i>	Lower the lift when true
<i>volt_up</i>	Motor voltage when raising the lift
<i>volt_down</i>	Motor voltage when lowering the lift

**5.40.3.3 control\_setpoints()**

```
template<typename T >
void Lift< T >::control_setpoints (
    bool up_step,
    bool down_step,
    vector< T > pos_list ) [inline]
```

Control the lift in "steps". When the "up" button is pressed, the lift will go to the next position as defined by pos\_list. Order matters!

**Parameters**

<i>up_step</i>	A button that increments the position of the lift.
<i>down_step</i>	A button that decrements the position of the lift.
<i>pos_list</i>	A list of positions for the lift to go through. The higher the index, the higher the lift should be (generally).

**5.40.3.4 get\_async()**

```
template<typename T >
bool Lift< T >::get_async ( ) [inline]
```

**Returns**

whether or not the background thread is running the lift

**5.40.3.5 get\_setpoint()**

```
template<typename T >
double Lift< T >::get_setpoint ( ) [inline]
```

**Returns**

The current setpoint for the lift

**5.40.3.6 hold()**

```
template<typename T >
void Lift< T >::hold ( ) [inline]
```

Target the class's setpoint. Calculate the PID output and set the lift motors accordingly.

### 5.40.3.7 home()

```
template<typename T >
void Lift< T >::home ( ) [inline]
```

A blocking function that automatically homes the lift based on a sensor or hard stop, and sets the position to 0. A watchdog times out after 3 seconds, to avoid damage.

### 5.40.3.8 set\_async()

```
template<typename T >
void Lift< T >::set_async (
    bool val ) [inline]
```

Enables or disables the background task. Note that running the control functions, or set\_position functions will immediately re-enable the task for autonomous use.

#### Parameters

<i>val</i>	Whether or not the background thread should run the lift
------------	----------------------------------------------------------

### 5.40.3.9 set\_position()

```
template<typename T >
bool Lift< T >::set_position (
    T pos ) [inline]
```

Enable the background task, and send the lift to a position, specified by the setpoint map from the constructor.

#### Parameters

<i>pos</i>	A lift position enum type
------------	---------------------------

#### Returns

True if the pid has reached the setpoint

### 5.40.3.10 set\_sensor\_function()

```
template<typename T >
void Lift< T >::set_sensor_function (
    double(*) (void) fn_ptr ) [inline]
```

Creates a custom hook for any other type of sensor to be used on the lift. Example: /code{.cpp} my\_lift.set\_sensor\_function( [](){return my\_sensor.position();}); /endcode

#### Parameters

<i>fn_ptr</i>	Pointer to custom sensor function
---------------	-----------------------------------

### 5.40.3.11 set\_sensor\_reset()

```
template<typename T >
void Lift< T >::set_sensor_reset (
    void(*)(void) fn_ptr ) [inline]
```

Creates a custom hook to reset the sensor used in [set\\_sensor\\_function\(\)](#). Example: /code{.cpp} my\_lift.set\_sensor\_reset( my\_sensor.resetPosition ); /endcode

### 5.40.3.12 set\_setpoint()

```
template<typename T >
bool Lift< T >::set_setpoint (
    double val ) [inline]
```

Manually set a setpoint value for the lift [PID](#) to go to.

#### Parameters

<i>val</i>	Lift setpoint, in motor revolutions or sensor units defined by <a href="#">get_sensor</a> . Cannot be outside the softstops.
------------	------------------------------------------------------------------------------------------------------------------------------

#### Returns

True if the pid has reached the setpoint

The documentation for this class was generated from the following file:

- include/subsystems/lift.h

## 5.41 Lift< T >::lift\_cfg\_t Struct Reference

```
#include <lift.h>
```

#### Public Attributes

- double **up\_speed**
- double **down\_speed**
- double **softstop\_up**
- double **softstop\_down**
- [PID::pid\\_config\\_t](#) **lift\_pid\_cfg**

### 5.41.1 Detailed Description

```
template<typename T>
struct Lift< T >::lift_cfg_t
```

[lift\\_cfg\\_t](#) holds the physical parameter specifications of a lify system. includes:

- maximum speeds for the system
- softstops to stop the lift from hitting the hard stops too hard

The documentation for this struct was generated from the following file:

- include/subsystems/lift.h

## 5.42 Logger Class Reference

Class to simplify writing to files.

```
#include <logger.h>
```

### Public Member Functions

- **Logger** (const std::string &filename)  
*Create a logger that will save to a file.*
- **Logger** (const **Logger** &l)=delete  
*copying not allowed*
- **Logger** & **operator=** (const **Logger** &l)=delete  
*copying not allowed*
- void **Log** (const std::string &s)  
*Write a string to the log.*
- void **Log** (LogLevel level, const std::string &s)  
*Write a string to the log with a loglevel.*
- void **LogIn** (const std::string &s)  
*Write a string and newline to the log.*
- void **LogIn** (LogLevel level, const std::string &s)  
*Write a string and a newline to the log with a loglevel.*
- void **Logf** (const char \*fmt,...)  
*Write a formatted string to the log.*
- void **Logf** (LogLevel level, const char \*fmt,...)  
*Write a formatted string to the log with a loglevel.*

### Static Public Attributes

- static constexpr int **MAX\_FORMAT\_LEN** = 512  
*maximum size for a string to be before it's written*

### 5.42.1 Detailed Description

Class to simplify writing to files.

### 5.42.2 Constructor & Destructor Documentation

#### 5.42.2.1 **Logger()**

```
Logger::Logger (
    const std::string & filename ) [explicit]
```

Create a logger that will save to a file.

**Parameters**

<i>filename</i>	the file to save to
-----------------	---------------------

### 5.42.3 Member Function Documentation

#### 5.42.3.1 Log() [1/2]

```
void Logger::Log (
    const std::string & s )
```

Write a string to the log.

**Parameters**

<i>s</i>	the string to write
----------	---------------------

#### 5.42.3.2 Log() [2/2]

```
void Logger::Log (
    LogLevel level,
    const std::string & s )
```

Write a string to the log with a loglevel.

**Parameters**

<i>level</i>	the level to write. DEBUG, NOTICE, WARNING, ERROR, CRITICAL, TIME
<i>s</i>	the string to write

#### 5.42.3.3 Logf() [1/2]

```
void Logger::Logf (
    const char * fmt,
    ... )
```

Write a formatted string to the log.

**Parameters**

<i>fmt</i>	the format string (like printf)
...	the args

### 5.42.3.4 Logf() [2/2]

```
void Logger::Logf (
    LogLevel level,
    const char * fmt,
    ...
)
```

Write a formatted string to the log with a loglevel.

#### Parameters

<i>level</i>	the level to write. DEBUG, NOTICE, WARNING, ERROR, CRITICAL, TIME
<i>fmt</i>	the format string (like printf)
...	the args

### 5.42.3.5 Logln() [1/2]

```
void Logger::Logln (
    const std::string & s )
```

Write a string and newline to the log.

#### Parameters

<i>s</i>	the string to write
----------	---------------------

### 5.42.3.6 Logln() [2/2]

```
void Logger::Logln (
    LogLevel level,
    const std::string & s )
```

Write a string and a newline to the log with a loglevel.

#### Parameters

<i>level</i>	the level to write. DEBUG, NOTICE, WARNING, ERROR, CRITICAL, TIME
<i>s</i>	the string to write

The documentation for this class was generated from the following files:

- include/utils/logger.h
- src/utils/logger.cpp

## 5.43 MotionController::m\_profile\_cfg\_t Struct Reference

---

```
#include <motion_controller.h>
```

## Public Attributes

- double **max\_v**  
*the maximum velocity the robot can drive*
- double **accel**  
*the most acceleration the robot can do*
- **PID::pid\_config\_t pid\_cfg**  
*configuration parameters for the internal PID controller*
- **FeedForward::ff\_config\_t ff\_cfg**  
*configuration parameters for the internal*

### 5.43.1 Detailed Description

m\_profile\_config holds all data the motion controller uses to plan paths. When motion profile is given a target to drive to, max\_v and accel are used to make the trapezoid profile instructing the controller how to drive. pid\_cfg, ff\_cfg are used to find the motor outputs necessary to execute this path.

The documentation for this struct was generated from the following file:

- include/utils/controls/motion\_controller.h

## 5.44 Mat2 Struct Reference

### Public Member Functions

- **point\_t operator\* (const point\_t p) const**

### Static Public Member Functions

- static **Mat2 FromRotationDegrees (double degrees)**

### Public Attributes

- double **X11**
- double **X12**
- double **X21**
- double **X22**

The documentation for this struct was generated from the following file:

- include/utils/geometry.h

## 5.45 StateMachine< System, IDType, Message, delay\_ms, do\_log >::MaybeMessage Class Reference

**MaybeMessage** a message of **Message** type or nothing. **MaybeMessage** m = {};// empty **MaybeMessage** m = **Message**::EnumField1.

```
#include <state_machine.h>
```

## Public Member Functions

- **MaybeMessage ()**  
*Empty message - when theres no message.*
- **MaybeMessage (Message msg)**  
*Create a maybe message with a message.*
- **bool has\_message ()**  
*check if the message is here*
- **Message message ()**  
*Get the message stored. The return value is invalid unless has\_message returned true.*

### 5.45.1 Detailed Description

```
template<typename System, typename IDType, typename Message, int32_t delay_ms, bool do_log = false>
class StateMachine< System, IDType, Message, delay_ms, do_log >::MaybeMessage
```

MaybeMessage a message of Message type or nothing MaybeMessage m = {}; // empty MaybeMessage m = Message::EnumField1.

### 5.45.2 Constructor & Destructor Documentation

#### 5.45.2.1 MaybeMessage()

```
template<typename System , typename IDType , typename Message , int32_t delay_ms, bool do_log
= false>
StateMachine< System, IDType, Message, delay_ms, do_log >::MaybeMessage::MaybeMessage (
    Message msg ) [inline]
```

Create a maybe message with a message.

##### Parameters

<code>msg</code>	the message to hold on to
------------------	---------------------------

### 5.45.3 Member Function Documentation

#### 5.45.3.1 has\_message()

```
template<typename System , typename IDType , typename Message , int32_t delay_ms, bool do_log
= false>
bool StateMachine< System, IDType, Message, delay_ms, do_log >::MaybeMessage::has_message ( )
[inline]
```

check if the message is here

##### Returns

true if there is a message

### 5.45.3.2 message()

```
template<typename System , typename IDType , typename Message , int32_t delay_ms, bool do_log
= false>
Message StateMachine< System, IDType, Message, delay_ms, do_log >::MaybeMessage::message ( )
[inline]
```

Get the message stored. The return value is invalid unless has\_message returned true.

#### Returns

The message if it exists. Undefined otherwise

The documentation for this class was generated from the following file:

- include/utils/state\_machine.h

## 5.46 MecanumDrive Class Reference

```
#include <mecanum_drive.h>
```

#### Classes

- struct [mecanumdrive\\_config\\_t](#)

#### Public Member Functions

- [MecanumDrive](#) (vex::motor &left\_front, vex::motor &right\_front, vex::motor &left\_rear, vex::motor &right\_rear, vex::rotation \*lateral\_wheel=NULL, vex::inertial \*imu=NULL, [mecanumdrive\\_config\\_t](#) \*config=NULL)
- void [drive\\_raw](#) (double direction\_deg, double magnitude, double rotation)
- void [drive](#) (double left\_y, double left\_x, double right\_x, int power=2)
- bool [auto\\_drive](#) (double inches, double direction, double speed, bool gyro\_correction=true)
- bool [auto\\_turn](#) (double degrees, double speed, bool ignore\_imu=false)

### 5.46.1 Detailed Description

A class representing the Mecanum drivetrain. Contains 4 motors, a possible IMU (intertial), and a possible undriven perpendicular wheel.

### 5.46.2 Constructor & Destructor Documentation

#### 5.46.2.1 MecanumDrive()

```
MecanumDrive::MecanumDrive (
    vex::motor & left_front,
    vex::motor & right_front,
    vex::motor & left_rear,
    vex::motor & right_rear,
    vex::rotation * lateral_wheel = NULL,
    vex::inertial * imu = NULL,
    mecanumdrive\_config\_t * config = NULL )
```

Create the Mecanum drivetrain object

### 5.46.3 Member Function Documentation

#### 5.46.3.1 auto\_drive()

```
bool MecanumDrive::auto_drive (
    double inches,
    double direction,
    double speed,
    bool gyro_correction = true )
```

Drive the robot in a straight line automatically. If the inertial was declared in the constructor, use it to correct while driving. If the lateral wheel was declared in the constructor, use it for more accurate positioning while strafing.

##### Parameters

<i>inches</i>	How far the robot should drive, in inches
<i>direction</i>	What direction the robot should travel in, in degrees. 0 is forward, +/-180 is reverse, clockwise is positive.
<i>speed</i>	The maximum speed the robot should travel, in percent: -1.0->+1.0
<i>gyro_correction</i>	=true Whether or not to use the gyro to help correct while driving. Will always be false if no gyro was declared in the constructor.

Drive the robot in a straight line automatically. If the inertial was declared in the constructor, use it to correct while driving. If the lateral wheel was declared in the constructor, use it for more accurate positioning while strafing.

##### Parameters

<i>inches</i>	How far the robot should drive, in inches
<i>direction</i>	What direction the robot should travel in, in degrees. 0 is forward, +/-180 is reverse, clockwise is positive.
<i>speed</i>	The maximum speed the robot should travel, in percent: -1.0->+1.0
<i>gyro_correction</i>	= true Whether or not to use the gyro to help correct while driving. Will always be false if no gyro was declared in the constructor.

##### Returns

Whether or not the maneuver is complete.

#### 5.46.3.2 auto\_turn()

```
bool MecanumDrive::auto_turn (
    double degrees,
    double speed,
    bool ignore_imu = false )
```

Autonomously turn the robot X degrees over it's center point. Uses a closed loop for control.

##### Parameters

<i>degrees</i>	How many degrees to rotate the robot. Clockwise positive.
<i>speed</i>	What percentage to run the motors at: 0.0 -> 1.0
<i>ignore_imu</i>	=false Whether or not to use the Inertial for determining angle. Will instead use circumference formula + robot's wheelbase + encoders to determine. Generated by Doxygen

**Returns**

whether or not the robot has finished the maneuver

Autonomously turn the robot X degrees over it's center point. Uses a closed loop for control.

**Parameters**

<i>degrees</i>	How many degrees to rotate the robot. Clockwise positive.
<i>speed</i>	What percentage to run the motors at: 0.0 -> 1.0
<i>ignore_imu</i>	= false Whether or not to use the Inertial for determining angle. Will instead use circumference formula + robot's wheelbase + encoders to determine.

**Returns**

whether or not the robot has finished the maneuver

**5.46.3.3 drive()**

```
void MecanumDrive::drive (
    double left_y,
    double left_x,
    double right_x,
    int power = 2 )
```

Drive the robot with a mecanum-style / arcade drive. Inputs are in percent (-100.0 -> 100.0) straight from the controller. Controls are mixed, so the robot can drive forward / strafe / rotate all at the same time.

**Parameters**

<i>left_y</i>	left joystick, Y axis (forward / backwards)
<i>left_x</i>	left joystick, X axis (strafe left / right)
<i>right_x</i>	right joystick, X axis (rotation left / right)
<i>power</i>	=2 how much of a "curve" there should be on drive controls; better for low speed maneuvers. Leave blank for a default curve of 2 (higher means more fidelity)

Drive the robot with a mecanum-style / arcade drive. Inputs are in percent (-100.0 -> 100.0) straight from the controller. Controls are mixed, so the robot can drive forward / strafe / rotate all at the same time.

**Parameters**

<i>left_y</i>	left joystick, Y axis (forward / backwards)
<i>left_x</i>	left joystick, X axis (strafe left / right)
<i>right_x</i>	right joystick, X axis (rotation left / right)
<i>power</i>	= 2 how much of a "curve" there should be on drive controls; better for low speed maneuvers. Leave blank for a default curve of 2 (higher means more fidelity)

#### 5.46.3.4 drive\_raw()

```
void MecanumDrive::drive_raw (
    double direction_deg,
    double magnitude,
    double rotation )
```

Drive the robot using vectors. This handles all the math required for mecanum control.

##### Parameters

<i>direction_deg</i>	the direction to drive the robot, in degrees. 0 is forward, 180 is back, clockwise is positive, counterclockwise is negative.
<i>magnitude</i>	How fast the robot should drive, in percent: 0.0->1.0
<i>rotation</i>	How fast the robot should rotate, in percent: -1.0->+1.0

The documentation for this class was generated from the following files:

- include/subsystems/mecanum\_drive.h
- src/subsystems/mecanum\_drive.cpp

## 5.47 MecanumDrive::mecanumdrive\_config\_t Struct Reference

```
#include <mecanum_drive.h>
```

##### Public Attributes

- [PID::pid\\_config\\_t drive\\_pid\\_conf](#)
- [PID::pid\\_config\\_t drive\\_gyro\\_pid\\_conf](#)
- [PID::pid\\_config\\_t turn\\_pid\\_conf](#)
- double **drive\_wheel\_diam**
- double **lateral\_wheel\_diam**
- double **wheelbase\_width**

### 5.47.1 Detailed Description

Configure the Mecanum drive [PID](#) tunings and robot configurations

The documentation for this struct was generated from the following file:

- include/subsystems/mecanum\_drive.h

## 5.48 motion\_t Struct Reference

```
#include <trapezoid_profile.h>
```

## Public Attributes

- **double pos**  
*1d position at this point in time*
- **double vel**  
*1d velocity at this point in time*
- **double accel**  
*1d acceleration at this point in time*

### 5.48.1 Detailed Description

`motion_t` is a description of 1 dimensional motion at a point in time.

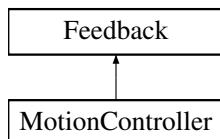
The documentation for this struct was generated from the following file:

- include/utils/controls/trapezoid\_profile.h

## 5.49 MotionController Class Reference

```
#include <motion_controller.h>
```

Inheritance diagram for MotionController:



## Classes

- struct `m_profile_cfg_t`

## Public Member Functions

- `MotionController (m_profile_cfg_t &config)`  
*Construct a new Motion Controller object.*
- `void init (double start_pt, double end_pt, double start_vel, double end_vel) override`  
*Initialize the motion profile for a new movement This will also reset the PID and profile timers.*
- `double update (double sensor_val) override`  
*Update the motion profile with a new sensor value.*
- `double get () override`
- `void set_limits (double lower, double upper) override`
- `bool is_on_target () override`
- `motion_t get_motion () const`
- `screen::Page * Page ()`

### Static Public Member Functions

- static `FeedForward::ff_config_t tune_feedforward (TankDrive &drive, OdometryTank &odometry, double pct=0.6, double duration=2)`

### Friends

- class **MotionControllerPage**

## 5.49.1 Detailed Description

Motion Controller class

This class defines a top-level motion profile, which can act as an intermediate between a subsystem class and the motors themselves

This takes the constants kS, kV, kA, kP, kI, kD, max\_v and acceleration and wraps around a feedforward, **PID** and trapezoid profile. It does so with the following formula:

```
out = feedforward.calculate(motion_profile.get(time_s)) + pid.get(motion_profile.get(time_s))
```

For **PID** and Feedforward specific formulae, see [pid.h](#), [feedforward.h](#), and [trapezoid\\_profile.h](#)

### Author

Ryan McGee

### Date

7/13/2022

## 5.49.2 Constructor & Destructor Documentation

### 5.49.2.1 MotionController()

```
MotionController::MotionController (
    m_profile_cfg_t & config )
```

Construct a new Motion Controller object.

#### Parameters

<code>config</code>	The definition of how the robot is able to move max_v Maximum velocity the movement is capable of accel Acceleration / deceleration of the movement pid_cfg Definitions of kP, kI, and kD ff_cfg Definitions of kS, kV, and kA
---------------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

### 5.49.3 Member Function Documentation

#### 5.49.3.1 get()

```
double MotionController::get ( ) [override], [virtual]
```

##### Returns

the last saved result from the feedback controller

Implements [Feedback](#).

#### 5.49.3.2 get\_motion()

```
motion_t MotionController::get_motion ( ) const
```

##### Returns

The current position, velocity and acceleration setpoints

#### 5.49.3.3 init()

```
void MotionController::init (
    double start_pt,
    double end_pt,
    double start_vel,
    double end_vel ) [override], [virtual]
```

Initialize the motion profile for a new movement This will also reset the [PID](#) and profile timers.

##### Parameters

<i>start_pt</i>	Movement starting position
<i>end_pt</i>	Movement ending position
<i>start_vel</i>	Movement starting velocity
<i>end_vel</i>	Movement ending velocity

Implements [Feedback](#).

#### 5.49.3.4 is\_on\_target()

```
bool MotionController::is_on_target ( ) [override], [virtual]
```

##### Returns

Whether or not the movement has finished, and the [PID](#) confirms it is on target

Implements [Feedback](#).

### 5.49.3.5 set\_limits()

```
void MotionController::set_limits (
    double lower,
    double upper ) [override], [virtual]
```

Clamp the upper and lower limits of the output. If both are 0, no limits should be applied. If limits are applied, the controller will not target any value below lower or above upper

#### Parameters

<i>lower</i>	upper limit
<i>upper</i>	lower limit

Clamp the upper and lower limits of the output. If both are 0, no limits should be applied.

#### Parameters

<i>lower</i>	Upper limit
<i>upper</i>	Lower limit

Implements [Feedback](#).

### 5.49.3.6 tune\_feedforward()

```
FeedForward::ff_config_t MotionController::tune_feedforward (
    TankDrive & drive,
    OdometryTank & odometry,
    double pct = 0.6,
    double duration = 2 ) [static]
```

This method attempts to characterize the robot's drivetrain and automatically tune the feedforward. It does this by first calculating the kS (voltage to overcome static friction) by slowly increasing the voltage until it moves.

Next is kV (voltage to sustain a certain velocity), where the robot will record its steady-state velocity at 'pct' speed.

Finally, kA (voltage needed to accelerate by a certain rate), where the robot will record the entire movement's velocity and acceleration, record a plot of [X=(pct-kV\*V-kS), Y=(Acceleration)] along the movement, and since kA\*Accel = pct-kV\*V-kS, the reciprocal of the linear regression is the kA value.

#### Parameters

<i>drive</i>	The tankdrive to operate on
<i>odometry</i>	The robot's odometry subsystem
<i>pct</i>	Maximum velocity in percent (0->1.0)
<i>duration</i>	Amount of time the robot should be moving for the test

#### Returns

A tuned feedforward object

### 5.49.3.7 update()

```
double MotionController::update (
    double sensor_val )  [override], [virtual]
```

Update the motion profile with a new sensor value.

#### Parameters

<code>sensor_val</code>	Value from the sensor
-------------------------	-----------------------

#### Returns

the motor input generated from the motion profile

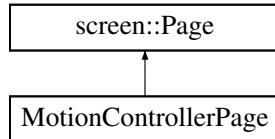
Implements [Feedback](#).

The documentation for this class was generated from the following files:

- include/utils/controls/motion\_controller.h
- src/utils/controls/motion\_controller.cpp

## 5.50 MotionControllerPage Class Reference

Inheritance diagram for MotionControllerPage:



#### Public Member Functions

- **MotionControllerPage** (const [MotionController](#) &mc)
- void [update](#) (bool was\_pressed, int x, int y) override  
*collect data, respond to screen input, do fast things (runs at 50hz even if you're not focused on this Page (only drawn page gets touch updates))*
- void [draw](#) (vex::brain::lcd &screen, bool first\_draw, unsigned int frame\_number)  
*draw stored data to the screen (runs at 10 hz and only runs if this page is in front)*

### 5.50.1 Member Function Documentation

#### 5.50.1.1 draw()

```
void MotionControllerPage::draw (
    vex::brain::lcd & screen,
    bool first_draw,
    unsigned int frame_number )  [inline], [virtual]
```

draw stored data to the screen (runs at 10 hz and only runs if this page is in front)

## Parameters

<code>first_draw</code>	true if we just switched to this page
<code>frame_number</code>	frame of drawing we are on (basically an animation tick)

Reimplemented from [screen::Page](#).

**5.50.1.2 update()**

```
void MotionControllerPage::update (
    bool was_pressed,
    int x,
    int y) [inline], [override], [virtual]
```

collect data, respond to screen input, do fast things (runs at 50hz even if you're not focused on this Page (only drawn page gets touch updates))

## Parameters

<code>was_pressed</code>	true if the screen has been pressed
<code>x</code>	x position of screen press (if the screen was pressed)
<code>y</code>	y position of screen press (if the screen was pressed)

Reimplemented from [screen::Page](#).

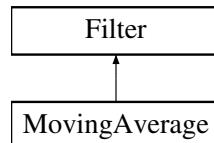
The documentation for this class was generated from the following file:

- [src/utils/controls/motion\\_controller.cpp](#)

**5.51 MovingAverage Class Reference**

```
#include <moving_average.h>
```

Inheritance diagram for MovingAverage:

**Public Member Functions**

- [`MovingAverage` \(int buffer\\_size\)](#)
- [`MovingAverage` \(int buffer\\_size, double starting\\_value\)](#)
- void [`add\_entry` \(double n\)](#) override
- double [`get\_value` \(\)](#) const override
- int [`get\_size` \(\)](#) const

### 5.51.1 Detailed Description

#### MovingAverage

A moving average is a way of smoothing out noisy data. For many sensor readings, the noise is roughly symmetric around the actual value. This means that if you collect enough samples those that are too high are cancelled out by the samples that are too low leaving the real value.

The [MovingAverage](#) class provides a simple interface to do this smoothing from our noisy sensor values.

**WARNING:** because we need a lot of samples to get the actual value, the value given by the [MovingAverage](#) will 'lag' behind the actual value that the sensor is reading. Using a [MovingAverage](#) is thus a tradeoff between accuracy and lag time (more samples) vs. less accuracy and faster updating (less samples).

### 5.51.2 Constructor & Destructor Documentation

#### 5.51.2.1 MovingAverage() [1/2]

```
MovingAverage::MovingAverage (
    int buffer_size )
```

Create a moving average calculator with 0 as the default value

##### Parameters

<i>buffer_size</i>	The size of the buffer. The number of samples that constitute a valid reading
--------------------	-------------------------------------------------------------------------------

#### 5.51.2.2 MovingAverage() [2/2]

```
MovingAverage::MovingAverage (
    int buffer_size,
    double starting_value )
```

Create a moving average calculator with a specified default value

##### Parameters

<i>buffer_size</i>	The size of the buffer. The number of samples that constitute a valid reading
<i>starting_value</i>	The value that the average will be before any data is added

### 5.51.3 Member Function Documentation

#### 5.51.3.1 add\_entry()

```
void MovingAverage::add_entry (
    double n ) [override], [virtual]
```

Add a reading to the buffer Before: [ 1 1 2 2 3 3 ] => 2 ^ After: [ 2 1 2 2 3 3 ] => 2.16 ^

**Parameters**

<code>n</code>	the sample that will be added to the moving average.
----------------	------------------------------------------------------

Implements [Filter](#).

### 5.51.3.2 `get_size()`

```
int MovingAverage::get_size ( ) const
```

How many samples the average is made from

**Returns**

the number of samples used to calculate this average

### 5.51.3.3 `get_value()`

```
double MovingAverage::get_value ( ) const [override], [virtual]
```

Returns the average based off of all the samples collected so far

**Returns**

the calculated average. sum(samples)/numsamples

How many samples the average is made from

**Returns**

the number of samples used to calculate this average

Implements [Filter](#).

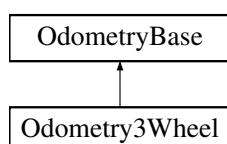
The documentation for this class was generated from the following files:

- include/utils/moving\_average.h
- src/utils/moving\_average.cpp

## 5.52 Odometry3Wheel Class Reference

```
#include <odometry_3wheel.h>
```

Inheritance diagram for Odometry3Wheel:



## Classes

- struct `odometry3wheel_cfg_t`

## Public Member Functions

- `Odometry3Wheel (CustomEncoder &lside_fwd, CustomEncoder &rside_fwd, CustomEncoder &off_axis, odometry3wheel_cfg_t &cfg, bool is_async=true)`
- `pose_t update () override`
- `void tune (vex::controller &con, TankDrive &drive)`

## Public Member Functions inherited from `OdometryBase`

- `OdometryBase (bool is_async)`
- `pose_t get_position (void)`
- `virtual void set_position (const pose_t &newpos=zero_pos)`
- `AutoCommand * SetPositionCmd (const pose_t &newpos=zero_pos)`
- `void end_async ()`
- `double get_speed ()`
- `double get_accel ()`
- `double get_angular_speed_deg ()`
- `double get_angular_accel_deg ()`

## Additional Inherited Members

### Static Public Member Functions inherited from `OdometryBase`

- static int `background_task (void *ptr)`
- static double `pos_diff (pose_t start_pos, pose_t end_pos)`
- static double `rot_diff (pose_t pos1, pose_t pos2)`
- static double `smallest_angle (double start_deg, double end_deg)`

### Public Attributes inherited from `OdometryBase`

- bool `end_task = false`  
*end\_task is true if we instruct the odometry thread to shut down*

### Static Public Attributes inherited from `OdometryBase`

- static constexpr `pose_t zero_pos = {.x = 0.0L, .y = 0.0L, .rot = 90.0L}`

### Protected Attributes inherited from `OdometryBase`

- vex::task \* `handle`
- vex::mutex `mut`
- `pose_t current_pos`
- `double speed`
- `double accel`
- `double ang_speed_deg`
- `double ang_accel_deg`

### 5.52.1 Detailed Description

#### Odometry3Wheel

This class handles the code for a standard 3-pod odometry setup, where there are 3 "pods" made up of undriven (dead) wheels connected to encoders in the following configuration:

```
+Y ----- ^ | | | | | | | O | | | | | | == | | ----- | +-----> + X
```

Where O is the center of rotation. The robot will monitor the changes in rotation of these wheels and calculate the robot's X, Y and rotation on the field.

This is a "set and forget" class, meaning once the object is created, the robot will immediately begin tracking its movement in the background.

#### Author

Ryan McGee

#### Date

Oct 31 2022

### 5.52.2 Constructor & Destructor Documentation

#### 5.52.2.1 Odometry3Wheel()

```
Odometry3Wheel::Odometry3Wheel (
    CustomEncoder & lside_fwd,
    CustomEncoder & rside_fwd,
    CustomEncoder & off_axis,
    odometry3wheel_cfg_t & cfg,
    bool is_async = true )
```

Construct a new Odometry 3 Wheel object

#### Parameters

<i>lside_fwd</i>	left-side encoder reference
<i>rside_fwd</i>	right-side encoder reference
<i>off_axis</i>	off-axis (perpendicular) encoder reference
<i>cfg</i>	robot odometry configuration
<i>is_async</i>	true to constantly run in the background

### 5.52.3 Member Function Documentation

#### 5.52.3.1 tune()

```
void Odometry3Wheel::tune (
    vex::controller & con,
    TankDrive & drive )
```

A guided tuning process to automatically find tuning parameters. This method is blocking, and returns when tuning has finished. Follow the instructions on the controller to complete the tuning process

#### Parameters

<i>con</i>	Controller reference, for screen and button control
<i>drive</i>	Drivetrain reference for robot control

A guided tuning process to automatically find tuning parameters. This method is blocking, and returns when tuning has finished. Follow the instructions on the controller to complete the tuning process

It is assumed the gear ratio and encoder PPR have been set correctly

#### 5.52.3.2 update()

```
pose_t Odometry3Wheel::update ( ) [override], [virtual]
```

Update the current position of the robot once, using the current state of the encoders and the previous known location

#### Returns

the robot's updated position

Implements [OdometryBase](#).

The documentation for this class was generated from the following files:

- include/subsystems/odometry/odometry\_3wheel.h
- src/subsystems/odometry/odometry\_3wheel.cpp

## 5.53 Odometry3Wheel::odometry3wheel\_cfg\_t Struct Reference

```
#include <odometry_3wheel.h>
```

#### Public Attributes

- double *wheelbase\_dist*
- double *off\_axis\_center\_dist*
- double *wheel\_diam*

#### 5.53.1 Detailed Description

[odometry3wheel\\_cfg\\_t](#) holds all the specifications for how to calculate position with 3 encoders See the core wiki for what exactly each of these parameters measures

## 5.53.2 Member Data Documentation

### 5.53.2.1 off\_axis\_center\_dist

```
double Odometry3Wheel::odometry3wheel_cfg_t::off_axis_center_dist
```

distance from the center of the robot to the center off axis wheel

### 5.53.2.2 wheel\_diam

```
double Odometry3Wheel::odometry3wheel_cfg_t::wheel_diam
```

the diameter of the tracking wheel

### 5.53.2.3 wheelbase\_dist

```
double Odometry3Wheel::odometry3wheel_cfg_t::wheelbase_dist
```

distance from the center of the left wheel to the center of the right wheel

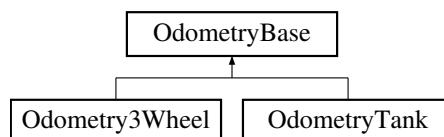
The documentation for this struct was generated from the following file:

- include/subsystems/odometry/odometry\_3wheel.h

## 5.54 OdometryBase Class Reference

```
#include <odometry_base.h>
```

Inheritance diagram for OdometryBase:



### Public Member Functions

- [OdometryBase \(bool is\\_async\)](#)
- [pose\\_t get\\_position \(void\)](#)
- virtual void [set\\_position \(const pose\\_t &newpos=zero\\_pos\)](#)
- [AutoCommand \\* SetPositionCmd \(const pose\\_t &newpos=zero\\_pos\)](#)
- virtual [pose\\_t update \(\)=0](#)
- void [end\\_async \(\)](#)
- double [get\\_speed \(\)](#)
- double [get\\_accel \(\)](#)
- double [get\\_angular\\_speed\\_deg \(\)](#)
- double [get\\_angular\\_accel\\_deg \(\)](#)

## Static Public Member Functions

- static int `background_task` (void \*ptr)
- static double `pos_diff` (`pose_t` start\_pos, `pose_t` end\_pos)
- static double `rot_diff` (`pose_t` pos1, `pose_t` pos2)
- static double `smallest_angle` (double start\_deg, double end\_deg)

## Public Attributes

- bool `end_task` = false  
*end\_task is true if we instruct the odometry thread to shut down*

## Static Public Attributes

- static constexpr `pose_t zero_pos` = {.x = 0.0L, .y = 0.0L, .rot = 90.0L}

## Protected Attributes

- vex::task \* `handle`
- vex::mutex `mut`
- `pose_t current_pos`
- double `speed`
- double `accel`
- double `ang_speed_deg`
- double `ang_accel_deg`

## 5.54.1 Detailed Description

### OdometryBase

This base class contains all the shared code between different implementations of odometry. It handles the asynchronous management, position input/output and basic math functions, and holds positional types specific to field orientation.

All future odometry implementations should extend this file and redefine `update()` function.

#### Author

Ryan McGee

#### Date

Aug 11 2021

## 5.54.2 Constructor & Destructor Documentation

### 5.54.2.1 OdometryBase()

```
OdometryBase::OdometryBase (
    bool is_async )
```

Construct a new Odometry Base object

**Parameters**

<i>is_async</i>	True to run constantly in the background, false to call <a href="#">update()</a> manually
-----------------	-------------------------------------------------------------------------------------------

### 5.54.3 Member Function Documentation

#### 5.54.3.1 `background_task()`

```
int OdometryBase::background_task (
    void * ptr ) [static]
```

Function that runs in the background task. This function pointer is passed to the vex::task constructor.

**Parameters**

<i>ptr</i>	Pointer to <a href="#">OdometryBase</a> object
------------	------------------------------------------------

**Returns**

Required integer return code. Unused.

#### 5.54.3.2 `end_async()`

```
void OdometryBase::end_async ( )
```

End the background task. Cannot be restarted. If the user wants to end the thread but keep the data up to date, they must run the [update\(\)](#) function manually from then on.

#### 5.54.3.3 `get_accel()`

```
double OdometryBase::get_accel ( )
```

Get the current acceleration

**Returns**

the acceleration rate of the robot (inch/s<sup>2</sup>)

#### 5.54.3.4 `get_angular_accel_deg()`

```
double OdometryBase::get_angular_accel_deg ( )
```

Get the current angular acceleration in degrees

**Returns**

the angular acceleration at which we are turning (deg/s<sup>2</sup>)

### 5.54.3.5 get\_angular\_speed\_deg()

```
double OdometryBase::get_angular_speed_deg ( )
```

Get the current angular speed in degrees

#### Returns

the angular velocity at which we are turning (deg/s)

### 5.54.3.6 get\_position()

```
pose_t OdometryBase::get_position (
    void )
```

Gets the current position and rotation

#### Returns

the position that the odometry believes the robot is at

Gets the current position and rotation

### 5.54.3.7 get\_speed()

```
double OdometryBase::get_speed ( )
```

Get the current speed

#### Returns

the speed at which the robot is moving and grooving (inch/s)

### 5.54.3.8 pos\_diff()

```
double OdometryBase::pos_diff (
    pose_t start_pos,
    pose_t end_pos ) [static]
```

Get the distance between two points

#### Parameters

<i>start_pos</i>	distance from this point
<i>end_pos</i>	to this point

**Returns**

the euclidean distance between start\_pos and end\_pos

**5.54.3.9 rot\_diff()**

```
double OdometryBase::rot_diff (
    pose_t pos1,
    pose_t pos2 ) [static]
```

Get the change in rotation between two points

**Parameters**

<i>pos1</i>	position with initial rotation
<i>pos2</i>	position with final rotation

**Returns**

change in rotation between pos1 and pos2

Get the change in rotation between two points

**5.54.3.10 set\_position()**

```
void OdometryBase::set_position (
    const pose_t & newpos = zero_pos ) [virtual]
```

Sets the current position of the robot

**Parameters**

<i>newpos</i>	the new position that the odometry will believe it is at
---------------	----------------------------------------------------------

Sets the current position of the robot

Reimplemented in [OdometryTank](#).

**5.54.3.11 smallest\_angle()**

```
double OdometryBase::smallest_angle (
    double start_deg,
    double end_deg ) [static]
```

Get the smallest difference in angle between a start heading and end heading. Returns the difference between -180 degrees and +180 degrees, representing the robot turning left or right, respectively.

**Parameters**

<code>start_deg</code>	initial angle (degrees)
<code>end_deg</code>	final angle (degrees)

**Returns**

the smallest angle from the initial to the final angle. This takes into account the wrapping of rotations around 360 degrees

Get the smallest difference in angle between a start heading and end heading. Returns the difference between -180 degrees and +180 degrees, representing the robot turning left or right, respectively.

**5.54.3.12 update()**

```
virtual pose_t OdometryBase::update ( ) [pure virtual]
```

Update the current position on the field based on the sensors

**Returns**

the location that the robot is at after the odometry does its calculations

Implemented in [Odometry3Wheel](#), and [OdometryTank](#).

**5.54.4 Member Data Documentation****5.54.4.1 accel**

```
double OdometryBase::accel [protected]
```

the rate at which we are accelerating (inch/s<sup>2</sup>)

**5.54.4.2 ang\_accel\_deg**

```
double OdometryBase::ang_accel_deg [protected]
```

the rate at which we are accelerating our turn (deg/s<sup>2</sup>)

**5.54.4.3 ang\_speed\_deg**

```
double OdometryBase::ang_speed_deg [protected]
```

the speed at which we are turning (deg/s)

#### 5.54.4.4 current\_pos

`pose_t OdometryBase::current_pos [protected]`

Current position of the robot in terms of x,y,rotation

#### 5.54.4.5 handle

`vex::task* OdometryBase::handle [protected]`

handle to the vex task that is running the odometry code

#### 5.54.4.6 mut

`vex::mutex OdometryBase::mut [protected]`

Mutex to control multithreading

#### 5.54.4.7 speed

`double OdometryBase::speed [protected]`

the speed at which we are travelling (inch/s)

#### 5.54.4.8 zero\_pos

`constexpr pose_t OdometryBase::zero_pos = { .x = 0.0L, .y = 0.0L, .rot = 90.0L} [inline], [static], [constexpr]`

Zeroed position. X=0, Y=0, Rotation= 90 degrees

The documentation for this class was generated from the following files:

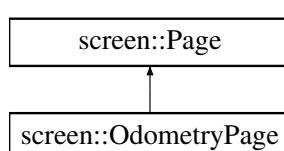
- `include/subsystems/odometry/odometry_base.h`
- `src/subsystems/odometry/odometry_base.cpp`

## 5.55 screen::OdometryPage Class Reference

a page that shows odometry position and rotation and a map (if an sd card with the file is on)

```
#include <screen.h>
```

Inheritance diagram for screen::OdometryPage:



## Public Member Functions

- [OdometryPage \(OdometryBase &odom, double robot\\_width, double robot\\_height, bool do\\_trail\)](#)  
*Create an odometry trail. Make sure odometry is initialized before now.*
- void [update \(bool was\\_pressed, int x, int y\) override](#)
- void [draw \(vex::brain::lcd &, bool first\\_draw, unsigned int frame\\_number\) override](#)

### 5.55.1 Detailed Description

a page that shows odometry position and rotation and a map (if an sd card with the file is on)

### 5.55.2 Constructor & Destructor Documentation

#### 5.55.2.1 OdometryPage()

```
screen::OdometryPage::OdometryPage (
    OdometryBase & odom,
    double robot_width,
    double robot_height,
    bool do_trail )
```

Create an odometry trail. Make sure odometry is initialized before now.

#### Parameters

<i>odom</i>	the odometry system to monitor
<i>robot_width</i>	the width (side to side) of the robot in inches. Used for visualization
<i>robot_height</i>	the robot_height (front to back) of the robot in inches. Used for visualization
<i>do_trail</i>	whether or not to calculate and draw the trail. Drawing and storing takes a very <i>slight</i> extra amount of processing power

### 5.55.3 Member Function Documentation

#### 5.55.3.1 draw()

```
void screen::OdometryPage::draw (
    vex::brain::lcd & scr,
    bool first_draw,
    unsigned int frame_number ) [override], [virtual]
```

#### See also

[Page::draw](#)

Reimplemented from [screen::Page](#).

### 5.55.3.2 update()

```
void screen::OdometryPage::update (
    bool was_pressed,
    int x,
    int y ) [override], [virtual]
```

See also

[Page::update](#)

Reimplemented from [screen::Page](#).

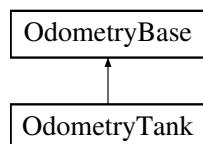
The documentation for this class was generated from the following files:

- [include/subsystems/screen.h](#)
- [src/subsystems/screen.cpp](#)

## 5.56 OdometryTank Class Reference

```
#include <odometry_tank.h>
```

Inheritance diagram for OdometryTank:



### Public Member Functions

- [OdometryTank \(vex::motor\\_group &left\\_side, vex::motor\\_group &right\\_side, \[robot\\\_specs\\\_t\]\(#\) &config, vex::inertial \\*imu=NULL, bool is\\_async=true\)](#)
- [OdometryTank \(CustomEncoder &left\\_custom\\_enc, CustomEncoder &right\\_custom\\_enc, \[robot\\\_specs\\\_t\]\(#\) &config, vex::inertial \\*imu=NULL, bool is\\_async=true\)](#)
- [OdometryTank \(vex::encoder &left\\_vex\\_enc, vex::encoder &right\\_vex\\_enc, \[robot\\\_specs\\\_t\]\(#\) &config, vex::inertial \\*imu=NULL, bool is\\_async=true\)](#)
- [pose\\_t update \(\) override](#)
- [void set\\_position \(const pose\\_t &newpos=zero\\_pos\) override](#)

### Public Member Functions inherited from [OdometryBase](#)

- [OdometryBase \(bool is\\_async\)](#)
- [pose\\_t get\\_position \(void\)](#)
- [AutoCommand \\* SetPositionCmd \(const pose\\_t &newpos=zero\\_pos\)](#)
- [void end\\_async \(\)](#)
- [double get\\_speed \(\)](#)
- [double get\\_accel \(\)](#)
- [double get\\_angular\\_speed\\_deg \(\)](#)
- [double get\\_angular\\_accel\\_deg \(\)](#)

## Additional Inherited Members

### Static Public Member Functions inherited from [OdometryBase](#)

- static int [background\\_task](#) (void \*ptr)
- static double [pos\\_diff](#) ([pose\\_t](#) start\_pos, [pose\\_t](#) end\_pos)
- static double [rot\\_diff](#) ([pose\\_t](#) pos1, [pose\\_t](#) pos2)
- static double [smallest\\_angle](#) (double start\_deg, double end\_deg)

### Public Attributes inherited from [OdometryBase](#)

- bool [end\\_task](#) = false  
*end\_task is true if we instruct the odometry thread to shut down*

### Static Public Attributes inherited from [OdometryBase](#)

- static constexpr [pose\\_t zero\\_pos](#) = {.x = 0.0L, .y = 0.0L, .rot = 90.0L}

### Protected Attributes inherited from [OdometryBase](#)

- vex::task \* [handle](#)
- vex::mutex [mut](#)
- [pose\\_t](#) [current\\_pos](#)
- double [speed](#)
- double [accel](#)
- double [ang\\_speed\\_deg](#)
- double [ang\\_accel\\_deg](#)

## 5.56.1 Detailed Description

[OdometryTank](#) defines an odometry system for a tank drivetrain. This requires encoders in the same orientation as the drive wheels. Odometry is a "start and forget" subsystem, which means once it's created and configured, it will constantly run in the background and track the robot's X, Y and rotation coordinates.

## 5.56.2 Constructor & Destructor Documentation

### 5.56.2.1 [OdometryTank\(\)](#) [1/3]

```
OdometryTank::OdometryTank (
    vex::motor_group & left_side,
    vex::motor_group & right_side,
    robot\_specs\_t & config,
    vex::inertial * imu = NULL,
    bool is_async = true )
```

Initialize the Odometry module, calculating position from the drive motors.

**Parameters**

<i>left_side</i>	The left motors
<i>right_side</i>	The right motors
<i>config</i>	the specifications that supply the odometry with descriptions of the robot. See <a href="#">robot_specs_t</a> for what is contained
<i>imu</i>	The robot's inertial sensor. If not included, rotation is calculated from the encoders.
<i>is_async</i>	If true, position will be updated in the background continuously. If false, the programmer will have to manually call <a href="#">update()</a> .

**5.56.2.2 OdometryTank() [2/3]**

```
OdometryTank::OdometryTank (
    CustomEncoder & left_custom_enc,
    CustomEncoder & right_custom_enc,
    robot_specs_t & config,
    vex::inertial * imu = NULL,
    bool is_async = true )
```

Initialize the Odometry module, calculating position from the drive motors.

**Parameters**

<i>left_custom_enc</i>	The left custom encoder
<i>right_custom_enc</i>	The right custom encoder
<i>config</i>	the specifications that supply the odometry with descriptions of the robot. See <a href="#">robot_specs_t</a> for what is contained
<i>imu</i>	The robot's inertial sensor. If not included, rotation is calculated from the encoders.
<i>is_async</i>	If true, position will be updated in the background continuously. If false, the programmer will have to manually call <a href="#">update()</a> .

**5.56.2.3 OdometryTank() [3/3]**

```
OdometryTank::OdometryTank (
    vex::encoder & left_vex_enc,
    vex::encoder & right_vex_enc,
    robot_specs_t & config,
    vex::inertial * imu = NULL,
    bool is_async = true )
```

Initialize the Odometry module, calculating position from the drive motors.

**Parameters**

<i>left_vex_enc</i>	The left vex encoder
<i>right_vex_enc</i>	The right vex encoder
<i>config</i>	the specifications that supply the odometry with descriptions of the robot. See <a href="#">robot_specs_t</a> for what is contained
<i>imu</i>	The robot's inertial sensor. If not included, rotation is calculated from the encoders.
<i>is_async</i>	If true, position will be updated in the background continuously. If false, the programmer will have to manually call <a href="#">update()</a> .

### 5.56.3 Member Function Documentation

#### 5.56.3.1 set\_position()

```
void OdometryTank::set_position (
    const pose_t & newpos = zero_pos ) [override], [virtual]
```

set\_position tells the odometry to place itself at a position

##### Parameters

<code>newpos</code>	the position the odometry will take
---------------------	-------------------------------------

Resets the position and rotational data to the input.

Reimplemented from [OdometryBase](#).

#### 5.56.3.2 update()

```
pose_t OdometryTank::update () [override], [virtual]
```

Update the current position on the field based on the sensors

##### Returns

the position that odometry has calculated itself to be at

Update, store and return the current position of the robot. Only use if not initializing with a separate thread.

Implements [OdometryBase](#).

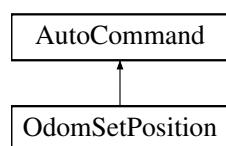
The documentation for this class was generated from the following files:

- include/subsystems/odometry/odometry\_tank.h
- src/subsystems/odometry/odometry\_tank.cpp

## 5.57 OdomSetPosition Class Reference

```
#include <drive_commands.h>
```

Inheritance diagram for OdomSetPosition:



## Public Member Functions

- `OdomSetPosition (OdometryBase &odom, const pose_t &newpos=OdometryBase::zero_pos)`
- `bool run () override`

## Public Member Functions inherited from [AutoCommand](#)

- `virtual void on_timeout ()`
- `AutoCommand * withTimeout (double t_seconds)`
- `AutoCommand * withCancelCondition (Condition *true_to_end)`

## Additional Inherited Members

## Public Attributes inherited from [AutoCommand](#)

- `double timeout_seconds = default_timeout`
- `Condition * true_to_end = nullptr`

## Static Public Attributes inherited from [AutoCommand](#)

- `static constexpr double default_timeout = 10.0`

## 5.57.1 Detailed Description

[AutoCommand](#) wrapper class for the set\_position function in the Odometry class

## 5.57.2 Constructor & Destructor Documentation

### 5.57.2.1 OdomSetPosition()

```
OdomSetPosition::OdomSetPosition (
    OdometryBase & odom,
    const pose_t & newpos = OdometryBase::zero_pos )
```

constructs a new [OdomSetPosition](#) command

#### Parameters

<code>odom</code>	the odometry system we are setting
<code>newpos</code>	the position we are telling the odometry to take. defaults to (0, 0), angle = 90

Construct an Odometry set pos

#### Parameters

<code>odom</code>	the odometry system we are setting
<code>newpos</code>	the now position to set the odometry to

### 5.57.3 Member Function Documentation

#### 5.57.3.1 run()

```
bool OdomSetPosition::run ( ) [override], [virtual]
```

Run set\_position Overrides run from [AutoCommand](#)

##### Returns

true when execution is complete, false otherwise

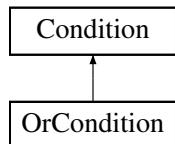
Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

- include/utils/command\_structure/drive\_commands.h
- src/utils/command\_structure/drive\_commands.cpp

## 5.58 OrCondition Class Reference

Inheritance diagram for OrCondition:



### Public Member Functions

- [OrCondition \(Condition \\*A, Condition \\*B\)](#)
- bool [test \(\) override](#)

### Public Member Functions inherited from [Condition](#)

- [Condition \\* Or \(Condition \\*b\)](#)
- [Condition \\* And \(Condition \\*b\)](#)

### 5.58.1 Member Function Documentation

#### 5.58.1.1 test()

```
bool OrCondition::test ( ) [inline], [override], [virtual]
```

Implements [Condition](#).

The documentation for this class was generated from the following file:

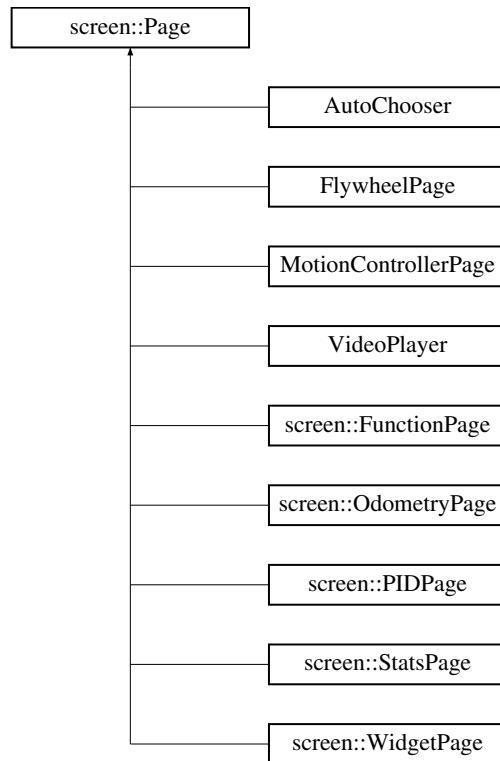
- src/utils/command\_structure/auto\_command.cpp

## 5.59 screen::Page Class Reference

[Page](#) describes one part of the screen slideshow.

```
#include <screen.h>
```

Inheritance diagram for screen::Page:



### Public Member Functions

- virtual void [update](#) (bool was\_pressed, int x, int y)  
*collect data, respond to screen input, do fast things (runs at 50hz even if you're not focused on this [Page](#) (only drawn page gets touch updates))*
- virtual void [draw](#) (vex::brain::lcd &screen, bool first\_draw, unsigned int frame\_number)  
*draw stored data to the screen (runs at 10 hz and only runs if this page is in front)*

### 5.59.1 Detailed Description

[Page](#) describes one part of the screen slideshow.

### 5.59.2 Member Function Documentation

#### 5.59.2.1 draw()

```
virtual void screen::Page::draw (
    vex::brain::lcd & screen,
    bool first_draw,
    unsigned int frame_number ) [virtual]
```

draw stored data to the screen (runs at 10 hz and only runs if this page is in front)

**Parameters**

<i>first_draw</i>	true if we just switched to this page
<i>frame_number</i>	frame of drawing we are on (basically an animation tick)

Reimplemented in [AutoChooser](#), [screen::WidgetPage](#), [screen::StatsPage](#), [screen::OdometryPage](#), [screen::FunctionPage](#), [screen::PIDPage](#), [MotionControllerPage](#), [VideoPlayer](#), and [FlywheelPage](#).

**5.59.2.2 update()**

```
virtual void screen::Page::update (
    bool was_pressed,
    int x,
    int y) [virtual]
```

collect data, respond to screen input, do fast things (runs at 50hz even if you're not focused on this [Page](#) (only drawn page gets touch updates))

**Parameters**

<i>was_pressed</i>	true if the screen has been pressed
<i>x</i>	x position of screen press (if the screen was pressed)
<i>y</i>	y position of screen press (if the screen was pressed)

Reimplemented in [AutoChooser](#), [VideoPlayer](#), [screen::WidgetPage](#), [screen::StatsPage](#), [screen::OdometryPage](#), [screen::FunctionPage](#), [screen::PIDPage](#), [MotionControllerPage](#), and [FlywheelPage](#).

The documentation for this class was generated from the following file:

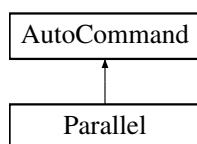
- include/subsystems/screen.h

## 5.60 Parallel Class Reference

[Parallel](#) runs multiple commands in parallel and waits for all to finish before continuing. if none finish before this command's timeout, it will call `on_timeout` on all children continue.

```
#include <auto_command.h>
```

Inheritance diagram for Parallel:



## Public Member Functions

- `Parallel (std::initializer_list< AutoCommand * > cmd)`
- `bool run () override`
- `void on_timeout () override`

## Public Member Functions inherited from [AutoCommand](#)

- `AutoCommand * withTimeout (double t_seconds)`
- `AutoCommand * withCancelCondition (Condition *true_to_end)`

## Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- `double timeout_seconds = default_timeout`
- `Condition * true_to_end = nullptr`

### Static Public Attributes inherited from [AutoCommand](#)

- `static constexpr double default_timeout = 10.0`

## 5.60.1 Detailed Description

[Parallel](#) runs multiple commands in parallel and waits for all to finish before continuing. if none finish before this command's timeout, it will call `on_timeout` on all children continue.

## 5.60.2 Member Function Documentation

### 5.60.2.1 `on_timeout()`

```
void Parallel::on_timeout ( ) [override], [virtual]
```

What to do if we timeout instead of finishing. timeout is specified by the timeout seconds in the constructor

Reimplemented from [AutoCommand](#).

### 5.60.2.2 `run()`

```
bool Parallel::run ( ) [override], [virtual]
```

Executes the command Overridden by child classes

#### Returns

true when the command is finished, false otherwise

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

- `include/utils/command_structure/auto_command.h`
- `src/utils/command_structure/auto_command.cpp`

## 5.61 parallel\_runner\_info Struct Reference

### Public Attributes

- int **index**
- std::vector< vex::task \* > \* **runners**
- AutoCommand \* **cmd**

The documentation for this struct was generated from the following file:

- src/utils/command\_structure/auto\_command.cpp

## 5.62 PurePursuit::Path Class Reference

```
#include <pure_pursuit.h>
```

### Public Member Functions

- Path (std::vector< point\_t > points, double radius)
- std::vector< point\_t > get\_points ()
- double get\_radius ()
- bool is\_valid ()

### 5.62.1 Detailed Description

Wrapper for a vector of points, checking if any of the points are too close for pure pursuit

### 5.62.2 Constructor & Destructor Documentation

#### 5.62.2.1 Path()

```
PurePursuit::Path::Path (
    std::vector< point_t > points,
    double radius )
```

Create a [Path](#)

#### Parameters

<i>points</i>	the points that make up the path
<i>radius</i>	the lookahead radius for pure pursuit

### 5.62.3 Member Function Documentation

#### 5.62.3.1 get\_points()

```
std::vector< point_t > PurePursuit::Path::get_points ( )
```

Get the points associated with this Path

#### 5.62.3.2 get\_radius()

```
double PurePursuit::Path::get_radius ( )
```

Get the radius associated with this Path

#### 5.62.3.3 is\_valid()

```
bool PurePursuit::Path::is_valid ( )
```

Get whether this path will behave as expected

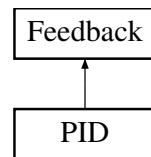
The documentation for this class was generated from the following files:

- include/utils/pure\_pursuit.h
- src/utils/pure\_pursuit.cpp

## 5.63 PID Class Reference

```
#include <pid.h>
```

Inheritance diagram for PID:



### Classes

- struct [pid\\_config\\_t](#)

### Public Types

- enum [ERROR\\_TYPE](#) { **LINEAR** , **ANGULAR** }

## Public Member Functions

- `PID (pid_config_t &config)`
- `void init (double start_pt, double set_pt, double start_vel=0, double end_vel=0) override`
- `double update (double sensor_val) override`
- `double get_sensor_val () const`  
`gets the sensor value that we were last updated with`
- `double get () override`
- `void set_limits (double lower, double upper) override`
- `bool is_on_target () override`
- `void reset ()`
- `double get_error ()`
- `double get_target () const`
- `void set_target (double target)`

## Public Attributes

- `pid_config_t & config`

### 5.63.1 Detailed Description

#### PID Class

Defines a standard feedback loop using the constants kP, kI, kD, deadband, and on\_target\_time. The formula is:

`out = kP*error + kI*integral(d Error) + kD*(dError/dt)`

The `PID` object will determine it is "on target" when the error is within the deadband, for a duration of `on_target_time`

#### Author

Ryan McGee

#### Date

4/3/2020

### 5.63.2 Member Enumeration Documentation

#### 5.63.2.1 ERROR\_TYPE

```
enum PID::ERROR_TYPE
```

An enum to distinguish between a linear and angular calculation of `PID` error.

### 5.63.3 Constructor & Destructor Documentation

#### 5.63.3.1 PID()

```
PID::PID (
    pid_config_t & config )
```

Create the `PID` object

**Parameters**

<i>config</i>	the configuration data for this controller
---------------	--------------------------------------------

Create the [PID](#) object

## 5.63.4 Member Function Documentation

### 5.63.4.1 [get\(\)](#)

```
double PID::get ( ) [override], [virtual]
```

Gets the current [PID](#) out value, from when [update\(\)](#) was last run

**Returns**

the Out value of the controller (voltage, RPM, whatever the [PID](#) controller is controlling)

Gets the current [PID](#) out value, from when [update\(\)](#) was last run

Implements [Feedback](#).

### 5.63.4.2 [get\\_error\(\)](#)

```
double PID::get_error ( )
```

Get the delta between the current sensor data and the target

**Returns**

the error calculated. how it is calculated depends on error\_method specified in [pid\\_config\\_t](#)

Get the delta between the current sensor data and the target

### 5.63.4.3 [get\\_sensor\\_val\(\)](#)

```
double PID::get_sensor_val ( ) const
```

gets the sensor value that we were last updated with

**Returns**

[sensor\\_val](#)

#### 5.63.4.4 get\_target()

```
double PID::get_target ( ) const
```

Get the [PID](#)'s target

##### Returns

the target the [PID](#) controller is trying to achieve

#### 5.63.4.5 init()

```
void PID::init (
    double start_pt,
    double set_pt,
    double start_vel = 0,
    double end_vel = 0 ) [override], [virtual]
```

Inherited from [Feedback](#) for interoperability. Update the setpoint and reset integral accumulation

`start_pt` can be safely ignored in this feedback controller

##### Parameters

<code>start_pt</code>	completely ignored for <a href="#">PID</a> . necessary to satisfy <a href="#">Feedback</a> base
<code>set_pt</code>	sets the target of the <a href="#">PID</a> controller
<code>start_vel</code>	completely ignored for <a href="#">PID</a> . necessary to satisfy <a href="#">Feedback</a> base
<code>end_vel</code>	sets the target end velocity of the <a href="#">PID</a> controller

Implements [Feedback](#).

#### 5.63.4.6 is\_on\_target()

```
bool PID::is_on_target ( ) [override], [virtual]
```

Checks if the [PID](#) controller is on target.

##### Returns

true if the loop is within [deadband] for [on\_target\_time] seconds

Returns true if the loop is within [deadband] for [on\_target\_time] seconds

Implements [Feedback](#).

#### 5.63.4.7 reset()

```
void PID::reset ( )
```

Reset the [PID](#) loop by resetting time since 0 and accumulated error.

#### 5.63.4.8 set\_limits()

```
void PID::set_limits (
    double lower,
    double upper ) [override], [virtual]
```

Set the limits on the [PID](#) out. The [PID](#) out will "clip" itself to be between the limits.

##### Parameters

<i>lower</i>	the lower limit. the <a href="#">PID</a> controller will never command the output go below <i>lower</i>
<i>upper</i>	the upper limit. the <a href="#">PID</a> controller will never command the output go higher than <i>upper</i>

Set the limits on the [PID](#) out. The [PID](#) out will "clip" itself to be between the limits.

Implements [Feedback](#).

#### 5.63.4.9 set\_target()

```
void PID::set_target (
    double target )
```

Set the target for the [PID](#) loop, where the robot is trying to end up

##### Parameters

<i>target</i>	the sensor reading we would like to achieve
---------------	---------------------------------------------

Set the target for the [PID](#) loop, where the robot is trying to end up

#### 5.63.4.10 update()

```
double PID::update (
    double sensor_val ) [override], [virtual]
```

Update the [PID](#) loop by taking the time difference from last update, and running the [PID](#) formula with the new sensor data

##### Parameters

<i>sensor_val</i>	the distance, angle, encoder position or whatever it is we are measuring
-------------------	--------------------------------------------------------------------------

##### Returns

the new output. What would be returned by [PID::get\(\)](#)

Implements [Feedback](#).

## 5.63.5 Member Data Documentation

### 5.63.5.1 config

`pid_config_t& PID::config`

configuration struct for this controller. see [pid\\_config\\_t](#) for information about what this contains

The documentation for this class was generated from the following files:

- include/utils/controls/pid.h
- src/utils/controls/pid.cpp

## 5.64 PID::pid\_config\_t Struct Reference

#include <pid.h>

### Public Attributes

- double **p**  
*proportional coefficient p \* error()*
- double **i**  
*integral coefficient i \* integral(error)*
- double **d**  
*derivative coefficient d \* derivative(error)*
- double **deadband**  
*at what threshold are we close enough to be finished*
- double **on\_target\_time**
- [ERROR\\_TYPE](#) **error\_method**

### 5.64.1 Detailed Description

`pid_config_t` holds the configuration parameters for a pid controller In addition to the constant of proportional, integral and derivative, these parameters include:

- deadband -
- on\_target\_time - for how long do we have to be at the target to stop As well, `pid_config_t` holds an error type which determines whether errors should be calculated as if the sensor position is a measure of distance or an angle

## 5.64.2 Member Data Documentation

### 5.64.2.1 error\_method

`ERROR_TYPE PID::pid_config_t::error_method`

Linear or angular. wheter to do error as a simple subtraction or to wrap

### 5.64.2.2 on\_target\_time

```
double PID::pid_config_t::on_target_time
```

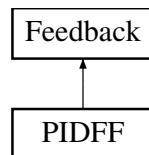
the time in seconds that we have to be on target for to say we are officially at the target

The documentation for this struct was generated from the following file:

- include/utils/controls/pid.h

## 5.65 PIDFF Class Reference

Inheritance diagram for PIDFF:



### Public Member Functions

- **PIDFF** ([PID::pid\\_config\\_t](#) &pid\_cfg, [FeedForward::ff\\_config\\_t](#) &ff\_cfg)
- void [init](#) (double start\_pt, double set\_pt, double start\_vel, double end\_vel) override
- void [set\\_target](#) (double set\_pt)
- double [get\\_target](#) () const
- double [get\\_sensor\\_val](#) () const
- double [update](#) (double val) override
- double [update](#) (double val, double vel\_setpt, double a\_setpt=0)
- double [get](#) () override
- void [set\\_limits](#) (double lower, double upper) override
- bool [is\\_on\\_target](#) () override
- void [reset](#) ()

### Public Attributes

- [PID pid](#)

### 5.65.1 Member Function Documentation

#### 5.65.1.1 get()

```
double PIDFF::get ( ) [override], [virtual]
```

##### Returns

the last saved result from the feedback controller

Implements [Feedback](#).

### 5.65.1.2 init()

```
void PIDFF::init (
    double start_pt,
    double set_pt,
    double start_vel,
    double end_vel ) [override], [virtual]
```

Initialize the feedback controller for a movement

**Parameters**

<i>start_pt</i>	the current sensor value
<i>set_pt</i>	where the sensor value should be
<i>start_vel</i>	the current rate of change of the sensor value
<i>end_vel</i>	the desired ending rate of change of the sensor value

Initialize the feedback controller for a movement

**Parameters**

<i>start←_pt</i>	the current sensor value
<i>set_pt</i>	where the sensor value should be

Implements [Feedback](#).

**5.65.1.3 is\_on\_target()**

```
bool PIDFF::is_on_target ( ) [override], [virtual]
```

**Returns**

true if the feedback controller has reached it's setpoint

Implements [Feedback](#).

**5.65.1.4 set\_limits()**

```
void PIDFF::set_limits (
    double lower,
    double upper ) [override], [virtual]
```

Clamp the upper and lower limits of the output. If both are 0, no limits should be applied.

**Parameters**

<i>lower</i>	Upper limit
<i>upper</i>	Lower limit

Implements [Feedback](#).

**5.65.1.5 set\_target()**

```
void PIDFF::set_target (
    double set_pt )
```

Set the target of the [PID](#) loop

**Parameters**

<i>setpt</i>	Setpoint / target value
--------------	-------------------------

**5.65.1.6 update() [1/2]**

```
double PIDFF::update (
    double val ) [override], [virtual]
```

Iterate the feedback loop once with an updated sensor value. Only kS for feedforward will be applied.

**Parameters**

<i>val</i>	value from the sensor
------------	-----------------------

**Returns**

feedback loop result

Implements [Feedback](#).

**5.65.1.7 update() [2/2]**

```
double PIDFF::update (
    double val,
    double vel_setpt,
    double a_setpt = 0 )
```

Iterate the feedback loop once with an updated sensor value

**Parameters**

<i>val</i>	value from the sensor
<i>vel_setpt</i>	Velocity for feedforward
<i>a_setpt</i>	Acceleration for feedforward

**Returns**

feedback loop result

The documentation for this class was generated from the following files:

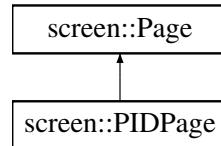
- include/utils/controls/pidff.h
- src/utils/controls/pidff.cpp

## 5.66 screen::PIDPage Class Reference

[PIDPage](#) provides a way to tune a pid controller on the screen.

```
#include <screen.h>
```

Inheritance diagram for screen::PIDPage:



### Public Member Functions

- [PIDPage](#) (`PID &pid, std::string name, std::function< void(void)> onchange=[]() {}`)  
Create a [PIDPage](#).
- [PIDPage](#) (`PIDFF &pidff, std::string name, std::function< void(void)> onchange=[]() {}`)
- void [update](#) (bool was\_pressed, int x, int y) override
- void [draw](#) (vex::brain::lcd &, bool first\_draw, unsigned int frame\_number) override

### 5.66.1 Detailed Description

[PIDPage](#) provides a way to tune a pid controller on the screen.

### 5.66.2 Constructor & Destructor Documentation

#### 5.66.2.1 PIDPage()

```
screen::PIDPage::PIDPage (
    PID & pid,
    std::string name,
    std::function< void(void)> onchange = []() {} )
```

Create a [PIDPage](#).

#### Parameters

<code>pid</code>	the pid controller we're changing
<code>name</code>	a name to recognize this pid controller if we've got multiple pid screens
<code>onchange</code>	a function that is called when a tuning parameter is changed. If you need to update stuff on that change register a handler here

### 5.66.3 Member Function Documentation

#### 5.66.3.1 draw()

```
void screen::PIDPage::draw (
    vex::brain::lcd & scr,
    bool first_draw,
    unsigned int frame_number ) [override], [virtual]
```

See also

[Page::draw](#)

Reimplemented from [screen::Page](#).

#### 5.66.3.2 update()

```
void screen::PIDPage::update (
    bool was_pressed,
    int x,
    int y ) [override], [virtual]
```

See also

[Page::update](#)

Reimplemented from [screen::Page](#).

The documentation for this class was generated from the following files:

- include/subsystems/screen.h
- src/subsystems/screen.cpp

## 5.67 plm\_frame\_t Struct Reference

### Public Attributes

- double **time**
- unsigned int **width**
- unsigned int **height**
- [plm\\_plane\\_t](#) **y**
- [plm\\_plane\\_t](#) **cr**
- [plm\\_plane\\_t](#) **cb**

The documentation for this struct was generated from the following file:

- include/subsystems/fun/pl\_mpeg.h

## 5.68 plm\_packet\_t Struct Reference

### Public Attributes

- int **type**
- double **pts**
- size\_t **length**
- uint8\_t \* **data**

The documentation for this struct was generated from the following file:

- include/subsystems/fun/pl\_mpeg.h

## 5.69 plm\_plane\_t Struct Reference

### Public Attributes

- unsigned int **width**
- unsigned int **height**
- uint8\_t \* **data**

The documentation for this struct was generated from the following file:

- include/subsystems/fun/pl\_mpeg.h

## 5.70 plm\_samples\_t Struct Reference

### Public Attributes

- double **time**
- unsigned int **count**
- float **interleaved** [PLM\_AUDIO\_SAMPLES\_PER\_FRAME \*2]

The documentation for this struct was generated from the following file:

- include/subsystems/fun/pl\_mpeg.h

## 5.71 point\_t Struct Reference

```
#include <geometry.h>
```

## Public Member Functions

- double `dist (const point_t other) const`
- `point_t operator+ (const point_t &other) const`
- `point_t operator- (const point_t &other) const`
- `point_t operator* (double s) const`
- `point_t operator/ (double s) const`
- `point_t operator- () const`
- `point_t operator+ () const`
- bool `operator== (const point_t &rhs)`

## Public Attributes

- double `x`  
*the x position in space*
- double `y`  
*the y position in space*

### 5.71.1 Detailed Description

Data structure representing an X,Y coordinate

### 5.71.2 Member Function Documentation

#### 5.71.2.1 dist()

```
double point_t::dist (
    const point_t other ) const [inline]
```

dist calculates the euclidian distance between this point and another point using the pythagorean theorem

##### Parameters

<code>other</code>	the point to measure the distance from
--------------------	----------------------------------------

##### Returns

the euclidian distance between this and other

#### 5.71.2.2 operator+()

```
point_t point_t::operator+ (
    const point_t & other ) const [inline]
```

Vector2D addition operation on points

**Parameters**

<code>other</code>	the point to add on to this
--------------------	-----------------------------

**Returns**

`this + other (this.x + other.x, this.y + other.y)`

### 5.71.2.3 operator-()

```
point_t point_t::operator- (
    const point_t & other ) const [inline]
```

Vector2D subtraction operation on points

**Parameters**

<code>other</code>	the <code>point_t</code> to subtract from this
--------------------	------------------------------------------------

**Returns**

`this - other (this.x - other.x, this.y - other.y)`

The documentation for this struct was generated from the following file:

- include/utils/geometry.h

## 5.72 pose\_t Struct Reference

```
#include <geometry.h>
```

### Public Member Functions

- `point_t get_point ()`

### Public Attributes

- `double x`  
*x position in the world*
- `double y`  
*y position in the world*
- `double rot`  
*rotation in the world*

### 5.72.1 Detailed Description

Describes a single position and rotation

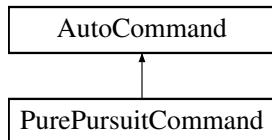
The documentation for this struct was generated from the following file:

- include/utils/geometry.h

## 5.73 PurePursuitCommand Class Reference

```
#include <drive_commands.h>
```

Inheritance diagram for PurePursuitCommand:



### Public Member Functions

- [PurePursuitCommand \(TankDrive &drive\\_sys, Feedback &feedback, PurePursuit::Path path, directionType dir, double max\\_speed=1, double end\\_speed=0\)](#)
- [bool run \(\) override](#)
- [void on\\_timeout \(\) override](#)

### Public Member Functions inherited from [AutoCommand](#)

- [AutoCommand \\* withTimeout \(double t\\_seconds\)](#)
- [AutoCommand \\* withCancelCondition \(Condition \\*true\\_to\\_end\)](#)

### Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- [double timeout\\_seconds = default\\_timeout](#)
- [Condition \\* true\\_to\\_end = nullptr](#)

### Static Public Attributes inherited from [AutoCommand](#)

- [static constexpr double default\\_timeout = 10.0](#)

### 5.73.1 Detailed Description

Autocommand wrapper class for pure pursuit function in the [TankDrive](#) class

## 5.73.2 Constructor & Destructor Documentation

### 5.73.2.1 PurePursuitCommand()

```
PurePursuitCommand::PurePursuitCommand (
    TankDrive & drive_sys,
    Feedback & feedback,
    PurePursuit::Path path,
    directionType dir,
    double max_speed = 1,
    double end_speed = 0 )
```

Construct a Pure Pursuit [AutoCommand](#)

#### Parameters

<i>path</i>	The list of coordinates to follow, in order
<i>dir</i>	Run the bot forwards or backwards
<i>feedback</i>	The feedback controller determining speed
<i>max_speed</i>	Limit the speed of the robot (for pid / pidff feedbacks)

## 5.73.3 Member Function Documentation

### 5.73.3.1 on\_timeout()

```
void PurePursuitCommand::on_timeout ( ) [override], [virtual]
```

Reset the drive system when it times out

Reimplemented from [AutoCommand](#).

### 5.73.3.2 run()

```
bool PurePursuitCommand::run ( ) [override], [virtual]
```

Direct call to [TankDrive::pure\\_pursuit](#)

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

- include/utils/command\_structure/drive\_commands.h
- src/utils/command\_structure/drive\_commands.cpp

## 5.74 Rect Struct Reference

### Public Member Functions

- [`point\_t dimensions \(\) const`](#)
- [`point\_t center \(\) const`](#)
- [`double width \(\) const`](#)
- [`double height \(\) const`](#)
- [`bool contains \(point\_t p\) const`](#)

### Static Public Member Functions

- static `Rect from_min_and_size (point_t min, point_t size)`

### Public Attributes

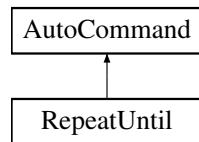
- `point_t min`
- `point_t max`

The documentation for this struct was generated from the following file:

- include/utils/geometry.h

## 5.75 RepeatUntil Class Reference

Inheritance diagram for RepeatUntil:



### Public Member Functions

- `RepeatUntil (InOrder cmd, size_t repeats)`  
*RepeatUntil that runs a fixed number of times.*
- `RepeatUntil (InOrder cmd, Condition *true_to_end)`  
*RepeatUntil the condition.*
- `bool run () override`
- `void on_timeout () override`

### Public Member Functions inherited from `AutoCommand`

- `AutoCommand * withTimeout (double t_seconds)`
- `AutoCommand * withCancelCondition (Condition *true_to_end)`

### Additional Inherited Members

### Public Attributes inherited from `AutoCommand`

- `double timeout_seconds = default_timeout`
- `Condition * true_to_end = nullptr`

### Static Public Attributes inherited from `AutoCommand`

- static constexpr double `default_timeout = 10.0`

## 5.75.1 Constructor & Destructor Documentation

### 5.75.1.1 RepeatUntil() [1/2]

```
RepeatUntil::RepeatUntil (
    InOrder cmds,
    size_t repeats )
```

[RepeatUntil](#) that runs a fixed number of times.

**Parameters**

<i>cmds</i>	the cmds to repeat
<i>repeats</i>	the number of repeats to do

**5.75.1.2 RepeatUntil() [2/2]**

```
RepeatUntil::RepeatUntil (
    InOrder cmds,
    Condition * true_to_end )
```

[RepeatUntil](#) the condition.

**Parameters**

<i>cmds</i>	the cmds to run
<i>true_to_end</i>	we will repeat until <i>true_or_end</i> .test() returns true

**5.75.2 Member Function Documentation****5.75.2.1 on\_timeout()**

```
void RepeatUntil::on_timeout ( ) [override], [virtual]
```

What to do if we timeout instead of finishing. timeout is specified by the timeout seconds in the constructor

Reimplemented from [AutoCommand](#).

**5.75.2.2 run()**

```
bool RepeatUntil::run ( ) [override], [virtual]
```

Executes the command Overridden by child classes

**Returns**

true when the command is finished, false otherwise

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

- include/utils/command\_structure/auto\_command.h
- src/utils/command\_structure/auto\_command.cpp

## 5.76 robot\_specs\_t Struct Reference

```
#include <robot_specs.h>
```

### Public Attributes

- double **robot\_radius**
- double **odom\_wheel\_diam**  
*the diameter of the wheels used for*
- double **odom\_gear\_ratio**
- double **dist\_between\_wheels**
- double **drive\_correction\_cutoff**
- **Feedback \* drive\_feedback**  
*the default feedback for autonomous driving*
- **Feedback \* turn\_feedback**  
*the default feedback for autonomous turning*
- **PID::pid\_config\_t correction\_pid**

### 5.76.1 Detailed Description

Main robot characterization struct. This will be passed to all the major subsystems that require info about the robot. All distance measurements are in inches.

### 5.76.2 Member Data Documentation

#### 5.76.2.1 correction\_pid

```
PID::pid_config_t robot_specs_t::correction_pid
```

the pid controller to keep the robot driving in as straight a line as possible

#### 5.76.2.2 dist\_between\_wheels

```
double robot_specs_t::dist_between_wheels
```

the distance between centers of the central drive wheels

#### 5.76.2.3 drive\_correction\_cutoff

```
double robot_specs_t::drive_correction_cutoff
```

the distance at which to stop trying to turn towards the target. If we are less than this value, we can continue driving forward to minimize our distance but will not try to spin around to point directly at the target

#### 5.76.2.4 `odom_gear_ratio`

```
double robot_specs_t::odom_gear_ratio
```

the ratio of the odometry wheel to the encoder reading odometry data

#### 5.76.2.5 `robot_radius`

```
double robot_specs_t::robot_radius
```

if you were to draw a circle with this radius, the robot would be entirely contained within it

The documentation for this struct was generated from the following file:

- include/robot\_specs.h

## 5.77 `screen::ScreenData` Struct Reference

The `ScreenData` class holds the data that will be passed to the screen thread you probably shouldnt have to use it.

### Public Member Functions

- `ScreenData` (const std::vector< [Page](#) \* > &m\_pages, int m\_page, vex::brain::lcd &m\_screen)

### Public Attributes

- std::vector< [Page](#) \* > **pages**
- int **page** = 0
- vex::brain::lcd **screen**

### 5.77.1 Detailed Description

The `ScreenData` class holds the data that will be passed to the screen thread you probably shouldnt have to use it.

The documentation for this struct was generated from the following file:

- src/subsystems/screen.cpp

## 5.78 `screen::ScreenRect` Struct Reference

### Public Attributes

- uint32\_t **x1**
- uint32\_t **y1**
- uint32\_t **x2**
- uint32\_t **y2**

The documentation for this struct was generated from the following file:

- include/subsystems/screen.h

## 5.79 Serializer Class Reference

Serializes Arbitrary data to a file on the SD Card.

```
#include <serializer.h>
```

### Public Member Functions

- **`~Serializer ()`**  
*Save and close upon destruction (bc of vex, this doesn't always get called when the program ends. To be sure, call `save_to_disk`)*
- **`Serializer (const std::string &filename, bool flush_always=true)`**  
*create a `Serializer`*
- **`void save_to_disk () const`**  
*saves current `Serializer` state to disk*
- **`void set_int (const std::string &name, int i)`**  
*Setters - not saved until `save_to_disk` is called.*
- **`void set_bool (const std::string &name, bool b)`**  
*sets a bool by the name of name to b. If `flush_always == true`, this will save to the sd card*
- **`void set_double (const std::string &name, double d)`**  
*sets a double by the name of name to d. If `flush_always == true`, this will save to the sd card*
- **`void set_string (const std::string &name, std::string str)`**  
*sets a string by the name of name to s. If `flush_always == true`, this will save to the sd card*
- **`int int_or (const std::string &name, int otherwise)`**  
*gets a value stored in the serializer. If not found, sets the value to otherwise*
- **`bool bool_or (const std::string &name, bool otherwise)`**  
*gets a value stored in the serializer. If not, sets the value to otherwise*
- **`double double_or (const std::string &name, double otherwise)`**  
*gets a value stored in the serializer. If not, sets the value to otherwise*
- **`std::string string_or (const std::string &name, std::string otherwise)`**  
*gets a value stored in the serializer. If not, sets the value to otherwise*

### 5.79.1 Detailed Description

Serializes Arbitrary data to a file on the SD Card.

### 5.79.2 Constructor & Destructor Documentation

#### 5.79.2.1 `Serializer()`

```
Serializer::Serializer (
    const std::string & filename,
    bool flush_always = true ) [inline], [explicit]
```

create a `Serializer`

**Parameters**

<i>filename</i>	the file to read from. If filename does not exist we will create that file
<i>flush_always</i>	If true, after every write flush to a file. If false, you are responsible for calling save_to_disk

**5.79.3 Member Function Documentation****5.79.3.1 bool\_or()**

```
bool Serializer::bool_or (
    const std::string & name,
    bool otherwise )
```

gets a value stored in the serializer. If not, sets the value to otherwise

**Parameters**

<i>name</i>	name of value
<i>otherwise</i>	value if the name is not specified

**Returns**

the value if found or otherwise

**5.79.3.2 double\_or()**

```
double Serializer::double_or (
    const std::string & name,
    double otherwise )
```

gets a value stored in the serializer. If not, sets the value to otherwise

**Parameters**

<i>name</i>	name of value
<i>otherwise</i>	value if the name is not specified

**Returns**

the value if found or otherwise

**5.79.3.3 int\_or()**

```
int Serializer::int_or (
    const std::string & name,
    int otherwise )
```

gets a value stored in the serializer. If not found, sets the value to otherwise

Getters Return value if it exists in the serializer

**Parameters**

<i>name</i>	name of value
<i>otherwise</i>	value if the name is not specified

**Returns**

the value if found or otherwise

**5.79.3.4 save\_to\_disk()**

```
void Serializer::save_to_disk ( ) const
saves current Serializer state to disk
forms data bytes then saves to filename this was opened with
```

**5.79.3.5 set\_bool()**

```
void Serializer::set_bool (
    const std::string & name,
    bool b )
```

sets a bool by the name of name to b. If flush\_always == true, this will save to the sd card

**Parameters**

<i>name</i>	name of bool
<i>b</i>	value of bool

**5.79.3.6 set\_double()**

```
void Serializer::set_double (
    const std::string & name,
    double d )
```

sets a double by the name of name to d. If flush\_always == true, this will save to the sd card

**Parameters**

<i>name</i>	name of double
<i>d</i>	value of double

**5.79.3.7 set\_int()**

```
void Serializer::set_int (
```

```
    const std::string & name,
    int i )
```

Setters - not saved until save\_to\_disk is called.

sets an integer by the name of name to i. If flush\_always == true, this will save to the sd card

#### Parameters

<i>name</i>	name of integer
<i>i</i>	value of integer

### 5.79.3.8 set\_string()

```
void Serializer::set_string (
    const std::string & name,
    std::string str )
```

sets a string by the name of name to s. If flush\_always == true, this will save to the sd card

#### Parameters

<i>name</i>	name of string
<i>i</i>	value of string

### 5.79.3.9 string\_or()

```
std::string Serializer::string_or (
    const std::string & name,
    std::string otherwise )
```

gets a value stored in the serializer. If not, sets the value to otherwise

#### Parameters

<i>name</i>	name of value
<i>otherwise</i>	value if the name is not specified

#### Returns

the value if found or otherwise

The documentation for this class was generated from the following files:

- include/utils/serializer.h
- src/utils/serializer.cpp

## 5.80 screen::SizedWidget Struct Reference

### Public Attributes

- int **size**
- [WidgetConfig](#) & **widget**

The documentation for this struct was generated from the following file:

- include/subsystems/screen.h

## 5.81 SliderCfg Struct Reference

### Public Attributes

- double & **val**
- double **min**
- double **max**

The documentation for this struct was generated from the following file:

- include/subsystems/layout.h

## 5.82 screen::SliderConfig Struct Reference

### Public Attributes

- double & **val**
- double **low**
- double **high**

The documentation for this struct was generated from the following file:

- include/subsystems/screen.h

## 5.83 screen::SliderWidget Class Reference

Widget that updates a double value. Updates by reference so watch out for race conditions cuz the screen stuff lives on another thread.

```
#include <screen.h>
```

## Public Member Functions

- `SliderWidget` (double &*val*, double *low*, double *high*, `Rect` *rect*, std::string *name*)  
*Creates a slider widget.*
- `bool update` (`bool was_pressed`, int *x*, int *y*)  
*responds to user input*
- `void draw` (`vex::brain::lcd &`, `bool first_draw`, unsigned int *frame\_number*)  
*Page::draws the slide to the screen*

### 5.83.1 Detailed Description

Widget that updates a double value. Updates by reference so watch out for race conditions cuz the screen stuff lives on another thread.

### 5.83.2 Constructor & Destructor Documentation

#### 5.83.2.1 SliderWidget()

```
screen::SliderWidget::SliderWidget (
    double & val,
    double low,
    double high,
    Rect rect,
    std::string name ) [inline]
```

Creates a slider widget.

#### Parameters

<i>val</i>	reference to the value to modify
<i>low</i>	minimum value to go to
<i>high</i>	maximum value to go to
<i>rect</i>	rect to draw it
<i>name</i>	name of the value

### 5.83.3 Member Function Documentation

#### 5.83.3.1 update()

```
bool screen::SliderWidget::update (
    bool was_pressed,
    int x,
    int y )
```

responds to user input

**Parameters**

<code>was_pressed</code>	if the screen is pressed
<code>x</code>	x position if the screen was pressed
<code>y</code>	y position if the screen was pressed

**Returns**

true if the value updated

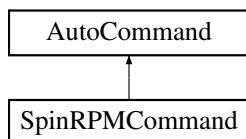
The documentation for this class was generated from the following files:

- include/subsystems/screen.h
- src/subsystems/screen.cpp

## 5.84 SpinRPMCommand Class Reference

```
#include <flywheel_commands.h>
```

Inheritance diagram for SpinRPMCommand:



### Public Member Functions

- [SpinRPMCommand \(Flywheel &flywheel, int rpm\)](#)
- bool [run \(\) override](#)

### Public Member Functions inherited from [AutoCommand](#)

- virtual void [on\\_timeout \(\)](#)
- [AutoCommand \\* withTimeout \(double t\\_seconds\)](#)
- [AutoCommand \\* withCancelCondition \(Condition \\*true\\_to\\_end\)](#)

### Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition \\* true\\_to\\_end](#) = nullptr

## Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double **default\_timeout** = 10.0

### 5.84.1 Detailed Description

File: [flywheel\\_commands.h](#) Desc: [insert meaningful desc] [AutoCommand](#) wrapper class for the spin\_rpm function in the [Flywheel](#) class

### 5.84.2 Constructor & Destructor Documentation

#### 5.84.2.1 SpinRPMCommand()

```
SpinRPMCommand::SpinRPMCommand (
    Flywheel & flywheel,
    int rpm )
```

Construct a SpinRPM Command

##### Parameters

<i>flywheel</i>	the flywheel sys to command
<i>rpm</i>	the rpm that we should spin at

File: [flywheel\\_commands.cpp](#) Desc: [insert meaningful desc]

### 5.84.3 Member Function Documentation

#### 5.84.3.1 run()

```
bool SpinRPMCommand::run ( ) [override], [virtual]
```

Run spin\_manual Overrides run from [AutoCommand](#)

##### Returns

true when execution is complete, false otherwise

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

- include/utils/command\_structure/flywheel\_commands.h
- src/utils/command\_structure/flywheel\_commands.cpp

## 5.85 PurePursuit::spline Struct Reference

```
#include <pure_pursuit.h>
```

### Public Member Functions

- double **getY** (double x)

### Public Attributes

- double **a**
- double **b**
- double **c**
- double **d**
- double **x\_start**
- double **x\_end**

### 5.85.1 Detailed Description

Represents a piece of a cubic spline with  $s(x) = a(x-x_i)^3 + b(x-x_i)^2 + c(x-x_i) + d$ . The **x\_start** and **x\_end** shows where the equation is valid.

The documentation for this struct was generated from the following file:

- include/utils/pure\_pursuit.h

## 5.86 StateMachine< System, IDType, Message, delay\_ms, do\_log >::State Struct Reference

```
#include <state_machine.h>
```

### Public Member Functions

- virtual void **entry** (System &)
- virtual **MaybeMessage** **work** (System &)
- virtual void **exit** (System &)
- virtual **State** \* **respond** (System &s, Message m)=0
- virtual IDType **id** () const =0

### 5.86.1 Detailed Description

```
template<typename System, typename IDType, typename Message, int32_t delay_ms, bool do_log = false>
struct StateMachine< System, IDType, Message, delay_ms, do_log >::State
```

Abstract class that all states for this machine must inherit from. States MUST override **respond()** and **id()** in order to function correctly (the compiler won't have it any other way)

The documentation for this struct was generated from the following file:

- include/utils/state\_machine.h

## 5.87 StateMachine< System, IDType, Message, delay\_ms, do\_log > Class Template Reference

**State Machine :))))))** A fun fun way of controlling stateful subsystems - used in the 2023-2024 Over Under game for our overly complex intake-cata subsystem (see there for an example) The statemachine runs in a background thread and a user thread can interact with it through current\_state and send\_message.

```
#include <state_machine.h>
```

### Classes

- class [MaybeMessage](#)

*MaybeMessage a message of Message type or nothing* [MaybeMessage m = {};](#) // empty [MaybeMessage m = Message::EnumField1.](#)

- struct [State](#)

### Public Types

- using [thread\\_data](#) = std::pair<[State](#) \*, [StateMachine](#) \*>

### Public Member Functions

- [StateMachine \(State \\*initial\)](#)

*Construct a state machine and immediately start running it.*

- [IDType current\\_state \(\) const](#)

*retrieve the current state of the state machine. This is safe to call from external threads*

- void [send\\_message \(Message msg\)](#)

*send a message to the state machine from outside*

### 5.87.1 Detailed Description

```
template<typename System, typename IDType, typename Message, int32_t delay_ms, bool do_log = false>
class StateMachine< System, IDType, Message, delay_ms, do_log >
```

**State Machine :))))))** A fun fun way of controlling stateful subsystems - used in the 2023-2024 Over Under game for our overly complex intake-cata subsystem (see there for an example) The statemachine runs in a background thread and a user thread can interact with it through current\_state and send\_message.

Designwise: the System class should hold onto any motors, feedback controllers, etc that are persistent in the system States themselves should hold any data that *only* that state needs. For example if a state should be exited after a certain amount of time, it should hold a timer rather than the System holding that timer. (see Junder from 2024 for an example of this design)

#### Template Parameters

<a href="#">System</a>	The system that this is the base class of class Thing : public StateMachine<Thing> @tparam IDType The ID enum that recognizes states. Hint hint, use an enum class`
<a href="#">Message</a>	the message enum that a state or an outside can send and that states respond to
<a href="#">delay_ms</a>	the delay to wait between each state processing to allow other threads to work
<a href="#">do_log</a>	if you want print statements describing incoming messages and current states. If true, it is expected that IDType and Message have a function called to_string that takes them as its only parameter and returns a std::string

## 5.87.2 Constructor & Destructor Documentation

### 5.87.2.1 StateMachine()

```
template<typename System , typename IDType , typename Message , int32_t delay_ms, bool do_log
= false>
StateMachine< System, IDType, Message, delay_ms, do_log >::StateMachine (
    State * initial ) [inline]
```

Construct a state machine and immediately start running it.

#### Parameters

<i>initial</i>	the state that the machine will begin in
----------------	------------------------------------------

## 5.87.3 Member Function Documentation

### 5.87.3.1 current\_state()

```
template<typename System , typename IDType , typename Message , int32_t delay_ms, bool do_log
= false>
IDType StateMachine< System, IDType, Message, delay_ms, do_log >::current_state ( ) const
[inline]
```

retrieve the current state of the state machine. This is safe to call from external threads

#### Returns

the current state

### 5.87.3.2 send\_message()

```
template<typename System , typename IDType , typename Message , int32_t delay_ms, bool do_log
= false>
void StateMachine< System, IDType, Message, delay_ms, do_log >::send_message (
    Message msg ) [inline]
```

send a message to the state machine from outside

#### Parameters

<i>msg</i>	the message to send This is safe to call from external threads
------------	----------------------------------------------------------------

The documentation for this class was generated from the following file:

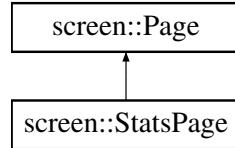
- include/utils/state\_machine.h

## 5.88 screen::StatsPage Class Reference

Draws motor stats and battery stats to the screen.

```
#include <screen.h>
```

Inheritance diagram for screen::StatsPage:



### Public Member Functions

- **StatsPage** (std::map< std::string, vex::motor & > motors)  
*Creates a stats page.*
- void **update** (bool was\_pressed, int x, int y) override
- void **draw** (vex::brain::lcd &, bool first\_draw, unsigned int frame\_number) override

### 5.88.1 Detailed Description

Draws motor stats and battery stats to the screen.

### 5.88.2 Constructor & Destructor Documentation

#### 5.88.2.1 StatsPage()

```
screen::StatsPage::StatsPage (
    std::map< std::string, vex::motor & > motors )
```

Creates a stats page.

##### Parameters

<i>motors</i>	a map of string to motor that we want to draw on this page
---------------	------------------------------------------------------------

### 5.88.3 Member Function Documentation

#### 5.88.3.1 draw()

```
void screen::StatsPage::draw (
    vex::brain::lcd & scr,
    bool first_draw,
    unsigned int frame_number ) [override], [virtual]
```

See also

[Page::draw](#)

Reimplemented from [screen::Page](#).

### 5.88.3.2 update()

```
void screen::StatsPage::update (
    bool was_pressed,
    int x,
    int y ) [override], [virtual]
```

See also

[Page::update](#)

Reimplemented from [screen::Page](#).

The documentation for this class was generated from the following files:

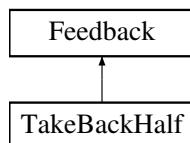
- include/subsystems/screen.h
- src/subsystems/screen.cpp

## 5.89 TakeBackHalf Class Reference

A velocity controller.

```
#include <take_back_half.h>
```

Inheritance diagram for TakeBackHalf:



### Public Member Functions

- **TakeBackHalf** (double [TBH\\_gain](#), double [first\\_cross\\_split](#), double [on\\_target\\_threshold](#))
- void [init](#) (double [start\\_pt](#), double [set\\_pt](#), double, double)
- double [update](#) (double [val](#)) override
- double [get](#) () override
- void [set\\_limits](#) (double [lower](#), double [upper](#)) override
- bool [is\\_on\\_target](#) () override

## Public Attributes

- double **TBH\_gain**  
*tuned parameter*
- double **first\_cross\_split**

### 5.89.1 Detailed Description

A velocity controller.

#### Warning

If you try to use this as a position controller, it will fail.

### 5.89.2 Member Function Documentation

#### 5.89.2.1 get()

```
double TakeBackHalf::get ( ) [override], [virtual]
```

##### Returns

the last saved result from the feedback controller

Implements [Feedback](#).

#### 5.89.2.2 init()

```
void TakeBackHalf::init (
    double start_pt,
    double set_pt,
    double ,
    double ) [virtual]
```

Initialize the feedback controller for a movement

##### Parameters

<i>start_pt</i>	the current sensor value
<i>set_pt</i>	where the sensor value should be
<i>start_vel</i>	Movement starting velocity (IGNORED)
<i>end_vel</i>	Movement ending velocity (IGNORED)

Implements [Feedback](#).

#### 5.89.2.3 is\_on\_target()

```
bool TakeBackHalf::is_on_target ( ) [override], [virtual]
```

**Returns**

true if the feedback controller has reached it's setpoint

Implements [Feedback](#).

**5.89.2.4 set\_limits()**

```
void TakeBackHalf::set_limits (
    double lower,
    double upper ) [override], [virtual]
```

Clamp the upper and lower limits of the output. If both are 0, no limits should be applied.

**Parameters**

<i>lower</i>	Upper limit
<i>upper</i>	Lower limit

Implements [Feedback](#).

**5.89.2.5 update()**

```
double TakeBackHalf::update (
    double val ) [override], [virtual]
```

Iterate the feedback loop once with an updated sensor value

**Parameters**

<i>val</i>	value from the sensor
------------	-----------------------

**Returns**

feedback loop result

Implements [Feedback](#).

The documentation for this class was generated from the following files:

- include/utils/controls/take\_back\_half.h
- src/utils/controls/take\_back\_half.cpp

**5.90 TankDrive Class Reference**

```
#include <tank_drive.h>
```

## Public Types

- enum class `BrakeType` { `None` , `ZeroVelocity` , `Smart` }

## Public Member Functions

- `TankDrive` (`motor_group &left_motors, motor_group &right_motors, robot_specs_t &config, OdometryBase *odom=NULL`)
- `AutoCommand * DriveToPointCmd` (`point_t pt, vex::directionType dir=vex::forward, double max_speed=1.0, double end_speed=0.0`)
- `AutoCommand * DriveToPointCmd` (`Feedback &fb, point_t pt, vex::directionType dir=vex::forward, double max_speed=1.0, double end_speed=0.0`)
- `AutoCommand * DriveForwardCmd` (`double dist, vex::directionType dir=vex::forward, double max_speed=1.0, double end_speed=0.0`)
- `AutoCommand * DriveForwardCmd` (`Feedback &fb, double dist, vex::directionType dir=vex::forward, double max_speed=1.0, double end_speed=0.0`)
- `AutoCommand * TurnToHeadingCmd` (`double heading, double max_speed=1.0, double end_speed=0.0`)
- `AutoCommand * TurnToHeadingCmd` (`Feedback &fb, double heading, double max_speed=1.0, double end_speed=0.0`)
- `AutoCommand * TurnToPointCmd` (`double x, double y, vex::directionType dir=vex::directionType::fwd, double max_speed=1.0, double end_speed=0.0`)
- `AutoCommand * TurnDegreesCmd` (`double degrees, double max_speed=1.0, double start_speed=0.0`)
- `AutoCommand * TurnDegreesCmd` (`Feedback &fb, double degrees, double max_speed=1.0, double end_speed=0.0`)
- `AutoCommand * PurePursuitCmd` (`PurePursuit::Path path, directionType dir, double max_speed=1, double end_speed=0`)
- `AutoCommand * PurePursuitCmd` (`Feedback &feedback, PurePursuit::Path path, directionType dir, double max_speed=1, double end_speed=0`)
- `Condition * DriveStalledCondition` (`double stall_time`)
- `AutoCommand * DriveTankCmd` (`double left, double right`)
- `void stop ()`
- `void drive_tank` (`double left, double right, int power=1, BrakeType bt=BrakeType::None`)
- `void drive_tank_raw` (`double left, double right`)
- `void drive_arcade` (`double forward_back, double left_right, int power=1, BrakeType bt=BrakeType::None`)
- `bool drive_forward` (`double inches, directionType dir, Feedback &feedback, double max_speed=1, double end_speed=0`)
- `bool drive_forward` (`double inches, directionType dir, double max_speed=1, double end_speed=0`)
- `bool turn_degrees` (`double degrees, Feedback &feedback, double max_speed=1, double end_speed=0`)
- `bool turn_degrees` (`double degrees, double max_speed=1, double end_speed=0`)
- `bool drive_to_point` (`double x, double y, vex::directionType dir, Feedback &feedback, double max_speed=1, double end_speed=0`)
- `bool drive_to_point` (`double x, double y, vex::directionType dir, double max_speed=1, double end_speed=0`)
- `bool turn_to_heading` (`double heading_deg, Feedback &feedback, double max_speed=1, double end_speed=0`)
- `bool turn_to_heading` (`double heading_deg, double max_speed=1, double end_speed=0`)
- `void reset_auto ()`
- `bool pure_pursuit` (`PurePursuit::Path path, directionType dir, Feedback &feedback, double max_speed=1, double end_speed=0`)
- `bool pure_pursuit` (`PurePursuit::Path path, directionType dir, double max_speed=1, double end_speed=0`)

## Static Public Member Functions

- static double `modify_inputs` (`double input, int power=2`)

### 5.90.1 Detailed Description

[TankDrive](#) is a class to run a tank drive system. A tank drive system, sometimes called differential drive, has a motor (or group of synchronized motors) on the left and right side

### 5.90.2 Member Enumeration Documentation

#### 5.90.2.1 BrakeType

```
enum class TankDrive::BrakeType [strong]
```

##### Enumerator

None	just send 0 volts to the motors
ZeroVelocity	try to bring the robot to rest. But don't try to hold position
Smart	bring the robot to rest and once it's stopped, try to hold that position

### 5.90.3 Constructor & Destructor Documentation

#### 5.90.3.1 TankDrive()

```
TankDrive::TankDrive (
    motor_group & left_motors,
    motor_group & right_motors,
    robot_specs_t & config,
    OdometryBase * odom = NULL )
```

Create the [TankDrive](#) object

##### Parameters

<i>left_motors</i>	left side drive motors
<i>right_motors</i>	right side drive motors
<i>config</i>	the configuration specification defining physical dimensions about the robot. See <a href="#">robot_specs_t</a> for more info
<i>odom</i>	an odometry system to track position and rotation. this is necessary to execute autonomous paths

### 5.90.4 Member Function Documentation

#### 5.90.4.1 drive\_arCADE()

```
void TankDrive::drive_arCADE (
    double forward_back,
    double left_right,
```

```
int power = 1,
BrakeType bt = BrakeType::None )
```

Drive the robot using arcade style controls. forward\_back controls the linear motion, left\_right controls the turning.

forward\_back and left\_right are in "percent": -1.0 -> 1.0

#### Parameters

<i>forward_back</i>	the percent to move forward or backward
<i>left_right</i>	the percent to turn left or right
<i>power</i>	modifies the input velocities left^power, right^power
<i>bt</i>	breaktype. What to do if the driver lets go of the sticks

Drive the robot using arcade style controls. forward\_back controls the linear motion, left\_right controls the turning.

left\_motors and right\_motors are in "percent": -1.0 -> 1.0

#### 5.90.4.2 drive\_forward() [1/2]

```
bool TankDrive::drive_forward (
    double inches,
    directionType dir,
    double max_speed = 1,
    double end_speed = 0 )
```

Autonomously drive the robot forward a certain distance

#### Parameters

<i>inches</i>	degrees by which we will turn relative to the robot (+) turns ccw, (-) turns cw
<i>dir</i>	the direction we want to travel forward and backward
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

Autonomously drive the robot forward a certain distance

#### Parameters

<i>inches</i>	degrees by which we will turn relative to the robot (+) turns ccw, (-) turns cw
<i>dir</i>	the direction we want to travel forward and backward
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

#### Returns

true if we have finished driving to our point

#### 5.90.4.3 drive\_forward() [2/2]

```
bool TankDrive::drive_forward (
    double inches,
    directionType dir,
    Feedback & feedback,
    double max_speed = 1,
    double end_speed = 0 )
```

Use odometry to drive forward a certain distance using a custom feedback controller

Returns whether or not the robot has reached it's destination.

##### Parameters

<i>inches</i>	the distance to drive forward
<i>dir</i>	the direction we want to travel forward and backward
<i>feedback</i>	the custom feedback controller we will use to travel. controls the rate at which we accelerate and drive.
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

##### Returns

true when we have reached our target distance

Use odometry to drive forward a certain distance using a custom feedback controller

Returns whether or not the robot has reached it's destination.

##### Parameters

<i>inches</i>	the distance to drive forward
<i>dir</i>	the direction we want to travel forward and backward
<i>feedback</i>	the custom feedback controller we will use to travel. controls the rate at which we accelerate and drive.
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

#### 5.90.4.4 drive\_tank()

```
void TankDrive::drive_tank (
    double left,
    double right,
    int power = 1,
    BrakeType bt = BrakeType::None )
```

Drive the robot using differential style controls. *left\_motors* controls the left motors, *right\_motors* controls the right motors.

*left\_motors* and *right\_motors* are in "percent": -1.0 -> 1.0

## Parameters

<i>left</i>	the percent to run the left motors
<i>right</i>	the percent to run the right motors
<i>power</i>	modifies the input velocities left^power, right^power
<i>bt</i>	breaktype. What to do if the driver lets go of the sticks

**5.90.4.5 drive\_tank\_raw()**

```
void TankDrive::drive_tank_raw (
    double left,
    double right )
```

Drive the robot raw-ly

## Parameters

<i>left</i>	the percent to run the left motors (-1, 1)
<i>right</i>	the percent to run the right motors (-1, 1)

**5.90.4.6 drive\_to\_point() [1/2]**

```
bool TankDrive::drive_to_point (
    double x,
    double y,
    vex::directionType dir,
    double max_speed = 1,
    double end_speed = 0 )
```

Use odometry to automatically drive the robot to a point on the field. X and Y is the final point we want the robot. Here we use the default feedback controller from the drive\_sys

Returns whether or not the robot has reached it's destination.

## Parameters

<i>x</i>	the x position of the target
<i>y</i>	the y position of the target
<i>dir</i>	the direction we want to travel forward and backward
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

Use odometry to automatically drive the robot to a point on the field. X and Y is the final point we want the robot. Here we use the default feedback controller from the drive\_sys

Returns whether or not the robot has reached it's destination.

**Parameters**

<i>x</i>	the x position of the target
<i>y</i>	the y position of the target
<i>dir</i>	the direction we want to travel forward and backward
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

**Returns**

true if we have reached our target point

**5.90.4.7 drive\_to\_point() [2/2]**

```
bool TankDrive::drive_to_point (
    double x,
    double y,
    vex::directionType dir,
    Feedback & feedback,
    double max_speed = 1,
    double end_speed = 0 )
```

Use odometry to automatically drive the robot to a point on the field. X and Y is the final point we want the robot.

Returns whether or not the robot has reached it's destination.

**Parameters**

<i>x</i>	the x position of the target
<i>y</i>	the y position of the target
<i>dir</i>	the direction we want to travel forward and backward
<i>feedback</i>	the feedback controller we will use to travel. controls the rate at which we accelerate and drive.
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

Use odometry to automatically drive the robot to a point on the field. X and Y is the final point we want the robot.

Returns whether or not the robot has reached it's destination.

**Parameters**

<i>x</i>	the x position of the target
<i>y</i>	the y position of the target
<i>dir</i>	the direction we want to travel forward and backward
<i>feedback</i>	the feedback controller we will use to travel. controls the rate at which we accelerate and drive.
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

**Returns**

true if we have reached our target point

**5.90.4.8 modify\_inputs()**

```
double TankDrive::modify_inputs (
    double input,
    int power = 2 ) [static]
```

Create a curve for the inputs, so that drivers have more control at lower speeds. Curves are exponential, with the default being squaring the inputs.

**Parameters**

<i>input</i>	the input before modification
<i>power</i>	the power to raise input to

**Returns**

$\text{input}^{\wedge} \text{power}$  (accounts for negative inputs and odd numbered powers)

Modify the inputs from the controller by squaring / cubing, etc Allows for better control of the robot at slower speeds

**Parameters**

<i>input</i>	the input signal -1 -> 1
<i>power</i>	the power to raise the signal to

**Returns**

$\text{input}^{\wedge} \text{power}$  accounting for any sign issues that would arise with this naive solution

**5.90.4.9 pure\_pursuit() [1/2]**

```
bool TankDrive::pure_pursuit (
    PurePursuit::Path path,
    directionType dir,
    double max_speed = 1,
    double end_speed = 0 )
```

Drive the robot autonomously using a pure-pursuit algorithm - Input path with a set of waypoints - the robot will attempt to follow the points while cutting corners (radius) to save time (compared to stop / turn / start)

Use the default drive feedback

**Parameters**

<i>path</i>	The list of coordinates to follow, in order
<i>dir</i>	Run the bot forwards or backwards
<i>max_speed</i>	Limit the speed of the robot (for pid / pidff feedbacks)
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

**Returns**

True when the path is complete

Drive the robot autonomously using a pure-pursuit algorithm - Input path with a set of waypoints - the robot will attempt to follow the points while cutting corners (radius) to save time (compared to stop / turn / start)

Use the default drive feedback

**Parameters**

<i>path</i>	The list of coordinates to follow, in order
<i>dir</i>	Run the bot forwards or backwards
<i>max_speed</i>	Limit the speed of the robot (for pid / pidff feedbacks)

**Returns**

True when the path is complete

**5.90.4.10 pure\_pursuit() [2/2]**

```
bool TankDrive::pure_pursuit (
    PurePursuit::Path path,
    directionType dir,
    Feedback & feedback,
    double max_speed = 1,
    double end_speed = 0 )
```

Drive the robot autonomously using a pure-pursuit algorithm - Input path with a set of waypoints - the robot will attempt to follow the points while cutting corners (radius) to save time (compared to stop / turn / start)

**Parameters**

<i>path</i>	The list of coordinates to follow, in order
<i>dir</i>	Run the bot forwards or backwards
<i>feedback</i>	The feedback controller determining speed
<i>max_speed</i>	Limit the speed of the robot (for pid / pidff feedbacks)
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

**Returns**

True when the path is complete

Drive the robot autonomously using a pure-pursuit algorithm - Input path with a set of waypoints - the robot will attempt to follow the points while cutting corners (radius) to save time (compared to stop / turn / start)

**Parameters**

<i>path</i>	The list of coordinates to follow, in order
<i>dir</i>	Run the bot forwards or backwards
<i>feedback</i>	The feedback controller determining speed
<i>max_speed</i>	Limit the speed of the robot (for pid / pidff feedbacks)

**Returns**

True when the path is complete

**5.90.4.11 reset\_auto()**

```
void TankDrive::reset_auto ( )
```

Reset the initialization for autonomous drive functions

**5.90.4.12 stop()**

```
void TankDrive::stop ( )
```

Stops rotation of all the motors using their "brake mode"

**5.90.4.13 turn\_degrees() [1/2]**

```
bool TankDrive::turn_degrees (
    double degrees,
    double max_speed = 1,
    double end_speed = 0 )
```

Autonomously turn the robot X degrees to counterclockwise (negative for clockwise), with a maximum motor speed of percent\_speed (-1.0 -> 1.0)

Uses the default turning feedback of the drive system.

**Parameters**

<i>degrees</i>	degrees by which we will turn relative to the robot (+) turns ccw, (-) turns cw
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

Autonomously turn the robot X degrees to counterclockwise (negative for clockwise), with a maximum motor speed of percent\_speed (-1.0 -> 1.0)

Uses the default turning feedback of the drive system.

**Parameters**

<i>degrees</i>	degrees by which we will turn relative to the robot (+) turns ccw, (-) turns cw
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

**Returns**

true if we turned to target number of degrees

#### 5.90.4.14 turn\_degrees() [2/2]

```
bool TankDrive::turn_degrees (
    double degrees,
    Feedback & feedback,
    double max_speed = 1,
    double end_speed = 0 )
```

Autonomously turn the robot X degrees counterclockwise (negative for clockwise), with a maximum motor speed of percent\_speed (-1.0 -> 1.0)

Uses PID + Feedforward for it's control.

##### Parameters

<i>degrees</i>	degrees by which we will turn relative to the robot (+) turns ccw, (-) turns cw
<i>feedback</i>	the feedback controller we will use to travel. controls the rate at which we accelerate and drive.
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power

Autonomously turn the robot X degrees to counterclockwise (negative for clockwise), with a maximum motor speed of percent\_speed (-1.0 -> 1.0)

Uses the specified feedback for it's control.

##### Parameters

<i>degrees</i>	degrees by which we will turn relative to the robot (+) turns ccw, (-) turns cw
<i>feedback</i>	the feedback controller we will use to travel. controls the rate at which we accelerate and drive.
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

##### Returns

true if we have turned our target number of degrees

#### 5.90.4.15 turn\_to\_heading() [1/2]

```
bool TankDrive::turn_to_heading (
    double heading_deg,
    double max_speed = 1,
    double end_speed = 0 )
```

Turn the robot in place to an exact heading relative to the field. 0 is forward. Uses the defualt turn feedback of the drive system

##### Parameters

<i>heading_deg</i>	the heading to which we will turn
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

Turn the robot in place to an exact heading relative to the field. 0 is forward. Uses the default turn feedback of the drive system

#### Parameters

<i>heading_deg</i>	the heading to which we will turn
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

#### Returns

true if we have reached our target heading

### 5.90.4.16 turn\_to\_heading() [2/2]

```
bool TankDrive::turn_to_heading (
    double heading_deg,
    Feedback & feedback,
    double max_speed = 1,
    double end_speed = 0 )
```

Turn the robot in place to an exact heading relative to the field. 0 is forward.

#### Parameters

<i>heading_deg</i>	the heading to which we will turn
<i>feedback</i>	the feedback controller we will use to travel. controls the rate at which we accelerate and drive.
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

Turn the robot in place to an exact heading relative to the field. 0 is forward.

#### Parameters

<i>heading_deg</i>	the heading to which we will turn
<i>feedback</i>	the feedback controller we will use to travel. controls the rate at which we accelerate and drive.
<i>max_speed</i>	the maximum percentage of robot speed at which the robot will travel. 1 = full power
<i>end_speed</i>	the movement profile will attempt to reach this velocity by its completion

#### Returns

true if we have reached our target heading

The documentation for this class was generated from the following files:

- include/subsystems/tank\_drive.h
- src/subsystems/tank\_drive.cpp

## 5.91 screen::TextConfig Struct Reference

### Public Attributes

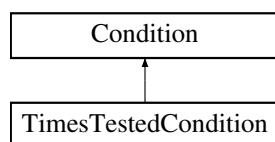
- std::function< std::string()> **text**

The documentation for this struct was generated from the following file:

- include/subsystems/screen.h

## 5.92 TimesTestedCondition Class Reference

Inheritance diagram for TimesTestedCondition:



### Public Member Functions

- **TimesTestedCondition** (size\_t N)
- bool **test** () override

### Public Member Functions inherited from [Condition](#)

- [Condition \\* Or \(Condition \\*b\)](#)
- [Condition \\* And \(Condition \\*b\)](#)

## 5.92.1 Member Function Documentation

### 5.92.1.1 test()

```
bool TimesTestedCondition::test ( ) [inline], [override], [virtual]
```

Implements [Condition](#).

The documentation for this class was generated from the following file:

- include/utils/command\_structure/auto\_command.h

## 5.93 trapezoid\_profile\_segment\_t Struct Reference

```
#include <trapezoid_profile.h>
```

## Public Attributes

- double **pos\_after**  
*1d position after this segment concludes*
- double **vel\_after**  
*1d velocity after this segment concludes*
- double **accel**  
*1d acceleration during the segment*
- double **duration**  
*duration of the segment*

### 5.93.1 Detailed Description

`trapezoid_profile_segment_t` is a description of one constant acceleration segment of a trapezoid motion profile

The documentation for this struct was generated from the following file:

- include/utils/controls/trapezoid\_profile.h

## 5.94 TrapezoidProfile Class Reference

```
#include <trapezoid_profile.h>
```

## Public Member Functions

- **TrapezoidProfile** (double max\_v, double accel)  
*Construct a new Trapezoid Profile object.*
- **motion\_t calculate** (double time\_s, double pos\_s)  
*Run the trapezoidal profile based on the time and distance that's elapsed.*
- **motion\_t calculate\_time\_based** (double time\_s)  
*Run the trapezoidal profile based on the time that's elapsed.*
- void **set\_endpts** (double start, double end)  
*set\_endpts defines a start and end position*
- void **set\_vel\_endpts** (double start, double end)  
*set start and end velocities*
- void **set\_accel** (double accel)  
*set\_accel sets the acceleration this profile will use (the left and right legs of the trapezoid)*
- void **set\_max\_v** (double max\_v)  
*sets the maximum velocity for the profile (the height of the top of the trapezoid)*
- double **get\_movement\_time** () const  
*uses the kinematic equations to and specified accel and max\_v to figure out how long moving along the profile would take*
- double **get\_max\_v** () const
- double **get\_accel** () const

### 5.94.1 Detailed Description

#### Trapezoid Profile

This is a motion profile defined by:

- maximum acceleration
- maximum velocity
- start position and velocity
- end position and velocity

Using this information, a parametric function is generated, with a period of acceleration, constant velocity, and deceleration. The velocity graph usually looks like a trapezoid, giving it its name.

If the maximum velocity is set high enough, this will become a S-curve profile, with only acceleration and deceleration.

If the initial velocity is in the wrong direction, the profile will first come to a stop, then continue a normal trapezoid profile.

If the initial velocity is higher than the maximum velocity, the profile will first try to achieve the maximum velocity.

If the end velocity is not achievable, the profile will try to get as close as possible. The end velocity must be in the direction of the end point.

This class is designed for use in properly modelling the motion of the robots to create a feedforward and target for **PID**. Acceleration and Maximum velocity should be measured on the robot and tuned down slightly to account for battery drop.

Here are the equations graphed for ease of understanding: <https://www.desmos.com/calculator/rkm3ivulyk>

#### Author

Ryan McGee

#### Date

7/12/2022

### 5.94.2 Constructor & Destructor Documentation

#### 5.94.2.1 TrapezoidProfile()

```
TrapezoidProfile::TrapezoidProfile (
    double max_v,
    double accel )
```

Construct a new Trapezoid Profile object.

**Parameters**

<i>max_v</i>	Maximum velocity the robot can run at
<i>accel</i>	Maximum acceleration of the robot

**5.94.3 Member Function Documentation****5.94.3.1 calculate()**

```
motion\_t TrapezoidProfile::calculate (
    double time_s,
    double pos_s )
```

Run the trapezoidal profile based on the time and distance that's elapsed.

**Parameters**

<i>time_s</i>	Time since start of movement
<i>pos_s</i>	The current position

**Returns**

[\*motion\\_t\*](#) Position, velocity and acceleration

**5.94.3.2 calculate\_time\_based()**

```
motion\_t TrapezoidProfile::calculate_time_based (
    double time_s )
```

Run the trapezoidal profile based on the time that's elapsed.

**Parameters**

<i>time_s</i>	Time since start of movement
---------------	------------------------------

**Returns**

[\*motion\\_t\*](#) Position, velocity and acceleration

**5.94.3.3 get\_movement\_time()**

```
double TrapezoidProfile::get_movement_time ( ) const
```

uses the kinematic equations to and specified accel and max\_v to figure out how long moving along the profile would take

**Returns**

the time the path will take to travel

**5.94.3.4 set\_accel()**

```
void TrapezoidProfile::set_accel (
    double accel )
```

`set_accel` sets the acceleration this profile will use (the left and right legs of the trapezoid)

**Parameters**

<i>accel</i>	the acceleration amount to use
--------------	--------------------------------

**5.94.3.5 set\_endpts()**

```
void TrapezoidProfile::set_endpts (
    double start,
    double end )
```

`set_endpts` defines a start and end position

**Parameters**

<i>start</i>	the starting position of the path
<i>end</i>	the ending position of the path

**5.94.3.6 set\_max\_v()**

```
void TrapezoidProfile::set_max_v (
    double max_v )
```

`sets the maximum velocity for the profile (the height of the top of the trapezoid)`

**Parameters**

<i>max_v</i>	the maximum velocity the robot can travel at
--------------	----------------------------------------------

**5.94.3.7 set\_vel\_endpts()**

```
void TrapezoidProfile::set_vel_endpts (
    double start,
    double end )
```

`set start and end velocities`

**Parameters**

<i>start</i>	the starting velocity of the path
<i>end</i>	the ending velocity of the path

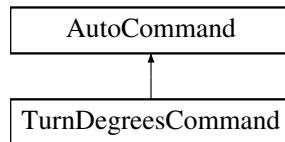
The documentation for this class was generated from the following files:

- include/utils/controls/trapezoid\_profile.h
- src/utils/trapezoid\_profile.cpp

## 5.95 TurnDegreesCommand Class Reference

```
#include <drive_commands.h>
```

Inheritance diagram for TurnDegreesCommand:



### Public Member Functions

- `TurnDegreesCommand (TankDrive &drive_sys, Feedback &feedback, double degrees, double max_speed=1, double end_speed=0)`
- `bool run () override`
- `void on_timeout () override`

### Public Member Functions inherited from [AutoCommand](#)

- `AutoCommand * withTimeout (double t_seconds)`
- `AutoCommand * withCancelCondition (Condition *true_to_end)`

### Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- `double timeout_seconds = default_timeout`
- `Condition * true_to_end = nullptr`

### Static Public Attributes inherited from [AutoCommand](#)

- `static constexpr double default_timeout = 10.0`

### 5.95.1 Detailed Description

[AutoCommand](#) wrapper class for the turn\_degrees function in the [TankDrive](#) class

### 5.95.2 Constructor & Destructor Documentation

#### 5.95.2.1 TurnDegreesCommand()

```
TurnDegreesCommand::TurnDegreesCommand (
    TankDrive & drive_sys,
    Feedback & feedback,
    double degrees,
    double max_speed = 1,
    double end_speed = 0 )
```

Construct a [TurnDegreesCommand](#) Command

##### Parameters

<i>drive_sys</i>	the drive system we are commanding
<i>feedback</i>	the feedback controller we are using to execute the turn
<i>degrees</i>	how many degrees to rotate
<i>max_speed</i>	0 -> 1 percentage of the drive systems speed to drive at

### 5.95.3 Member Function Documentation

#### 5.95.3.1 on\_timeout()

```
void TurnDegreesCommand::on_timeout ( ) [override], [virtual]
```

Cleans up drive system if we time out before finishing

reset the drive system if we timeout

Reimplemented from [AutoCommand](#).

#### 5.95.3.2 run()

```
bool TurnDegreesCommand::run ( ) [override], [virtual]
```

Run turn\_degrees Overrides run from [AutoCommand](#)

##### Returns

true when execution is complete, false otherwise

Reimplemented from [AutoCommand](#).

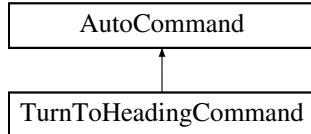
The documentation for this class was generated from the following files:

- include/utils/command\_structure/drive\_commands.h
- src/utils/command\_structure/drive\_commands.cpp

## 5.96 TurnToHeadingCommand Class Reference

```
#include <drive_commands.h>
```

Inheritance diagram for TurnToHeadingCommand:



### Public Member Functions

- [TurnToHeadingCommand \(TankDrive &drive\\_sys, Feedback &feedback, double heading\\_deg, double speed=1, double end\\_speed=0\)](#)
- [bool run \(\) override](#)
- [void on\\_timeout \(\) override](#)

### Public Member Functions inherited from [AutoCommand](#)

- [AutoCommand \\* withTimeout \(double t\\_seconds\)](#)
- [AutoCommand \\* withCancelCondition \(Condition \\*true\\_to\\_end\)](#)

### Additional Inherited Members

#### Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition \\* true\\_to\\_end](#) = nullptr

#### Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double [default\\_timeout](#) = 10.0

### 5.96.1 Detailed Description

[AutoCommand](#) wrapper class for the turn\_to\_heading() function in the [TankDrive](#) class

### 5.96.2 Constructor & Destructor Documentation

#### 5.96.2.1 TurnToHeadingCommand()

```
TurnToHeadingCommand::TurnToHeadingCommand (
    TankDrive & drive_sys,
    Feedback & feedback,
    double heading_deg,
    double max_speed = 1,
    double end_speed = 0 )
```

Construct a [TurnToHeadingCommand](#) Command

**Parameters**

<i>drive_sys</i>	the drive system we are commanding
<i>feedback</i>	the feedback controller we are using to execute the drive
<i>heading_deg</i>	the heading to turn to in degrees
<i>max_speed</i>	0 -> 1 percentage of the drive systems speed to drive at

**5.96.3 Member Function Documentation****5.96.3.1 on\_timeout()**

```
void TurnToHeadingCommand::on_timeout ( ) [override], [virtual]
```

Cleans up drive system if we time out before finishing

reset the drive system if we don't hit our target

Reimplemented from [AutoCommand](#).

**5.96.3.2 run()**

```
bool TurnToHeadingCommand::run ( ) [override], [virtual]
```

Run turn\_to\_heading Overrides run from [AutoCommand](#)

**Returns**

true when execution is complete, false otherwise

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

- include/utils/command\_structure/drive\_commands.h
- src/utils/command\_structure/drive\_commands.cpp

**5.97 Vector2D Class Reference**

```
#include <vector2d.h>
```

## Public Member Functions

- [Vector2D \(double dir, double mag\)](#)
- [Vector2D \(point\\_t p\)](#)
- [double get\\_dir \(\) const](#)
- [double get\\_mag \(\) const](#)
- [double get\\_x \(\) const](#)
- [double get\\_y \(\) const](#)
- [Vector2D normalize \(\)](#)
- [point\\_t point \(\)](#)
- [Vector2D operator\\* \(const double &x\)](#)
- [Vector2D operator+ \(const Vector2D &other\)](#)
- [Vector2D operator- \(const Vector2D &other\)](#)

### 5.97.1 Detailed Description

`Vector2D` is an x,y pair Used to represent 2D locations on the field. It can also be treated as a direction and magnitude

### 5.97.2 Constructor & Destructor Documentation

#### 5.97.2.1 Vector2D() [1/2]

```
Vector2D::Vector2D (
    double dir,
    double mag )
```

Construct a vector object.

##### Parameters

<code>dir</code>	Direction, in radians. 'forward' is 0, clockwise positive when viewed from the top.
<code>mag</code>	Magnitude.

#### 5.97.2.2 Vector2D() [2/2]

```
Vector2D::Vector2D (
    point_t p )
```

Construct a vector object from a cartesian point.

##### Parameters

<code>p</code>	<code>point_t.x</code> , <code>point_t.y</code>
----------------	-------------------------------------------------

### 5.97.3 Member Function Documentation

#### 5.97.3.1 get\_dir()

```
double Vector2D::get_dir ( ) const
```

Get the direction of the vector, in radians. '0' is forward, clockwise positive when viewed from the top.

Use r2d() to convert.

##### Returns

the direction of the vector in radians

Get the direction of the vector, in radians. '0' is forward, clockwise positive when viewed from the top.

Use r2d() to convert.

#### 5.97.3.2 get\_mag()

```
double Vector2D::get_mag ( ) const
```

##### Returns

the magnitude of the vector

Get the magnitude of the vector

#### 5.97.3.3 get\_x()

```
double Vector2D::get_x ( ) const
```

##### Returns

the X component of the vector; positive to the right.

Get the X component of the vector; positive to the right.

#### 5.97.3.4 get\_y()

```
double Vector2D::get_y ( ) const
```

##### Returns

the Y component of the vector, positive forward.

Get the Y component of the vector, positive forward.

### 5.97.3.5 normalize()

```
Vector2D Vector2D::normalize ( )
```

Changes the magnitude of the vector to 1

#### Returns

the normalized vector

Changes the magnitude of the vector to 1

### 5.97.3.6 operator\*()

```
Vector2D Vector2D::operator* (
    const double & x )
```

Scales a [Vector2D](#) by a scalar with the \* operator

#### Parameters

x	the value to scale the vector by
---	----------------------------------

#### Returns

the this [Vector2D](#) scaled by x

### 5.97.3.7 operator+()

```
Vector2D Vector2D::operator+ (
    const Vector2D & other )
```

Add the components of two vectors together  $\text{Vector2D} + \text{Vector2D} = (\text{this.x} + \text{other.x}, \text{this.y} + \text{other.y})$

#### Parameters

other	the vector to add to this
-------	---------------------------

#### Returns

the sum of the vectors

### 5.97.3.8 operator-()

```
Vector2D Vector2D::operator- (
    const Vector2D & other )
```

Subtract the components of two vectors together  $\text{Vector2D} - \text{Vector2D} = (\text{this.x} - \text{other.x}, \text{this.y} - \text{other.y})$

**Parameters**

<i>other</i>	the vector to subtract from this
--------------	----------------------------------

**Returns**

the difference of the vectors

**5.97.3.9 point()**

`point_t Vector2D::point ( )`

Returns a point from the vector

**Returns**

the point represented by the vector

Convert a direction and magnitude representation to an x, y representation

**Returns**

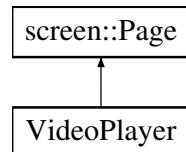
the x, y representation of the vector

The documentation for this class was generated from the following files:

- `include/utils/vector2d.h`
- `src/utils/vector2d.cpp`

**5.98 VideoPlayer Class Reference**

Inheritance diagram for VideoPlayer:

**Public Member Functions**

- void `update` (bool *was\_pressed*, int *x*, int *y*) override  
*collect data, respond to screen input, do fast things (runs at 50hz even if you're not focused on this Page (only drawn page gets touch updates))*
- void `draw` (vex::brain::lcd &*screen*, bool *first\_draw*, unsigned int *frame\_number*) override  
*draw stored data to the screen (runs at 10 hz and only runs if this page is in front)*

**5.98.1 Member Function Documentation****5.98.1.1 draw()**

```

void VideoPlayer::draw (
    vex::brain::lcd & screen,
    bool first_draw,
    unsigned int frame_number ) [override], [virtual]
  
```

*draw stored data to the screen (runs at 10 hz and only runs if this page is in front)*

#### Parameters

<code>first_draw</code>	true if we just switched to this page
<code>frame_number</code>	frame of drawing we are on (basically an animation tick)

Reimplemented from [screen::Page](#).

#### 5.98.1.2 update()

```
void VideoPlayer::update (
    bool was_pressed,
    int x,
    int y) [override], [virtual]
```

collect data, respond to screen input, do fast things (runs at 50hz even if you're not focused on this Page (only drawn page gets touch updates))

#### Parameters

<code>was_pressed</code>	true if the screen has been pressed
<code>x</code>	x position of screen press (if the screen was pressed)
<code>y</code>	y position of screen press (if the screen was pressed)

Reimplemented from [screen::Page](#).

The documentation for this class was generated from the following files:

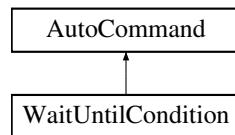
- `include/subsystems/fun/video.h`
- `src/subsystems/fun/video.cpp`

## 5.99 WaitUntilCondition Class Reference

Waits until the condition is true.

```
#include <auto_command.h>
```

Inheritance diagram for WaitUntilCondition:



#### Public Member Functions

- `WaitUntilCondition (Condition *cond)`
- `bool run () override`

## Public Member Functions inherited from [AutoCommand](#)

- virtual void [on\\_timeout \(\)](#)
- [AutoCommand \\* withTimeout](#) (double t\_seconds)
- [AutoCommand \\* withCancelCondition](#) ([Condition](#) \*true\_to\_end)

## Additional Inherited Members

### Public Attributes inherited from [AutoCommand](#)

- double [timeout\\_seconds](#) = default\_timeout
- [Condition \\* true\\_to\\_end](#) = nullptr

### Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double [default\\_timeout](#) = 10.0

## 5.99.1 Detailed Description

Waits until the condition is true.

## 5.99.2 Member Function Documentation

### 5.99.2.1 run()

```
bool WaitUntilCondition::run ( ) [inline], [override], [virtual]
```

Executes the command Overridden by child classes

#### Returns

true when the command is finished, false otherwise

Reimplemented from [AutoCommand](#).

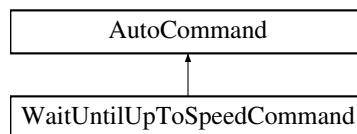
The documentation for this class was generated from the following file:

- include/utils/command\_structure/auto\_command.h

## 5.100 WaitUntilUpToSpeedCommand Class Reference

```
#include <flywheel_commands.h>
```

Inheritance diagram for WaitUntilUpToSpeedCommand:



## Public Member Functions

- [WaitUntilUpToSpeedCommand \(`Flywheel` &`flywheel`, int `threshold\_rpm`\)](#)
- bool [run \(\)](#) override

## Public Member Functions inherited from [AutoCommand](#)

- virtual void [on\\_timeout \(\)](#)
- [AutoCommand \\* withTimeout](#) (double `t_seconds`)
- [AutoCommand \\* withCancelCondition](#) (`Condition` \*`true_to_end`)

## Additional Inherited Members

## Public Attributes inherited from [AutoCommand](#)

- double `timeout_seconds` = `default_timeout`
- `Condition` \* `true_to_end` = `nullptr`

## Static Public Attributes inherited from [AutoCommand](#)

- static constexpr double `default_timeout` = 10.0

## 5.100.1 Detailed Description

[AutoCommand](#) that listens to the [Flywheel](#) and waits until it is at its target speed +/- the specified threshold

## 5.100.2 Constructor & Destructor Documentation

### 5.100.2.1 WaitUntilUpToSpeedCommand()

```
WaitUntilUpToSpeedCommand::WaitUntilUpToSpeedCommand (
    Flywheel & flywheel,
    int threshold_rpm )
```

Create a [WaitUntilUpToSpeedCommand](#)

#### Parameters

<code>flywheel</code>	the flywheel system we are commanding
<code>threshold_rpm</code>	the threshold over and under the flywheel target RPM that we define to be acceptable

### 5.100.3 Member Function Documentation

#### 5.100.3.1 run()

```
bool WaitUntilUpToSpeedCommand::run ( ) [override], [virtual]
```

Run spin\_manual Overrides run from [AutoCommand](#)

##### Returns

true when execution is complete, false otherwise

Reimplemented from [AutoCommand](#).

The documentation for this class was generated from the following files:

- include/utils/command\_structure/flywheel\_commands.h
- src/utils/command\_structure/flywheel\_commands.cpp

## 5.101 screen::WidgetConfig Struct Reference

### Public Types

- enum **Type** {  
    **Col** , **Row** , **Slider** , **Button** ,  
    **Checkbox** , **Label** , **Text** , **Graph** }

### Public Attributes

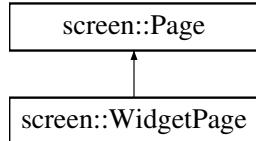
- Type **type**
- union {  
    std::vector< [SizedWidget](#) > **widgets**  
    [SliderConfig](#) **slider**  
    [ButtonConfig](#) **button**  
    [CheckboxConfig](#) **checkbox**  
    [LabelConfig](#) **label**  
    [TextConfig](#) **text**  
    [GraphDrawer](#) \* **graph**  
} **config**

The documentation for this struct was generated from the following file:

- include/subsystems/screen.h

## 5.102 screen::WidgetPage Class Reference

Inheritance diagram for screen::WidgetPage:



### Public Member Functions

- **WidgetPage** ([WidgetConfig &cfg](#))
- void [update](#) (bool was\_pressed, int x, int y) override  
*collect data, respond to screen input, do fast things (runs at 50hz even if you're not focused on this [Page](#) (only drawn page gets touch updates))*
- void [draw](#) (vex::brain::lcd &, bool first\_draw, unsigned int frame\_number) override  
*draw stored data to the screen (runs at 10 hz and only runs if this page is in front)*

### 5.102.1 Member Function Documentation

#### 5.102.1.1 draw()

```
void screen::WidgetPage::draw (
    vex::brain::lcd & screen,
    bool first_draw,
    unsigned int frame_number ) [inline], [override], [virtual]
```

draw stored data to the screen (runs at 10 hz and only runs if this page is in front)

##### Parameters

<i>first_draw</i>	true if we just switched to this page
<i>frame_number</i>	frame of drawing we are on (basically an animation tick)

Reimplemented from [screen::Page](#).

#### 5.102.1.2 update()

```
void screen::WidgetPage::update (
    bool was_pressed,
    int x,
    int y ) [override], [virtual]
```

collect data, respond to screen input, do fast things (runs at 50hz even if you're not focused on this [Page](#) (only drawn page gets touch updates))

**Parameters**

<i>was_pressed</i>	true if the screen has been pressed
<i>x</i>	x position of screen press (if the screen was pressed)
<i>y</i>	y position of screen press (if the screen was pressed)

Reimplemented from [screen::Page](#).

The documentation for this class was generated from the following file:

- include/subsystems/screen.h

# Chapter 6

## File Documentation

### 6.1 robot\_specs.h

```
00001 #pragma once
00002 #include "../core/include/utils/controls/feedback_base.h"
00003 #include "../core/include/utils/controls/pid.h"
00004
00011 typedef struct {
00012     double robot_radius;
00014
00015     double odom_wheel_diam;
00016     double odom_gear_ratio;
00018     double dist_between_wheels;
00020
00021     double drive_correction_cutoff;
00026
00027     Feedback *drive_feedback;
00028     Feedback *turn_feedback;
00029     PID::pid_config_t correction_pid;
00031
00032 } robot_specs_t;
```

### 6.2 custom\_encoder.h

```
00001 #pragma once
00002 #include "vex.h"
00003
00008 class CustomEncoder : public vex::encoder {
00009     typedef vex::encoder super;
00010
00011 public:
00018     CustomEncoder(vex::tripoint::port &port, double ticks_per_rev);
00019
00026     void setRotation(double val, vex::rotationUnits units);
00027
00034     void setPosition(double val, vex::rotationUnits units);
00035
00041     double rotation(vex::rotationUnits units);
00042
00048     double position(vex::rotationUnits units);
00049
00055     double velocity(vex::velocityUnits units);
00056
00057 private:
00058     double tick_scalar;
00059 };
```

### 6.3 flywheel.h

```
00001 #pragma once
00002
00003 #include "../core/include/robot_specs.h"
```

```

00004 #include "../core/include/subsystems/screen.h"
00005 #include "../core/include/utils/command_structure/auto_command.h"
00006 #include "../core/include/utils/controls/feedforward.h"
00007 #include "../core/include/utils/controls/pid.h"
00008 #include "vex.h"
00009 #include <atomic>
00010
00020 class Flywheel {
00021
00022 public:
00023     // CONSTRUCTORS, GETTERS, AND SETTERS
00034     Flywheel(vex::motor_group &motors, Feedback &feedback, FeedForward &helper, const double ratio,
00035             Filter &filt);
00036
00040     double get_target() const;
00041
00045     double getRPM() const;
00046
00050     vex::motor_group &get_motors() const;
00051
00059     void spin_manual(double speed, directionType dir = fwd);
00060
00066     void spin_rpm(double rpm);
00067
00072     void stop();
00073
00078     bool is_on_target() { return fb.is_on_target(); }
00079
00085     screen::Page *Page() const;
00086
00093     AutoCommand *SpinRpmCmd(int rpm) {
00094
00095         return new FunctionCommand([this, rpm]() {
00096             spin_rpm(rpm);
00097             return true;
00098         });
00099     }
00100
00106     AutoCommand *WaitUntilUpToSpeedCmd() {
00107         return new WaitUntilCondition(new FunctionCondition([this]() { return is_on_target(); }));
00108     }
00109
00110 private:
00111     friend class FlywheelPage;
00112     friend int spinRPMTask(void *wheelPointer);
00113
00114     vex::motor_group &motors;
00115     bool task_running = false;
00116     Feedback &fb;
00117     FeedForward &ffd;
00118     vex::mutex fb_mut;
00119     double ratio;
00121     std::atomic<double> target_rpm;
00122     task rpm_task;
00123     Filter &avger;
00124
00125     // Functions for internal use only
00130     void set_target(double value);
00135     double measure_RPM();
00136
00143     void spin_raw(double speed, directionType dir = fwd);
00144 };

```

## 6.4 pl\_mpeg.h

```

00001 #include "vex.h"
00002 /*
00003 PL_MPEG - MPEG1 Video decoder, MP2 Audio decoder, MPEG-PS demuxer
00004
00005 Dominic Szablewski - https://phoboslab.org
00006
00007
00008 -- LICENSE: The MIT License(MIT)
00009
00010 Copyright(c) 2019 Dominic Szablewski
00011
00012 Permission is hereby granted, free of charge, to any person obtaining a copy of
00013 this software and associated documentation files(the "Software"), to deal in
00014 the Software without restriction, including without limitation the rights to
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```

```

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00025 OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE
00026 SOFTWARE.
00027
00028
00029
00030
00031 -- Synopsis
00032
00033 // Define `PL_MPEG_IMPLEMENTATION` in *one* C/C++ file before including this
00034 // library to create the implementation.
00035
00036 #define PL_MPEG_IMPLEMENTATION
00037 #include "plmpeg.h"
00038
00039 // This function gets called for each decoded video frame
00040 void my_video_callback(plm_t *plm, plm_frame_t *frame, void *user) {
00041     // Do something with frame->y.data, frame->cr.data, frame->cb.data
00042 }
00043
00044 // This function gets called for each decoded audio frame
00045 void my_audio_callback(plm_t *plm, plm_samples_t *frame, void *user) {
00046     // Do something with samples->interleaved
00047 }
00048
00049 // Load a .mpg (MPEG Program Stream) file
00050 plm_t *plm = plm_create_with_filename("some-file.mpg");
00051
00052 // Install the video & audio decode callbacks
00053 plm_set_video_decode_callback(plm, my_video_callback, my_data);
00054 plm_set_audio_decode_callback(plm, my_audio_callback, my_data);
00055
00056
00057 // Decode
00058 do {
00059     plm_decode(plm, time_since_last_call);
00060 } while (!plm_has-ended(plm));
00061
00062 // All done
00063 plm_destroy(plm);
00064
00065
00066
00067 -- Documentation
00068
00069 This library provides several interfaces to load, demux and decode MPEG video
00070 and audio data. A high-level API combines the demuxer, video & audio decoders
00071 in an easy to use wrapper.
00072
00073 Lower-level APIs for accessing the demuxer, video decoder and audio decoder,
00074 as well as providing different data sources are also available.
00075
00076 Interfaces are written in an object oriented style, meaning you create object
00077 instances via various different constructor functions (plm_*create()),
00078 do some work on them and later dispose them via plm_*destroy().
00079
00080 plm_* ..... the high-level interface, combining demuxer and decoders
00081 plm_buffer_* .. the data source used by all interfaces
00082 plm_demux_* ... the MPEG-PS demuxer
00083 plm_video_* ... the MPEG1 Video ("mpeg1") decoder
00084 plm_audio_* ... the MPEG1 Audio Layer II ("mp2") decoder
00085
00086
00087 With the high-level interface you have two options to decode video & audio:
00088
00089 1. Use plm_decode() and just hand over the delta time since the last call.
00090     It will decode everything needed and call your callbacks (specified through
00091     plm_set_{video|audio}_decode_callback()) any number of times.
00092
00093 2. Use plm_decode_video() and plm_decode_audio() to decode exactly one
00094     frame of video or audio data at a time. How you handle the synchronization
00095     of both streams is up to you.
00096
00097 If you only want to decode video *or* audio through these functions, you should
00098 disable the other stream (plm_set_{video|audio}_enabled(FALSE))
00099
00100 Video data is decoded into a struct with all 3 planes (Y, Cr, Cb) stored in
00101 separate buffers. You can either convert this to RGB on the CPU (slow) via the
00102 plm_frame_to_rgb() function or do it on the GPU with the following matrix:
00103
00104 mat4 bt601 = mat4(
00105     1.16438, 0.00000, 1.59603, -0.87079,

```

```

00106      1.16438, -0.39176, -0.81297,  0.52959,
00107      1.16438,  2.01723,  0.00000, -1.08139,
00108      0, 0, 0, 1
00109  );
00110 gl_FragColor = vec4(y, cb, cr, 1.0) * bt601;
00111
00112 Audio data is decoded into a struct with either one single float array with the
00113 samples for the left and right channel interleaved, or if the
00114 PLM_AUDIO_SEPARATE_CHANNELS is defined *before* including this library, into
00115 two separate float arrays - one for each channel.
00116
00117
00118 Data can be supplied to the high level interface, the demuxer and the decoders
00119 in three different ways:
00120
00121 1. Using plm_create_from_filename() or with a file handle with
00122     plm_create_from_file().
00123
00124 2. Using plm_create_with_memory() and supplying a pointer to memory that
00125     contains the whole file.
00126
00127 3. Using plm_create_with_buffer(), supplying your own plm_buffer_t instance and
00128     periodically writing to this buffer.
00129
00130 When using your own plm_buffer_t instance, you can fill this buffer using
00131 plm_buffer_write(). You can either monitor plm_buffer_get_remaining() and push
00132 data when appropriate, or install a callback on the buffer with
00133 plm_buffer_set_load_callback() that gets called whenever the buffer needs more
00134 data.
00135
00136 A buffer created with plm_buffer_create_with_capacity() is treated as a ring
00137 buffer, meaning that data that has already been read, will be discarded. In
00138 contrast, a buffer created with plm_buffer_create_forAppending() will keep all
00139 data written to it in memory. This enables seeking in the already loaded data.
00140
00141
00142 There should be no need to use the lower level plm_demux_*, plm_video_* and
00143 plm_audio_* functions, if all you want to do is read/decode an MPEG-PS file.
00144 However, if you get raw mpegvideo data or raw mp2 audio data from a different
00145 source, these functions can be used to decode the raw data directly. Similarly,
00146 if you only want to analyze an MPEG-PS file or extract raw video or audio
00147 packets from it, you can use the plm_demux_* functions.
00148
00149
00150 This library uses malloc(), realloc() and free() to manage memory. Typically
00151 all allocation happens up-front when creating the interface. However, the
00152 default buffer size may be too small for certain inputs. In these cases plmpeg
00153 will realloc() the buffer with a larger size whenever needed. You can configure
00154 the default buffer size by defining PLM_BUFFER_DEFAULT_SIZE *before*
00155 including this library.
00156
00157 You can also define PLM_MALLOC, PLM_REALLOC and PLM_FREE to provide your own
00158 memory management functions.
00159
00160
00161 See below for detailed the API documentation.
00162
00163 */
00164
00165 #ifndef PL_MPEG_H
00166 #define PL_MPEG_H
00167
00168 #include <stdint.h>
00169 // #include <stdio.h>
00170
00171 #ifdef __cplusplus
00172 extern "C" {
00173 #endif
00174
00175 // -----
00176 // Public Data Types
00177
00178 // Object types for the various interfaces
00179
00180 typedef struct plm_t plm_t;
00181 typedef struct plm_buffer_t plm_buffer_t;
00182 typedef struct plm_demux_t plm_demux_t;
00183 typedef struct plm_video_t plm_video_t;
00184 typedef struct plm_audio_t plm_audio_t;
00185
00186 // Demuxed MPEG PS packet
00187 // The type maps directly to the various MPEG-PES start codes. PTS is the
00188 // presentation time stamp of the packet in seconds. Note that not all packets
00189 // have a PTS value, indicated by PLM_PACKET_INVALID_TS.
00190
00191 #define PLM_PACKET_INVALID_TS -1
00192

```

```

00193 typedef struct {
00194     int type;
00195     double pts;
00196     size_t length;
00197     uint8_t *data;
00198 } plm_packet_t;
00199
00200 // Decoded Video Plane
00201 // The byte length of the data is width * height. Note that different planes
00202 // have different sizes: the Luma plane (Y) is double the size of each of
00203 // the two Chroma planes (Cr, Cb) - i.e. 4 times the byte length.
00204 // Also note that the size of the plane does *not* denote the size of the
00205 // displayed frame. The sizes of planes are always rounded up to the nearest
00206 // macroblock (16px).
00207
00208 typedef struct {
00209     unsigned int width;
00210     unsigned int height;
00211     uint8_t *data;
00212 } plm_plane_t;
00213
00214 // Decoded Video Frame
00215 // width and height denote the desired display size of the frame. This may be
00216 // different from the internal size of the 3 planes.
00217
00218 typedef struct {
00219     double time;
00220     unsigned int width;
00221     unsigned int height;
00222     plm_plane_t y;
00223     plm_plane_t cr;
00224     plm_plane_t cb;
00225 } plm_frame_t;
00226
00227 // Callback function type for decoded video frames used by the high-level
00228 // plm_* interface
00229
00230 typedef void (*plm_video_decode_callback)(plm_t *self, plm_frame_t *frame, void *user);
00231
00232 // Decoded Audio Samples
00233 // Samples are stored as normalized (-1, 1) float either interleaved, or if
00234 // PLM_AUDIO_SEPARATE_CHANNELS is defined, in two separate arrays.
00235 // The `count` is always PLM_AUDIO_SAMPLES_PER_FRAME and just there for
00236 // convenience.
00237
00238 #define PLM_AUDIO_SAMPLES_PER_FRAME 1152
00239
00240 typedef struct {
00241     double time;
00242     unsigned int count;
00243     #ifdef PLM_AUDIO_SEPARATE_CHANNELS
00244         float left[PLM_AUDIO_SAMPLES_PER_FRAME];
00245         float right[PLM_AUDIO_SAMPLES_PER_FRAME];
00246     #else
00247         float interleaved[PLM_AUDIO_SAMPLES_PER_FRAME * 2];
00248     #endif
00249 } plm_samples_t;
00250
00251 // Callback function type for decoded audio samples used by the high-level
00252 // plm_* interface
00253
00254 typedef void (*plm_audio_decode_callback)(plm_t *self, plm_samples_t *samples, void *user);
00255
00256 // Callback function for plm_buffer when it needs more data
00257
00258 typedef void (*plm_buffer_load_callback)(plm_buffer_t *self, void *user);
00259
00260 // -----
00261 // plm_* public API
00262 // High-Level API for loading/demuxing/decoding MPEG-PS data
00263
00264 // Create a plmpeg instance with a filename. Returns NULL if the file could not
00265 // be opened.
00266
00267 plm_t *plm_create_with_filename(const char *filename);
00268
00269 // Create a plmpeg instance with a file handle. Pass TRUE to close_when_done to
00270 // let plmpeg call fclose() on the handle when plm_destroy() is called.
00271
00272 plm_t *plm_create_with_file(FIL *fh, int close_when_done);
00273
00274 // Create a plmpeg instance with a pointer to memory as source. This assumes the
00275 // whole file is in memory. The memory is not copied. Pass TRUE to
00276 // free_when_done to let plmpeg call free() on the pointer when plm_destroy()
00277 // is called.
00278
00279 plm_t *plm_create_with_memory(uint8_t *bytes, size_t length, int free_when_done);

```

```

00280
00281 // Create a plmpeg instance with a plm_buffer as source. Pass TRUE to
00282 // destroy_when_done to let plmpeg call plm_buffer_destroy() on the buffer when
00283 // plm_destroy() is called.
00284
00285 plm_t *plm_create_with_buffer(plm_buffer_t *buffer, int destroy_when_done);
00286
00287 // Destroy a plmpeg instance and free all data.
00288
00289 void plm_destroy(plm_t *self);
00290
00291 // Get whether we have headers on all available streams and we can accurately
00292 // report the number of video/audio streams, video dimensions, framerate and
00293 // audio samplerate.
00294 // This returns FALSE if the file is not an MPEG-PS file or - when not using a
00295 // file as source - when not enough data is available yet.
00296
00297 int plm_has_headers(plm_t *self);
00298
00299 // Get or set whether video decoding is enabled. Default TRUE.
00300
00301 int plm_get_video_enabled(plm_t *self);
00302 void plm_set_video_enabled(plm_t *self, int enabled);
00303
00304 // Get the number of video streams (0--1) reported in the system header.
00305
00306 int plm_get_num_video_streams(plm_t *self);
00307
00308 // Get the display width/height of the video stream.
00309
00310 int plm_get_width(plm_t *self);
00311 int plm_get_height(plm_t *self);
00312
00313 // Get the framerate of the video stream in frames per second.
00314
00315 double plm_get_framerate(plm_t *self);
00316
00317 // Get or set whether audio decoding is enabled. Default TRUE.
00318
00319 int plm_get_audio_enabled(plm_t *self);
00320 void plm_set_audio_enabled(plm_t *self, int enabled);
00321
00322 // Get the number of audio streams (0--4) reported in the system header.
00323
00324 int plm_get_num_audio_streams(plm_t *self);
00325
00326 // Set the desired audio stream (0--3). Default 0.
00327
00328 void plm_set_audio_stream(plm_t *self, int stream_index);
00329
00330 // Get the samplerate of the audio stream in samples per second.
00331
00332 int plm_get_samplerate(plm_t *self);
00333
00334 // Get or set the audio lead time in seconds - the time in which audio samples
00335 // are decoded in advance (or behind) the video decode time. Typically this
00336 // should be set to the duration of the buffer of the audio API that you use
00337 // for output. E.g. for SDL2: (SDL_AudioSpec.samples / samplerate)
00338
00339 double plm_get_audio_lead_time(plm_t *self);
00340 void plm_set_audio_lead_time(plm_t *self, double lead_time);
00341
00342 // Get the current internal time in seconds.
00343
00344 double plm_get_time(plm_t *self);
00345
00346 // Get the video duration of the underlying source in seconds.
00347
00348 double plm_get_duration(plm_t *self);
00349
00350 // Rewind all buffers back to the beginning.
00351
00352 void plm_rewind(plm_t *self);
00353
00354 // Get or set looping. Default FALSE.
00355
00356 int plm_get_loop(plm_t *self);
00357 void plm_set_loop(plm_t *self, int loop);
00358
00359 // Get whether the file has ended. If looping is enabled, this will always
00360 // return FALSE.
00361
00362 int plm_hasEnded(plm_t *self);
00363
00364 // Set the callback for decoded video frames used with plm_decode(). If no
00365 // callback is set, video data will be ignored and not be decoded. The *user
00366 // Parameter will be passed to your callback.

```

```

00367
00368 void plm_set_video_decode_callback(plm_t *self, plm_video_decode_callback fp, void *user);
00369
00370 // Set the callback for decoded audio samples used with plm_decode(). If no
00371 // callback is set, audio data will be ignored and not be decoded. The *user
00372 // Parameter will be passed to your callback.
00373
00374 void plm_set_audio_decode_callback(plm_t *self, plm_audio_decode_callback fp, void *user);
00375
00376 // Advance the internal timer by seconds and decode video/audio up to this time.
00377 // This will call the video_decode_callback and audio_decode_callback any number
00378 // of times. A frame-skip is not implemented, i.e. everything up to current time
00379 // will be decoded.
00380
00381 void plm_decode(plm_t *self, double seconds);
00382
00383 // Decode and return one video frame. Returns NULL if no frame could be decoded
00384 // (either because the source ended or data is corrupt). If you only want to
00385 // decode video, you should disable audio via plm_set_audio_enabled().
00386 // The returned plm_frame_t is valid until the next call to plm_decode_video()
00387 // or until plm_destroy() is called.
00388
00389 plm_frame_t *plm_decode_video(plm_t *self);
00390
00391 // Decode and return one audio frame. Returns NULL if no frame could be decoded
00392 // (either because the source ended or data is corrupt). If you only want to
00393 // decode audio, you should disable video via plm_set_video_enabled().
00394 // The returned plm_samples_t is valid until the next call to plm_decode_audio()
00395 // or until plm_destroy() is called.
00396
00397 plm_samples_t *plm_decode_audio(plm_t *self);
00398
00399 // Seek to the specified time, clamped between 0 -- duration. This can only be
00400 // used when the underlying plm_buffer is seekable, i.e. for files, fixed
00401 // memory buffers or _forAppending buffers.
00402 // If seek_exact is TRUE this will seek to the exact time, otherwise it will
00403 // seek to the last intra frame just before the desired time. Exact seeking can
00404 // be slow, because all frames up to the seeked one have to be decoded on top of
00405 // the previous intra frame.
00406 // If seeking succeeds, this function will call the video_decode_callback
00407 // exactly once with the target frame. If audio is enabled, it will also call
00408 // the audio_decode_callback any number of times, until the audio_lead_time is
00409 // satisfied.
00410 // Returns TRUE if seeking succeeded or FALSE if no frame could be found.
00411
00412 int plm_seek(plm_t *self, double time, int seek_exact);
00413
00414 // Similar to plm_seek(), but will not call the video_decode_callback,
00415 // audio_decode_callback or make any attempts to sync audio.
00416 // Returns the found frame or NULL if no frame could be found.
00417
00418 plm_frame_t *plm_seek_frame(plm_t *self, double time, int seek_exact);
00419
00420 // -----
00421 // plm_buffer public API
00422 // Provides the data source for all other plm_* interfaces
00423
00424 // The default size for buffers created from files or by the high-level API
00425
00426 #ifndef PLM_BUFFER_DEFAULT_SIZE
00427 #define PLM_BUFFER_DEFAULT_SIZE (128 * 1024)
00428 #endif
00429
00430 // Create a buffer instance with a filename. Returns NULL if the file could not
00431 // be opened.
00432
00433 plm_buffer_t *plm_buffer_create_with_filename(const char *filename);
00434
00435 // Create a buffer instance with a file handle. Pass TRUE to close_when_done
00436 // to let plmpeg call fclose() on the handle when plm_destroy() is called.
00437
00438 plm_buffer_t *plm_buffer_create_with_file(FIL *fh, int close_when_done);
00439
00440 // Create a buffer instance with a pointer to memory as source. This assumes
00441 // the whole file is in memory. The bytes are not copied. Pass 1 to
00442 // free_when_done to let plmpeg call free() on the pointer when plm_destroy()
00443 // is called.
00444
00445 plm_buffer_t *plm_buffer_create_with_memory(uint8_t *bytes, size_t length, int free_when_done);
00446
00447 // Create an empty buffer with an initial capacity. The buffer will grow
00448 // as needed. Data that has already been read, will be discarded.
00449
00450 plm_buffer_t *plm_buffer_create_with_capacity(size_t capacity);
00451
00452 // Create an empty buffer with an initial capacity. The buffer will grow
00453 // as needed. Decoded data will *not* be discarded. This can be used when

```

```

00454 // loading a file over the network, without needing to throttle the download.
00455 // It also allows for seeking in the already loaded data.
00456
00457 plm_buffer_t *plm_buffer_create_for_appending(size_t initial_capacity);
00458
00459 // Destroy a buffer instance and free all data
00460
00461 void plm_buffer_destroy(plm_buffer_t *self);
00462
00463 // Copy data into the buffer. If the data to be written is larger than the
00464 // available space, the buffer will realloc() with a larger capacity.
00465 // Returns the number of bytes written. This will always be the same as the
00466 // passed in length, except when the buffer was created _with_memory() for
00467 // which _write() is forbidden.
00468
00469 size_t plm_buffer_write(plm_buffer_t *self, uint8_t *bytes, size_t length);
00470
00471 // Mark the current byte length as the end of this buffer and signal that no
00472 // more data is expected to be written to it. This function should be called
00473 // just after the last plm_buffer_write().
00474 // For _with_capacity buffers, this is cleared on a plm_buffer_rewind().
00475
00476 void plm_buffer_signal_end(plm_buffer_t *self);
00477
00478 // Set a callback that is called whenever the buffer needs more data
00479
00480 void plm_buffer_set_load_callback(plm_buffer_t *self, plm_buffer_load_callback fp, void *user);
00481
00482 // Rewind the buffer back to the beginning. When loading from a file handle,
00483 // this also seeks to the beginning of the file.
00484
00485 void plm_buffer_rewind(plm_buffer_t *self);
00486
00487 // Get the total size. For files, this returns the file size. For all other
00488 // types it returns the number of bytes currently in the buffer.
00489
00490 size_t plm_buffer_get_size(plm_buffer_t *self);
00491
00492 // Get the number of remaining (yet unread) bytes in the buffer. This can be
00493 // useful to throttle writing.
00494
00495 size_t plm_buffer_get_remaining(plm_buffer_t *self);
00496
00497 // Get whether the read position of the buffer is at the end and no more data
00498 // is expected.
00499
00500 int plm_buffer_has-ended(plm_buffer_t *self);
00501
00502 // -----
00503 // plm_demux public API
00504 // Demux an MPEG Program Stream (PS) data into separate packages
00505
00506 // Various Packet Types
00507
00508 static const int PLM_DEMUX_PACKET_PRIVATE = 0xBD;
00509 static const int PLM_DEMUX_PACKET_AUDIO_1 = 0xC0;
00510 static const int PLM_DEMUX_PACKET_AUDIO_2 = 0xC1;
00511 static const int PLM_DEMUX_PACKET_AUDIO_3 = 0xC2;
00512 static const int PLM_DEMUX_PACKET_AUDIO_4 = 0xC2;
00513 static const int PLM_DEMUX_PACKET_VIDEO_1 = 0xE0;
00514
00515 // Create a demuxer with a plm_buffer as source. This will also attempt to read
00516 // the pack and system headers from the buffer.
00517
00518 plm_demux_t *plm_demux_create(plm_buffer_t *buffer, int destroy_when_done);
00519
00520 // Destroy a demuxer and free all data.
00521
00522 void plm_demux_destroy(plm_demux_t *self);
00523
00524 // Returns TRUE/FALSE whether pack and system headers have been found. This will
00525 // attempt to read the headers if non are present yet.
00526
00527 int plm_demux_has_headers(plm_demux_t *self);
00528
00529 // Returns the number of video streams found in the system header. This will
00530 // attempt to read the system header if non is present yet.
00531
00532 int plm_demux_get_num_video_streams(plm_demux_t *self);
00533
00534 // Returns the number of audio streams found in the system header. This will
00535 // attempt to read the system header if non is present yet.
00536
00537 int plm_demux_get_num_audio_streams(plm_demux_t *self);
00538
00539 // Rewind the internal buffer. See plm_buffer_rewind().
00540

```

```
00541 void plm_demux_rewind(plm_demux_t *self);
00542
00543 // Get whether the file has ended. This will be cleared on seeking or rewind.
00544
00545 int plm_demux_has-ended(plm_demux_t *self);
00546
00547 // Seek to a packet of the specified type with a PTS just before specified time.
00548 // If force_intra is TRUE, only packets containing an intra frame will be
00549 // considered - this only makes sense when the type is PLM_DEMUX_PACKET_VIDEO_1.
00550 // Note that the specified time is considered 0-based, regardless of the first
00551 // PTS in the data source.
00552
00553 plm_packet_t *plm_demux_seek(plm_demux_t *self, double time, int type, int force_intra);
00554
00555 // Get the PTS of the first packet of this type. Returns PLM_PACKET_INVALID_TS
00556 // if no packet of this packet type can be found.
00557
00558 double plm_demux_get_start_time(plm_demux_t *self, int type);
00559
00560 // Get the duration for the specified packet type - i.e. the span between the
00561 // the first PTS and the last PTS in the data source. This only makes sense when
00562 // the underlying data source is a file or fixed memory.
00563
00564 double plm_demux_get_duration(plm_demux_t *self, int type);
00565
00566 // Decode and return the next packet. The returned packet_t is valid until
00567 // the next call to plm_demux_decode() or until the demuxer is destroyed.
00568
00569 plm_packet_t *plm_demux_decode(plm_demux_t *self);
00570
00571 // -----
00572 // plm_video public API
00573 // Decode MPEG1 Video ("mpeg1") data into raw YCrCb frames
00574
00575 // Create a video decoder with a plm_buffer as source.
00576
00577 plm_video_t *plm_video_create_with_buffer(plm_buffer_t *buffer, int destroy_when_done);
00578
00579 // Destroy a video decoder and free all data.
00580
00581 void plm_video_destroy(plm_video_t *self);
00582
00583 // Get whether a sequence header was found and we can accurately report on
00584 // dimensions and framerate.
00585
00586 int plm_video_has_header(plm_video_t *self);
00587
00588 // Get the framerate in frames per second.
00589
00590 double plm_video_get_framerate(plm_video_t *self);
00591
00592 // Get the display width/height.
00593
00594 int plm_video_get_width(plm_video_t *self);
00595 int plm_video_get_height(plm_video_t *self);
00596
00597 // Set "no delay" mode. When enabled, the decoder assumes that the video does
00598 // *not* contain any B-Frames. This is useful for reducing lag when streaming.
00599 // The default is FALSE.
00600
00601 void plm_video_set_no_delay(plm_video_t *self, int no_delay);
00602
00603 // Get the current internal time in seconds.
00604
00605 double plm_video_get_time(plm_video_t *self);
00606
00607 // Set the current internal time in seconds. This is only useful when you
00608 // manipulate the underlying video buffer and want to enforce a correct
00609 // timestamps.
00610
00611 void plm_video_set_time(plm_video_t *self, double time);
00612
00613 // Rewind the internal buffer. See plm_buffer_rewind().
00614
00615 void plm_video_rewind(plm_video_t *self);
00616
00617 // Get whether the file has ended. This will be cleared on rewind.
00618
00619 int plm_video_has-ended(plm_video_t *self);
00620
00621 // Decode and return one frame of video and advance the internal time by
00622 // 1/framerate seconds. The returned frame_t is valid until the next call of
00623 // plm_video_decode() or until the video decoder is destroyed.
00624
00625 plm_frame_t *plm_video_decode(plm_video_t *self);
00626
00627 // Convert the YCrCb data of a frame into interleaved R G B data. The stride
```

```

00628 // specifies the width in bytes of the destination buffer. I.e. the number of
00629 // bytes from one line to the next. The stride must be at least
00630 // (frame->width * bytes_per_pixel). The buffer pointed to by *dest must have a
00631 // size of at least (stride * frame->height).
00632 // Note that the alpha component of the dest buffer is always left untouched.
00633
00634 void plm_frame_to_rgb(plm_frame_t *frame, uint8_t *dest, int stride);
00635 void plm_frame_to_bgr(plm_frame_t *frame, uint8_t *dest, int stride);
00636 void plm_frame_to_rgba(plm_frame_t *frame, uint8_t *dest, int stride);
00637 void plm_frame_to_bgra(plm_frame_t *frame, uint8_t *dest, int stride);
00638 void plm_frame_to_argb(plm_frame_t *frame, uint8_t *dest, int stride);
00639 void plm_frame_to_abgr(plm_frame_t *frame, uint8_t *dest, int stride);
00640
00641 // -----
00642 // plm_audio public API
00643 // Decode MPEG-1 Audio Layer II ("mp2") data into raw samples
00644
00645 // Create an audio decoder with a plm_buffer as source.
00646
00647 plm_audio_t *plm_audio_create_with_buffer(plm_buffer_t *buffer, int destroy_when_done);
00648
00649 // Destroy an audio decoder and free all data.
00650
00651 void plm_audio_destroy(plm_audio_t *self);
00652
00653 // Get whether a frame header was found and we can accurately report on
00654 // samplerate.
00655
00656 int plm_audio_has_header(plm_audio_t *self);
00657
00658 // Get the samplerate in samples per second.
00659
00660 int plm_audio_get_samplerate(plm_audio_t *self);
00661
00662 // Get the current internal time in seconds.
00663
00664 double plm_audio_get_time(plm_audio_t *self);
00665
00666 // Set the current internal time in seconds. This is only useful when you
00667 // manipulate the underlying video buffer and want to enforce a correct
00668 // timestamps.
00669
00670 void plm_audio_set_time(plm_audio_t *self, double time);
00671
00672 // Rewind the internal buffer. See plm_buffer_rewind().
00673
00674 void plm_audio_rewind(plm_audio_t *self);
00675
00676 // Get whether the file has ended. This will be cleared on rewind.
00677
00678 int plm_audio_has-ended(plm_audio_t *self);
00679
00680 // Decode and return one "frame" of audio and advance the internal time by
00681 // (PLM_AUDIO_SAMPLES_PER_FRAME/samplerate) seconds. The returned samples_t
00682 // is valid until the next call of plm_audio_decode() or until the audio
00683 // decoder is destroyed.
00684
00685 plm_samples_t *plm_audio_decode(plm_audio_t *self);
00686
00687 #ifdef __cplusplus
00688 }
00689 #endif
00690
00691 #endif // PL_MPEG_H
00692
00693 // -----
00694 // -----
00695 // IMPLEMENTATION
00696
00697 #ifdef PL_MPEG_IMPLEMENTATION
00698
00699 #include <stdlib.h>
00700 #include <string.h>
00701
00702 #ifndef TRUE
00703 #define TRUE 1
00704 #define FALSE 0
00705 #endif
00706
00707 #ifndef PLM_MALLOC
00708 #define PLM_MALLOC(sz) malloc(sz)
00709 #define PLM_FREE(p) free(p)
00710 #define PLM_REALLOC(p, sz) realloc(p, sz)
00711 #endif
00712
00713 #define PLM_UNUSED(expr) (void)(expr)
00714

```

```
00715 // -----
00716 // plm (high-level interface) implementation
00717
00718 struct plm_t {
00719     plm_demux_t *demux;
00720     double time;
00721     int has_ended;
00722     int loop;
00723     int has_decoders;
00724
00725     int video_enabled;
00726     int video_packet_type;
00727     plm_buffer_t *video_buffer;
00728     plm_video_t *video_decoder;
00729
00730     int audio_enabled;
00731     int audio_stream_index;
00732     int audio_packet_type;
00733     double audio_lead_time;
00734     plm_buffer_t *audio_buffer;
00735     plm_audio_t *audio_decoder;
00736
00737     plm_video_decode_callback video_decode_callback;
00738     void *video_decode_callback_user_data;
00739
00740     plm_audio_decode_callback audio_decode_callback;
00741     void *audio_decode_callback_user_data;
00742 };
00743
00744 int plm_init_decoders(plm_t *self);
00745 void plm_handle_end(plm_t *self);
00746 void plm_read_video_packet(plm_buffer_t *buffer, void *user);
00747 void plm_read_audio_packet(plm_buffer_t *buffer, void *user);
00748 void plm_read_packets(plm_t *self, int requested_type);
00749
00750 plm_t *plm_create_with_filename(const char *filename) {
00751     plm_buffer_t *buffer = plm_buffer_create_with_filename(filename);
00752     if (!buffer)
00753         return NULL;
00754     }
00755     return plm_create_with_buffer(buffer, TRUE);
00756 }
00757
00758 plm_t *plm_create_with_file(FIL *fh, int close_when_done) {
00759     plm_buffer_t *buffer = plm_buffer_create_with_file(fh, close_when_done);
00760     return plm_create_with_buffer(buffer, TRUE);
00761 }
00762
00763 plm_t *plm_create_with_memory(uint8_t *bytes, size_t length, int free_when_done) {
00764     plm_buffer_t *buffer = plm_buffer_create_with_memory(bytes, length, free_when_done);
00765     return plm_create_with_buffer(buffer, TRUE);
00766 }
00767
00768 plm_t *plm_create_with_buffer(plm_buffer_t *buffer, int destroy_when_done) {
00769     plm_t *self = (plm_t *)PLM_MALLOC(sizeof(plm_t));
00770     memset(self, 0, sizeof(plm_t));
00771
00772     self->demux = plm_demux_create(buffer, destroy_when_done);
00773     self->video_enabled = TRUE;
00774     self->audio_enabled = TRUE;
00775     plm_init_decoders(self);
00776
00777     return self;
00778 }
00779
00780 int plm_init_decoders(plm_t *self) {
00781     if (self->has_decoders)
00782         return TRUE;
00783     }
00784
00785     if (!plm_demux_has_headers(self->demux))
00786         return FALSE;
00787     }
00788
00789     if (plm_demux_get_num_video_streams(self->demux) > 0) {
00790         if (self->video_enabled)
00791             self->video_packet_type = PLM_DEMUX_PACKET_VIDEO_1;
00792         }
00793         self->video_buffer = plm_buffer_create_with_capacity(PLM_BUFFER_DEFAULT_SIZE);
00794         plm_buffer_set_load_callback(self->video_buffer, plm_read_video_packet, self);
00795     }
00796
00797     if (plm_demux_get_num_audio_streams(self->demux) > 0) {
00798         if (self->audio_enabled)
00799             self->audio_packet_type = PLM_DEMUX_PACKET_AUDIO_1 + self->audio_stream_index;
00800         }
00801         self->audio_buffer = plm_buffer_create_with_capacity(PLM_BUFFER_DEFAULT_SIZE);
```

```

00802     plm_buffer_set_load_callback(self->audio_buffer, plm_read_audio_packet, self);
00803 }
00804
00805 if (self->video_buffer) {
00806     self->video_decoder = plm_video_create_with_buffer(self->video_buffer, TRUE);
00807 }
00808
00809 if (self->audio_buffer) {
00810     self->audio_decoder = plm_audio_create_with_buffer(self->audio_buffer, TRUE);
00811 }
00812
00813 self->has_decoders = TRUE;
00814 return TRUE;
00815 }
00816
00817 void plm_destroy(plm_t *self) {
00818     if (self->video_decoder) {
00819         plm_video_destroy(self->video_decoder);
00820     }
00821     if (self->audio_decoder) {
00822         plm_audio_destroy(self->audio_decoder);
00823     }
00824
00825     plm_demux_destroy(self->demux);
00826     PLM_FREE(self);
00827 }
00828
00829 int plm_get_audio_enabled(plm_t *self) { return self->audio_enabled; }
00830
00831 int plm_has_headers(plm_t *self) {
00832     if (!plm_demux_has_headers(self->demux)) {
00833         return FALSE;
00834     }
00835
00836     if (!plm_init_decoders(self)) {
00837         return FALSE;
00838     }
00839
00840     if ((self->video_decoder && !plm_video_has_header(self->video_decoder)) ||
00841         (self->audio_decoder && !plm_audio_has_header(self->audio_decoder))) {
00842         return FALSE;
00843     }
00844
00845     return TRUE;
00846 }
00847
00848 void plm_set_audio_enabled(plm_t *self, int enabled) {
00849     self->audio_enabled = enabled;
00850
00851     if (!enabled) {
00852         self->audio_packet_type = 0;
00853         return;
00854     }
00855
00856     self->audio_packet_type =
00857         (plm_init_decoders(self) && self->audio_decoder) ? PLM_DEMUX_PACKET_AUDIO_1 +
00858         self->audio_stream_index : 0;
00859
00860 void plm_set_audio_stream(plm_t *self, int stream_index) {
00861     if (stream_index < 0 || stream_index > 3) {
00862         return;
00863     }
00864     self->audio_stream_index = stream_index;
00865
00866 // Set the correct audio_packet_type
00867     plm_set_audio_enabled(self, self->audio_enabled);
00868 }
00869
00870 int plm_get_video_enabled(plm_t *self) { return self->video_enabled; }
00871
00872 void plm_set_video_enabled(plm_t *self, int enabled) {
00873     self->video_enabled = enabled;
00874
00875     if (!enabled) {
00876         self->video_packet_type = 0;
00877         return;
00878     }
00879
00880     self->video_packet_type = (plm_init_decoders(self) && self->video_decoder) ?
00881         PLM_DEMUX_PACKET_VIDEO_1 : 0;
00882
00883 int plm_get_num_video_streams(plm_t *self) { return plm_demux_get_num_video_streams(self->demux); }
00884
00885 int plm_get_width(plm_t *self) {
00886     return (plm_init_decoders(self) && self->video_decoder) ? plm_video_get_width(self->video_decoder) :

```

```

0;
00887 }
00888
00889 int plm_get_height(plm_t *self) {
00890     return (plm_init_decoders(self) && self->video_decoder) ? plm_video_get_height(self->video_decoder)
00891 : 0;
00892
00893 double plm_get_framerate(plm_t *self) {
00894     return (plm_init_decoders(self) && self->video_decoder) ?
00895         plm_video_get_framerate(self->video_decoder) : 0;
00896
00897 int plm_get_num_audio_streams(plm_t *self) { return plm_demux_get_num_audio_streams(self->demux); }
00898
00899 int plm_get_samplerate(plm_t *self) {
00900     return (plm_init_decoders(self) && self->audio_decoder) ?
00901         plm_audio_get_samplerate(self->audio_decoder) : 0;
00902
00903 double plm_get_audio_lead_time(plm_t *self) { return self->audio_lead_time; }
00904
00905 void plm_set_audio_lead_time(plm_t *self, double lead_time) { self->audio_lead_time = lead_time; }
00906
00907 double plm_get_time(plm_t *self) { return self->time; }
00908
00909 double plm_get_duration(plm_t *self) { return plm_demux_get_duration(self->demux,
00910     PLM_DEMUX_PACKET_VIDEO_1); }
00911
00912 void plm_rewind(plm_t *self) {
00913     if (self->video_decoder) {
00914         plm_video_rewind(self->video_decoder);
00915
00916     if (self->audio_decoder) {
00917         plm_audio_rewind(self->audio_decoder);
00918     }
00919
00920     plm_demux_rewind(self->demux);
00921     self->time = 0;
00922 }
00923
00924 int plm_get_loop(plm_t *self) { return self->loop; }
00925
00926 void plm_set_loop(plm_t *self, int loop) { self->loop = loop; }
00927
00928 int plm_has-ended(plm_t *self) { return self->has-ended; }
00929
00930 void plm_set_video_decode_callback(plm_t *self, plm_video_decode_callback fp, void *user) {
00931     self->video_decode_callback = fp;
00932     self->video_decode_callback_user_data = user;
00933 }
00934
00935 void plm_set_audio_decode_callback(plm_t *self, plm_audio_decode_callback fp, void *user) {
00936     self->audio_decode_callback = fp;
00937     self->audio_decode_callback_user_data = user;
00938 }
00939
00940 void plm_decode(plm_t *self, double tick) {
00941     if (!plm_init_decoders(self)) {
00942         return;
00943     }
00944
00945     int decode_video = (self->video_decode_callback && self->video_packet_type);
00946     int decode_audio = (self->audio_decode_callback && self->audio_packet_type);
00947
00948     if (!decode_video && !decode_audio) {
00949         // Nothing to do here
00950         return;
00951     }
00952
00953     int did_decode = FALSE;
00954     int decode_video_failed = FALSE;
00955     int decode_audio_failed = FALSE;
00956
00957     double video_target_time = self->time + tick;
00958     double audio_target_time = self->time + tick + self->audio_lead_time;
00959
00960     do {
00961         did_decode = FALSE;
00962
00963         if (decode_video && plm_video_get_time(self->video_decoder) < video_target_time) {
00964             plm_frame_t *frame = plm_video_decode(self->video_decoder);
00965             if (frame) {
00966                 self->video_decode_callback(self, frame, self->video_decode_callback_user_data);
00967                 did_decode = TRUE;
00968             } else {

```

```

00969         decode_video_failed = TRUE;
00970     }
00971 }
00972
00973 if (decode_audio && plm_audio_get_time(self->audio_decoder) < audio_target_time) {
00974     plm_samples_t *samples = plm_audio_decode(self->audio_decoder);
00975     if (samples) {
00976         self->audio_decode_callback(self, samples, self->audio_decode_callback_user_data);
00977         did_decode = TRUE;
00978     } else {
00979         decode_audio_failed = TRUE;
00980     }
00981 }
00982 } while (did_decode);
00983
00984 // Did all sources we wanted to decode fail and the demuxer is at the end?
00985 if ((!decode_video || decode_video_failed) && (!decode_audio || decode_audio_failed) &&
00986     plm_demux_has-ended(self->demux)) {
00987     plm_handle_end(self);
00988     return;
00989 }
00990
00991 self->time += tick;
00992 }
00993
00994 plm_frame_t *plm_decode_video(plm_t *self) {
00995     if (!plm_init_decoders(self)) {
00996         return NULL;
00997     }
00998
00999     if (!self->video_packet_type) {
01000         return NULL;
01001     }
01002
01003     plm_frame_t *frame = plm_video_decode(self->video_decoder);
01004     if (frame) {
01005         self->time = frame->time;
01006     } else if (plm_demux_has-ended(self->demux)) {
01007         plm_handle_end(self);
01008     }
01009     return frame;
01010 }
01011
01012 plm_samples_t *plm_decode_audio(plm_t *self) {
01013     if (!plm_init_decoders(self)) {
01014         return NULL;
01015     }
01016
01017     if (!self->audio_packet_type) {
01018         return NULL;
01019     }
01020
01021     plm_samples_t *samples = plm_audio_decode(self->audio_decoder);
01022     if (samples) {
01023         self->time = samples->time;
01024     } else if (plm_demux_has-ended(self->demux)) {
01025         plm_handle_end(self);
01026     }
01027     return samples;
01028 }
01029
01030 void plm_handle_end(plm_t *self) {
01031     if (self->loop) {
01032         plm_rewind(self);
01033     } else {
01034         self->has-ended = TRUE;
01035     }
01036 }
01037
01038 void plm_read_video_packet(plm_buffer_t *buffer, void *user) {
01039     PLM_UNUSED(buffer);
01040     plm_t *self = (plm_t *)user;
01041     plm_read_packets(self, self->video_packet_type);
01042 }
01043
01044 void plm_read_audio_packet(plm_buffer_t *buffer, void *user) {
01045     PLM_UNUSED(buffer);
01046     plm_t *self = (plm_t *)user;
01047     plm_read_packets(self, self->audio_packet_type);
01048 }
01049
01050 void plm_read_packets(plm_t *self, int requested_type) {
01051     plm_packet_t *packet;
01052     while ((packet = plm_demux_decode(self->demux))) {
01053         if (packet->type == self->video_packet_type) {
01054             plm_buffer_write(self->video_buffer, packet->data, packet->length);
01055         } else if (packet->type == self->audio_packet_type) {

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01056     plm_buffer_write(self->audio_buffer, packet->data, packet->length);
01057 }
01058
01059     if (packet->type == requested_type) {
01060         return;
01061     }
01062 }
01063
01064     if (plm_demux_has-ended(self->demux)) {
01065         if (self->video_buffer) {
01066             plm_buffer_signal_end(self->video_buffer);
01067         }
01068         if (self->audio_buffer) {
01069             plm_buffer_signal_end(self->audio_buffer);
01070         }
01071     }
01072 }
01073
01074 plm_frame_t *plm_seek_frame(plm_t *self, double time, int seek_exact) {
01075     if (!plm_init_decoders(self)) {
01076         return NULL;
01077     }
01078
01079     if (!self->video_packet_type) {
01080         return NULL;
01081     }
01082
01083     int type = self->video_packet_type;
01084
01085     double start_time = plm_demux_get_start_time(self->demux, type);
01086     double duration = plm_demux_get_duration(self->demux, type);
01087
01088     if (time < 0) {
01089         time = 0;
01090     } else if (time > duration) {
01091         time = duration;
01092     }
01093
01094     plm_packet_t *packet = plm_demux_seek(self->demux, time, type, TRUE);
01095     if (!packet) {
01096         return NULL;
01097     }
01098
01099 // Disable writing to the audio buffer while decoding video
01100 int previous_audio_packet_type = self->audio_packet_type;
01101 self->audio_packet_type = 0;
01102
01103 // Clear video buffer and decode the found packet
01104 plm_video_rewind(self->video_decoder);
01105 plm_video_set_time(self->video_decoder, packet->pts - start_time);
01106 plm_buffer_write(self->video_buffer, packet->data, packet->length);
01107 plm_frame_t *frame = plm_video_decode(self->video_decoder);
01108
01109 // If we want to seek to an exact frame, we have to decode all frames
01110 // on top of the intra frame we just jumped to.
01111 if (seek_exact) {
01112     while (frame && frame->time < time) {
01113         frame = plm_video_decode(self->video_decoder);
01114     }
01115 }
01116
01117 // Enable writing to the audio buffer again?
01118 self->audio_packet_type = previous_audio_packet_type;
01119
01120 if (frame) {
01121     self->time = frame->time;
01122 }
01123
01124 self->has-ended = FALSE;
01125 return frame;
01126 }
01127
01128 int plm_seek(plm_t *self, double time, int seek_exact) {
01129     plm_frame_t *frame = plm_seek_frame(self, time, seek_exact);
01130
01131     if (!frame) {
01132         return FALSE;
01133     }
01134
01135     if (self->video_decode_callback) {
01136         self->video_decode_callback(self, frame, self->video_decode_callback_user_data);
01137     }
01138
01139 // If audio is not enabled we are done here.
01140 if (!self->audio_packet_type) {
01141     return TRUE;
01142 }

```

```

01143
01144 // Sync up Audio. This demuxes more packets until the first audio packet
01145 // with a PTS greater than the current time is found. plm_decode() is then
01146 // called to decode enough audio data to satisfy the audio_lead_time.
01147
01148 double start_time = plm_demux_get_start_time(self->demux, self->video_packet_type);
01149 plm_audio_rewind(self->audio_decoder);
01150
01151 plm_packet_t *packet = NULL;
01152 while ((packet = plm_demux_decode(self->demux))) {
01153     if (packet->type == self->video_packet_type) {
01154         plm_buffer_write(self->video_buffer, packet->data, packet->length);
01155     } else if (packet->type == self->audio_packet_type && packet->pts - start_time > self->time) {
01156         plm_audio_set_time(self->audio_decoder, packet->pts - start_time);
01157         plm_buffer_write(self->audio_buffer, packet->data, packet->length);
01158         plm_decode(self, 0);
01159         break;
01160     }
01161 }
01162
01163 return TRUE;
01164 }
01165
01166 // -----
01167 // plm_buffer implementation
01168
01169 enum plm_buffer_mode { PLM_BUFFER_MODE_FILE, PLM_BUFFER_MODE_FIXED_MEM, PLM_BUFFER_MODE_RING,
01170     PLM_BUFFER_MODE_APPEND };
01171 struct plm_buffer_t {
01172     size_t bit_index;
01173     size_t capacity;
01174     size_t length;
01175     size_t total_size;
01176     int discard_read_bytes;
01177     int has-ended;
01178     int free_when_done;
01179     int close_when_done;
01180     FIL *fh;
01181     plm_buffer_load_callback load_callback;
01182     void *load_callback_user_data;
01183     uint8_t *bytes;
01184     enum plm_buffer_mode mode;
01185 };
01186
01187 typedef struct {
01188     int16_t index;
01189     int16_t value;
01190 } plm_vlc_t;
01191
01192 typedef struct {
01193     int16_t index;
01194     uint16_t value;
01195 } plm_vlc_uint_t;
01196
01197 void plm_buffer_seek(plm_buffer_t *self, size_t pos);
01198 size_t plm_buffer_tell(plm_buffer_t *self);
01199 void plm_buffer_discard_read_bytes(plm_buffer_t *self);
01200 void plm_buffer_load_file_callback(plm_buffer_t *self, void *user);
01201
01202 int plm_buffer_has(plm_buffer_t *self, size_t count);
01203 int plm_buffer_read(plm_buffer_t *self, int count);
01204 void plm_buffer_align(plm_buffer_t *self);
01205 void plm_buffer_skip(plm_buffer_t *self, size_t count);
01206 int plm_buffer_skip_bytes(plm_buffer_t *self, uint8_t v);
01207 int plm_buffer_next_start_code(plm_buffer_t *self);
01208 int plm_buffer_find_start_code(plm_buffer_t *self, int code);
01209 int plm_buffer_no_start_code(plm_buffer_t *self);
01210 int16_t plm_buffer_read_vlc(plm_buffer_t *self, const plm_vlc_t *table);
01211 uint16_t plm_buffer_read_vlc_uint(plm_buffer_t *self, const plm_vlc_uint_t *table);
01212
01213 plm_buffer_t *plm_buffer_create_with_filename(const char *filename) {
01214     FIL *fh = vexFileOpen(filename, "rb"); // fopen(filename, "rb");
01215     if (!fh) {
01216         return NULL;
01217     }
01218     return plm_buffer_create_with_file(fh, TRUE);
01219 }
01220
01221 plm_buffer_t *plm_buffer_create_with_file(FIL *fh, int close_when_done) {
01222     plm_buffer_t *self = plm_buffer_create_with_capacity(PLM_BUFFER_DEFAULT_SIZE);
01223     self->fh = fh;
01224     self->close_when_done = close_when_done;
01225     self->mode = PLM_BUFFER_MODE_FILE;
01226     self->discard_read_bytes = TRUE;
01227     vexFileSeek(self->fh, 0, SEEK_END);

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01229     self->total_size = vexFileTell(self->fh);
01230     vexFileSeek(self->fh, 0, SEEK_SET);
01231
01232     plm_buffer_set_load_callback(self, plm_buffer_load_file_callback, NULL);
01233     return self;
01234 }
01235
01236 plm_buffer_t *plm_buffer_create_with_memory(uint8_t *bytes, size_t length, int free_when_done) {
01237     plm_buffer_t *self = (plm_buffer_t *)PLM_MALLOC(sizeof(plm_buffer_t));
01238     memset(self, 0, sizeof(plm_buffer_t));
01239     self->capacity = length;
01240     self->length = length;
01241     self->total_size = length;
01242     self->free_when_done = free_when_done;
01243     self->bytes = bytes;
01244     self->mode = PLM_BUFFER_MODE_FIXED_MEM;
01245     self->discard_read_bytes = FALSE;
01246     return self;
01247 }
01248
01249 plm_buffer_t *plm_buffer_create_with_capacity(size_t capacity) {
01250     plm_buffer_t *self = (plm_buffer_t *)PLM_MALLOC(sizeof(plm_buffer_t));
01251     memset(self, 0, sizeof(plm_buffer_t));
01252     self->capacity = capacity;
01253     self->free_when_done = TRUE;
01254     self->bytes = (uint8_t *)PLM_MALLOC(capacity);
01255     self->mode = PLM_BUFFER_MODE_RING;
01256     self->discard_read_bytes = TRUE;
01257     return self;
01258 }
01259
01260 plm_buffer_t *plm_buffer_create_for_appending(size_t initial_capacity) {
01261     plm_buffer_t *self = plm_buffer_create_with_capacity(initial_capacity);
01262     self->mode = PLM_BUFFER_MODE_APPEND;
01263     self->discard_read_bytes = FALSE;
01264     return self;
01265 }
01266
01267 void plm_buffer_destroy(plm_buffer_t *self) {
01268     if (self->fh && self->close_when_done) {
01269         vexFileClose(self->fh);
01270     }
01271     if (self->free_when_done) {
01272         PLM_FREE(self->bytes);
01273     }
01274     PLM_FREE(self);
01275 }
01276
01277 size_t plm_buffer_get_size(plm_buffer_t *self) {
01278     return (self->mode == PLM_BUFFER_MODE_FILE) ? self->total_size : self->length;
01279 }
01280
01281 size_t plm_buffer_get_remaining(plm_buffer_t *self) { return self->length - (self->bit_index >> 3); }
01282
01283 size_t plm_buffer_write(plm_buffer_t *self, uint8_t *bytes, size_t length) {
01284     if (self->mode == PLM_BUFFER_MODE_FIXED_MEM) {
01285         return 0;
01286     }
01287
01288     if (self->discard_read_bytes) {
01289         // This should be a ring buffer, but instead it just shifts all unread
01290         // data to the beginning of the buffer and appends new data at the end.
01291         // Seems to be good enough.
01292
01293         plm_buffer_discard_read_bytes(self);
01294         if (self->mode == PLM_BUFFER_MODE_RING) {
01295             self->total_size = 0;
01296         }
01297     }
01298
01299     // Do we have to resize to fit the new data?
01300     size_t bytes_available = self->capacity - self->length;
01301     if (bytes_available < length) {
01302         size_t new_size = self->capacity;
01303         do {
01304             new_size *= 2;
01305         } while (new_size - self->length < length);
01306         self->bytes = (uint8_t *)PLM_REALLOC(self->bytes, new_size);
01307         self->capacity = new_size;
01308     }
01309
01310     memcpy(self->bytes + self->length, bytes, length);
01311     self->length += length;
01312     self->has-ended = FALSE;
01313     return length;
01314 }
01315

```

```

01316 void plm_buffer_signal_end(plm_buffer_t *self) { self->total_size = self->length; }
01317
01318 void plm_buffer_set_load_callback(plm_buffer_t *self, plm_buffer_load_callback fp, void *user) {
01319     self->load_callback = fp;
01320     self->load_callback_user_data = user;
01321 }
01322
01323 void plm_buffer_rewind(plm_buffer_t *self) { plm_buffer_seek(self, 0); }
01324
01325 void plm_buffer_seek(plm_buffer_t *self, size_t pos) {
01326     self->hasEnded = FALSE;
01327
01328     if (self->mode == PLM_BUFFER_MODE_FILE) {
01329         vexFileSeek(self->fh, pos, SEEK_SET);
01330         self->bit_index = 0;
01331         self->length = 0;
01332     } else if (self->mode == PLM_BUFFER_MODE_RING) {
01333         if (pos != 0) {
01334             // Seeking to non-0 is forbidden for dynamic-mem buffers
01335             return;
01336         }
01337         self->bit_index = 0;
01338         self->length = 0;
01339         self->total_size = 0;
01340     } else if (pos < self->length) {
01341         self->bit_index = pos << 3;
01342     }
01343 }
01344
01345 size_t plm_buffer_tell(plm_buffer_t *self) {
01346     return self->mode == PLM_BUFFER_MODE_FILE ? vexFileTell(self->fh) + (self->bit_index >> 3) -
01347         self->length
01348                                         : self->bit_index >> 3;
01349 }
01350
01351 void plm_buffer_discard_read_bytes(plm_buffer_t *self) {
01352     size_t byte_pos = self->bit_index >> 3;
01353     if (byte_pos == self->length) {
01354         self->bit_index = 0;
01355         self->length = 0;
01356     } else if (byte_pos > 0) {
01357         memmove(self->bytes, self->bytes + byte_pos, self->length - byte_pos);
01358         self->bit_index -= byte_pos << 3;
01359         self->length -= byte_pos;
01360     }
01361
01362 void plm_buffer_load_file_callback(plm_buffer_t *self, void *user) {
01363     PLM_UNUSED(user);
01364
01365     if (self->discard_read_bytes) {
01366         plm_buffer_discard_read_bytes(self);
01367     }
01368
01369     size_t bytes_available = self->capacity - self->length;
01370     size_t bytes_read = vexFileRead((char *)self->bytes + self->length, 1, bytes_available, self->fh);
01371     self->length += bytes_read;
01372
01373     if (bytes_read == 0) {
01374         self->hasEnded = TRUE;
01375     }
01376 }
01377
01378 int plm_buffer_hasEnded(plm_buffer_t *self) { return self->hasEnded; }
01379
01380 int plm_buffer_has(plm_buffer_t *self, size_t count) {
01381     if (((self->length << 3) - self->bit_index) >= count) {
01382         return TRUE;
01383     }
01384
01385     if (self->load_callback) {
01386         self->load_callback(self, self->load_callback_user_data);
01387
01388         if (((self->length << 3) - self->bit_index) >= count) {
01389             return TRUE;
01390         }
01391     }
01392
01393     if (self->total_size != 0 && self->length == self->total_size) {
01394         self->hasEnded = TRUE;
01395     }
01396     return FALSE;
01397 }
01398
01399 int plm_buffer_read(plm_buffer_t *self, int count) {
01400     if (!plm_buffer_has(self, count)) {
01401         return 0;

```

```
01402 }
01403 int value = 0;
01404 while (count) {
01405     int current_byte = self->bytes[self->bit_index >> 3];
01406     int remaining = 8 - (self->bit_index & 7);           // Remaining bits in byte
01407     int read = remaining < count ? remaining : count; // Bits in self run
01408     int shift = remaining - read;
01409     int mask = (0xff >> (8 - read));
01410
01411     value = (value << read) | ((current_byte & (mask << shift)) >> shift);
01412
01413     self->bit_index += read;
01414     count -= read;
01415 }
01416
01417 return value;
01418
01419
01420 void plm_buffer_align(plm_buffer_t *self) {
01421     self->bit_index = ((self->bit_index + 7) >> 3) << 3; // Align to next byte
01422 }
01423
01424 void plm_buffer_skip(plm_buffer_t *self, size_t count) {
01425     if (plm_buffer_has(self, count)) {
01426         self->bit_index += count;
01427     }
01428 }
01429
01430
01431 int plm_buffer_skip_bytes(plm_buffer_t *self, uint8_t v) {
01432     plm_buffer_align(self);
01433     int skipped = 0;
01434     while (plm_buffer_has(self, 8) && self->bytes[self->bit_index >> 3] == v) {
01435         self->bit_index += 8;
01436         skipped++;
01437     }
01438     return skipped;
01439 }
01440
01441
01442 int plm_buffer_next_start_code(plm_buffer_t *self) {
01443     plm_buffer_align(self);
01444
01445     while (plm_buffer_has(self, (5 << 3))) {
01446         size_t byte_index = (self->bit_index) >> 3;
01447         if (self->bytes[byte_index] == 0x00 && self->bytes[byte_index + 1] == 0x00 &&
01448             self->bytes[byte_index + 2] == 0x01) {
01449             self->bit_index = (byte_index + 4) << 3;
01450             return self->bytes[byte_index + 3];
01451         }
01452         self->bit_index += 8;
01453     }
01454     return -1;
01455 }
01456
01457 int plm_buffer_find_start_code(plm_buffer_t *self, int code) {
01458     int current = 0;
01459     while (TRUE) {
01460         current = plm_buffer_next_start_code(self);
01461         if (current == code || current == -1) {
01462             return current;
01463         }
01464     }
01465 }
01466
01467 int plm_buffer_has_start_code(plm_buffer_t *self, int code) {
01468     size_t previous_bit_index = self->bit_index;
01469     int previous_discard_read_bytes = self->discard_read_bytes;
01470
01471     self->discard_read_bytes = FALSE;
01472     int current = plm_buffer_find_start_code(self, code);
01473
01474     self->bit_index = previous_bit_index;
01475     self->discard_read_bytes = previous_discard_read_bytes;
01476     return current;
01477 }
01478
01479 int plm_buffer_peek_non_zero(plm_buffer_t *self, int bit_count) {
01480     if (!plm_buffer_has(self, bit_count)) {
01481         return FALSE;
01482     }
01483
01484     int val = plm_buffer_read(self, bit_count);
01485     self->bit_index -= bit_count;
01486     return val != 0;
01487 }
```

```

01488 int16_t plm_buffer_read_vlc(plm_buffer_t *self, const plm_vlc_t *table) {
01489     plm_vlc_t state = {0, 0};
01490     do {
01491         state = table[state.index + plm_buffer_read(self, 1)];
01492     } while (state.index > 0);
01493     return state.value;
01494 }
01495 }
01496
01497 uint16_t plm_buffer_read_vlc_uint(plm_buffer_t *self, const plm_vlc_uint_t *table) {
01498     return (uint16_t)plm_buffer_read_vlc(self, (const plm_vlc_t *)table);
01499 }
01500
01501 // -----
01502 // plm_demux implementation
01503
01504 static const int PLM_START_PACK = 0xBA;
01505 static const int PLM_START_END = 0xB9;
01506 static const int PLM_START_SYSTEM = 0xBB;
01507
01508 struct plm_demux_t {
01509     plm_buffer_t *buffer;
01510     int destroy_buffer_when_done;
01511     double system_clock_ref;
01512
01513     size_t last_file_size;
01514     double last_decoded_pts;
01515     double start_time;
01516     double duration;
01517
01518     int start_code;
01519     int has_pack_header;
01520     int has_system_header;
01521     int has_headers;
01522
01523     int num_audio_streams;
01524     int num_video_streams;
01525     plm_packet_t current_packet;
01526     plm_packet_t next_packet;
01527 };
01528
01529 void plm_demux_buffer_seek(plm_demux_t *self, size_t pos);
01530 double plm_demux_decode_time(plm_demux_t *self);
01531 plm_packet_t *plm_demux_decode_packet(plm_demux_t *self, int type);
01532 plm_packet_t *plm_demux_get_packet(plm_demux_t *self);
01533
01534 plm_demux_t *plm_demux_create(plm_buffer_t *buffer, int destroy_when_done) {
01535     plm_demux_t *self = (plm_demux_t *)PLM_MALLOC(sizeof(plm_demux_t));
01536     memset(self, 0, sizeof(plm_demux_t));
01537
01538     self->buffer = buffer;
01539     self->destroy_buffer_when_done = destroy_when_done;
01540
01541     self->start_time = PLM_PACKET_INVALID_TS;
01542     self->duration = PLM_PACKET_INVALID_TS;
01543     self->start_code = -1;
01544
01545     plm_demux_has_headers(self);
01546     return self;
01547 }
01548
01549 void plm_demux_destroy(plm_demux_t *self) {
01550     if (self->destroy_buffer_when_done) {
01551         plm_buffer_destroy(self->buffer);
01552     }
01553     PLM_FREE(self);
01554 }
01555
01556 int plm_demux_has_headers(plm_demux_t *self) {
01557     if (self->has_headers) {
01558         return TRUE;
01559     }
01560
01561     // Decode pack header
01562     if (!self->has_pack_header) {
01563         if (self->start_code != PLM_START_PACK && plm_buffer_find_start_code(self->buffer, PLM_START_PACK)
01564 == -1) {
01565             return FALSE;
01566         }
01567         self->start_code = PLM_START_PACK;
01568         if (!plm_buffer_has(self->buffer, 64)) {
01569             return FALSE;
01570         }
01571         self->start_code = -1;
01572         if (plm_buffer_read(self->buffer, 4) != 0x02) {

```

```

01574     return FALSE;
01575 }
01576
01577     self->system_clock_ref = plm_demux_decode_time(self);
01578     plm_buffer_skip(self->buffer, 1);
01579     plm_buffer_skip(self->buffer, 22); // mux_rate * 50
01580     plm_buffer_skip(self->buffer, 1);
01581
01582     self->has_pack_header = TRUE;
01583 }
01584
01585 // Decode system header
01586 if (!self->has_system_header) {
01587     if (self->start_code != PLM_START_SYSTEM && plm_buffer_find_start_code(self->buffer,
01588         PLM_START_SYSTEM) == -1) {
01589         return FALSE;
01590     }
01591     self->start_code = PLM_START_SYSTEM;
01592     if (!plm_buffer_has(self->buffer, 56)) {
01593         return FALSE;
01594     }
01595     self->start_code = -1;
01596
01597     plm_buffer_skip(self->buffer, 16); // header_length
01598     plm_buffer_skip(self->buffer, 24); // rate bound
01599     self->num_audio_streams = plm_buffer_read(self->buffer, 6);
01600     plm_buffer_skip(self->buffer, 5); // misc flags
01601     self->num_video_streams = plm_buffer_read(self->buffer, 5);
01602
01603     self->has_system_header = TRUE;
01604 }
01605
01606     self->has_headers = TRUE;
01607     return TRUE;
01608 }
01609
01610 int plm_demux_get_num_video_streams(plm_demux_t *self) {
01611     return plm_demux_has_headers(self) ? self->num_video_streams : 0;
01612 }
01613
01614 int plm_demux_get_num_audio_streams(plm_demux_t *self) {
01615     return plm_demux_has_headers(self) ? self->num_audio_streams : 0;
01616 }
01617
01618 void plm_demux_rewind(plm_demux_t *self) {
01619     plm_buffer_rewind(self->buffer);
01620     self->current_packet.length = 0;
01621     self->next_packet.length = 0;
01622     self->start_code = -1;
01623 }
01624
01625 int plm_demux_has-ended(plm_demux_t *self) { return plm_buffer_has-ended(self->buffer); }
01626
01627 void plm_demux_buffer_seek(plm_demux_t *self, size_t pos) {
01628     plm_buffer_seek(self->buffer, pos);
01629     self->current_packet.length = 0;
01630     self->next_packet.length = 0;
01631     self->start_code = -1;
01632 }
01633
01634 double plm_demux_get_start_time(plm_demux_t *self, int type) {
01635     if (self->start_time != PLM_PACKET_INVALID_TS) {
01636         return self->start_time;
01637     }
01638
01639     int previous_pos = plm_buffer_tell(self->buffer);
01640     int previous_start_code = self->start_code;
01641
01642     // Find first video PTS
01643     plm_demux_rewind(self);
01644     do {
01645         plm_packet_t *packet = plm_demux_decode(self);
01646         if (!packet) {
01647             break;
01648         }
01649         if (packet->type == type) {
01650             self->start_time = packet->pts;
01651         }
01652     } while (self->start_time == PLM_PACKET_INVALID_TS);
01653
01654     plm_demux_buffer_seek(self, previous_pos);
01655     self->start_code = previous_start_code;
01656     return self->start_time;
01657 }
01658
01659 double plm_demux_get_duration(plm_demux_t *self, int type) {

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01660     size_t file_size = plm_buffer_get_size(self->buffer);
01661
01662     if (self->duration != PLM_PACKET_INVALID_TS && self->last_file_size == file_size) {
01663         return self->duration;
01664     }
01665
01666     size_t previous_pos = plm_buffer_tell(self->buffer);
01667     int previous_start_code = self->start_code;
01668
01669     // Find last video PTS. Start searching 64kb from the end and go further
01670     // back if needed.
01671     long start_range = 64 * 1024;
01672     long max_range = 4096 * 1024;
01673     for (long range = start_range; range <= max_range; range *= 2) {
01674         long seek_pos = file_size - range;
01675         if (seek_pos < 0) {
01676             seek_pos = 0;
01677             range = max_range; // Make sure to bail after this round
01678         }
01679         plm_demux_buffer_seek(self, seek_pos);
01680         self->current_packet.length = 0;
01681
01682         double last_pts = PLM_PACKET_INVALID_TS;
01683         plm_packet_t *packet = NULL;
01684         while ((packet = plm_demux_decode(self))) {
01685             if (packet->pts != PLM_PACKET_INVALID_TS && packet->type == type) {
01686                 last_pts = packet->pts;
01687             }
01688         }
01689         if (last_pts != PLM_PACKET_INVALID_TS) {
01690             self->duration = last_pts - plm_demux_get_start_time(self, type);
01691             break;
01692         }
01693     }
01694
01695     plm_demux_buffer_seek(self, previous_pos);
01696     self->start_code = previous_start_code;
01697     self->last_file_size = file_size;
01698     return self->duration;
01699 }
01700
01701 plm_packet_t *plm_demux_seek(plm_demux_t *self, double seek_time, int type, int force_intra) {
01702     if (!plm_demux_has_headers(self)) {
01703         return NULL;
01704     }
01705
01706     // Using the current time, current byte position and the average bytes per
01707     // second for this file, try to jump to a byte position that hopefully has
01708     // packets containing timestamps within one second before to the desired
01709     // seek_time.
01710
01711     // If we hit close to the seek_time scan through all packets to find the
01712     // last one (just before the seek_time) containing an intra frame.
01713     // Otherwise we should at least be closer than before. Calculate the bytes
01714     // per second for the jumped range and jump again.
01715
01716     // The number of retries here is hard-limited to a generous amount. Usually
01717     // the correct range is found after 1--5 jumps, even for files with very
01718     // variable bitrates. If significantly more jumps are needed, there's
01719     // probably something wrong with the file and we just avoid getting into an
01720     // infinite loop. 32 retries should be enough for anybody.
01721
01722     double duration = plm_demux_get_duration(self, type);
01723     long file_size = plm_buffer_get_size(self->buffer);
01724     long byterate = file_size / duration;
01725
01726     double cur_time = self->last_decoded_pts;
01727     double scan_span = 1;
01728
01729     if (seek_time > duration) {
01730         seek_time = duration;
01731     } else if (seek_time < 0) {
01732         seek_time = 0;
01733     }
01734     seek_time += self->start_time;
01735
01736     for (int retry = 0; retry < 32; retry++) {
01737         int found_packet_with_pts = FALSE;
01738         int found_packet_in_range = FALSE;
01739         long last_valid_packet_start = -1;
01740         double first_packet_time = PLM_PACKET_INVALID_TS;
01741
01742         long cur_pos = plm_buffer_tell(self->buffer);
01743
01744         // Estimate byte offset and jump to it.
01745         long offset = (seek_time - cur_time - scan_span) * byterate;
01746         long seek_pos = cur_pos + offset;

```

```

01747     if (seek_pos < 0) {
01748         seek_pos = 0;
01749     } else if (seek_pos > file_size - 256) {
01750         seek_pos = file_size - 256;
01751     }
01752
01753     plm_demux_buffer_seek(self, seek_pos);
01754
01755     // Scan through all packets up to the seek_time to find the last packet
01756     // containing an intra frame.
01757     while (plm_buffer_find_start_code(self->buffer, type) != -1) {
01758         long packet_start = plm_buffer_tell(self->buffer);
01759         plm_packet_t *packet = plm_demux_decode_packet(self, type);
01760
01761         // Skip packet if it has no PTS
01762         if (!packet || packet->pts == PLM_PACKET_INVALID_TS) {
01763             continue;
01764         }
01765
01766         // Bail scanning through packets if we hit one that is outside
01767         // seek_time - scan_span.
01768         // We also adjust the cur_time and byterate values here so the next
01769         // iteration can be a bit more precise.
01770         if (packet->pts > seek_time || packet->pts < seek_time - scan_span) {
01771             found_packet_with_pts = TRUE;
01772             byterate = (seek_pos - cur_pos) / (packet->pts - cur_time);
01773             cur_time = packet->pts;
01774             break;
01775         }
01776
01777         // If we are still here, it means this packet is in close range to
01778         // the seek_time. If this is the first packet for this jump position
01779         // record the PTS. If we later have to back off, when there was no
01780         // intra frame in this range, we can lower the seek_time to not scan
01781         // this range again.
01782         if (!found_packet_in_range) {
01783             found_packet_in_range = TRUE;
01784             first_packet_time = packet->pts;
01785         }
01786
01787         // Check if this is an intra frame packet. If so, record the buffer
01788         // position of the start of this packet. We want to jump back to it
01789         // later, when we know it's the last intra frame before desired
01790         // seek time.
01791         if (force_intra) {
01792             for (size_t i = 0; i < packet->length - 6; i++) {
01793                 // Find the START_PICTURE code
01794                 if (packet->data[i] == 0x00 && packet->data[i + 1] == 0x00 && packet->data[i + 2] == 0x01 &&
01795                     packet->data[i + 3] == 0x00) {
01796                     // Bits 11--13 in the picture header contain the frame
01797                     // type, where 1=Intra
01798                     if ((packet->data[i + 5] & 0x38) == 8) {
01799                         last_valid_packet_start = packet_start;
01800                     }
01801                     break;
01802                 }
01803             }
01804         }
01805
01806         // If we don't want intra frames, just use the last PTS found.
01807         else {
01808             last_valid_packet_start = packet_start;
01809         }
01810     }
01811
01812     // If there was at least one intra frame in the range scanned above,
01813     // our search is over. Jump back to the packet and decode it again.
01814     if (last_valid_packet_start != -1) {
01815         plm_demux_buffer_seek(self, last_valid_packet_start);
01816         return plm_demux_decode_packet(self, type);
01817     }
01818
01819     // If we hit the right range, but still found no intra frame, we have
01820     // to increase the scan_span. This is done exponentially to also handle
01821     // video files with very few intra frames.
01822     else if (found_packet_in_range) {
01823         scan_span *= 2;
01824         seek_time = first_packet_time;
01825     }
01826
01827     // If we didn't find any packet with a PTS, it probably means we reached
01828     // the end of the file. Estimate byterate and cur_time accordingly.
01829     else if (!found_packet_with_pts) {
01830         byterate = (seek_pos - cur_pos) / (duration - cur_time);
01831         cur_time = duration;
01832     }
01833 }

```

```

01834
01835     return NULL;
01836 }
01837
01838 plm_packet_t *plm_demux_decode(plm_demux_t *self) {
01839     if (!plm_demux_has_headers(self)) {
01840         return NULL;
01841     }
01842
01843     if (self->current_packet.length) {
01844         size_t bits_till_next_packet = self->current_packet.length << 3;
01845         if (!plm_buffer_has(self->buffer, bits_till_next_packet)) {
01846             return NULL;
01847         }
01848         plm_buffer_skip(self->buffer, bits_till_next_packet);
01849         self->current_packet.length = 0;
01850     }
01851
01852     // Pending packet waiting for data?
01853     if (self->next_packet.length) {
01854         return plm_demux_get_packet(self);
01855     }
01856
01857     // Pending packet waiting for header?
01858     if (self->start_code != -1) {
01859         return plm_demux_decode_packet(self, self->start_code);
01860     }
01861
01862     do {
01863         self->start_code = plm_buffer_next_start_code(self->buffer);
01864         if (self->start_code == PLM_DEMUX_PACKET_VIDEO_1 || self->start_code == PLM_DEMUX_PACKET_PRIVATE
01865         ||
01866             (self->start_code >= PLM_DEMUX_PACKET_AUDIO_1 && self->start_code <=
01867             PLM_DEMUX_PACKET_AUDIO_4)) {
01868             return plm_demux_decode_packet(self, self->start_code);
01869         }
01870     } while (self->start_code != -1);
01871
01872     return NULL;
01873 }
01874
01875 double plm_demux_decode_time(plm_demux_t *self) {
01876     int64_t clock = plm_buffer_read(self->buffer, 3) << 30;
01877     plm_buffer_skip(self->buffer, 1);
01878     clock |= plm_buffer_read(self->buffer, 15) << 15;
01879     plm_buffer_skip(self->buffer, 1);
01880     clock |= plm_buffer_read(self->buffer, 15);
01881     plm_buffer_skip(self->buffer, 1);
01882     return (double)clock / 90000.0;
01883 }
01884
01885 plm_packet_t *plm_demux_decode_packet(plm_demux_t *self, int type) {
01886     if (!plm_buffer_has(self->buffer, 16 << 3)) {
01887         return NULL;
01888     }
01889
01890     self->start_code = -1;
01891
01892     self->next_packet.type = type;
01893     self->next_packet.length = plm_buffer_read(self->buffer, 16);
01894     self->next_packet.length -= plm_buffer_skip_bytes(self->buffer, 0xff); // stuffing
01895
01896     // skip P-STD
01897     if (plm_buffer_read(self->buffer, 2) == 0x01) {
01898         plm_buffer_skip(self->buffer, 16);
01899         self->next_packet.length -= 2;
01900     }
01901
01902     int pts_dts_marker = plm_buffer_read(self->buffer, 2);
01903     if (pts_dts_marker == 0x03) {
01904         self->next_packet.pts = plm_demux_decode_time(self);
01905         self->last_decoded_pts = self->next_packet.pts;
01906         plm_buffer_skip(self->buffer, 40); // skip dts
01907         self->next_packet.length -= 10;
01908     } else if (pts_dts_marker == 0x02) {
01909         self->next_packet.pts = plm_demux_decode_time(self);
01910         self->last_decoded_pts = self->next_packet.pts;
01911         self->next_packet.length -= 5;
01912     } else if (pts_dts_marker == 0x00) {
01913         self->next_packet.pts = PLM_PACKET_INVALID_TS;
01914         plm_buffer_skip(self->buffer, 4);
01915         self->next_packet.length -= 1;
01916     } else {
01917         return NULL; // invalid
01918     }
01919
01920     return plm_demux_get_packet(self);

```

```

01919 }
01920
01921 plm_packet_t *plm_demux_get_packet(plm_demux_t *self) {
01922     if (!plm_buffer_has(self->buffer, self->next_packet.length << 3)) {
01923         return NULL;
01924     }
01925
01926     self->current_packet.data = self->buffer->bytes + (self->buffer->bit_index >> 3);
01927     self->current_packet.length = self->next_packet.length;
01928     self->current_packet.type = self->next_packet.type;
01929     self->current_packet.pts = self->next_packet.pts;
01930
01931     self->next_packet.length = 0;
01932     return &self->current_packet;
01933 }
01934
01935 // -----
01936 // plm_video implementation
01937
01938 // Inspired by Java MPEG-1 Video Decoder and Player by Zoltan Korandi
01939 // https://sourceforge.net/projects/javampeg1video/
01940
01941 static const int PLM_VIDEO_PICTURE_TYPE_INTRA = 1;
01942 static const int PLM_VIDEO_PICTURE_TYPE_PREDICTIVE = 2;
01943 static const int PLM_VIDEO_PICTURE_TYPE_B = 3;
01944
01945 static const int PLM_START_SEQUENCE = 0xB3;
01946 static const int PLM_START_SLICE_FIRST = 0x01;
01947 static const int PLM_START_SLICE_LAST = 0xAF;
01948 static const int PLM_START_PICTURE = 0x00;
01949 static const int PLM_START_EXTENSION = 0xB5;
01950 static const int PLM_START_USER_DATA = 0xB2;
01951
01952 #define PLM_START_IS_SLICE(c) (c >= PLM_START_SLICE_FIRST && c <= PLM_START_SLICE_LAST)
01953
01954 static const double PLM_VIDEO_PICTURE_RATE[] = {0.000, 23.976, 24.000, 25.000, 29.970, 30.000,
01955 50.000, 59.940,
01956 60.000, 0.000, 0.000, 0.000, 0.000, 0.000, 0.000,
0.000};
01957
01958 static const uint8_t PLM_VIDEO_ZIG_ZAG[] = {0, 1, 8, 16, 9, 2, 3, 10, 17, 24, 32, 25, 18, 11, 4,
01959 5,
01960 12, 19, 26, 33, 40, 48, 41, 34, 27, 20, 13, 6, 7, 14,
01961 21, 28,
01962 35, 42, 49, 56, 57, 50, 43, 36, 29, 22, 15, 23, 30, 37,
01963 44, 51,
01964 58, 59, 52, 45, 38, 31, 39, 46, 53, 60, 61, 54, 47, 55,
01965 62, 63};
01966
01967 static const uint8_t PLM_VIDEO_INTRA_QUANT_MATRIX[] = {8, 16, 19, 22, 26, 27, 29, 34, 16, 16, 22, 24,
01968 27, 29, 34, 37,
01969 19, 22, 26, 27, 29, 34, 34, 38, 22, 22, 26, 27,
01970 29, 34, 37, 40,
01971 22, 26, 27, 29, 32, 35, 40, 48, 26, 27, 29, 32,
01972 35, 40, 48, 58,
01973 26, 27, 29, 34, 38, 46, 56, 69, 27, 29, 35, 38,
01974 46, 56, 69, 83};
01975
01976 static const uint8_t PLM_VIDEO_NON_INTRA_QUANT_MATRIX[] = {
01977 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16,
01978 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16,
01979 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16};
01980
01981 static const uint8_t PLM_VIDEO_PREMULTIPLIER_MATRIX[] = {32, 44, 42, 38, 32, 25, 17, 9, 44, 62, 58,
01982 52, 44, 35, 24, 12,
01983 42, 58, 55, 49, 42, 33, 23, 12, 38, 52, 49,
01984 44, 38, 30, 20, 10,
01985 32, 44, 42, 38, 32, 25, 17, 9, 25, 35, 33,
01986 30, 25, 20, 14, 7,
01987 17, 24, 23, 20, 17, 14, 9, 5, 9, 12, 12,
01988 10, 9, 7, 5, 2};
01989
01990 static const plm_vlc_t PLM_VIDEO_MACROBLOCK_ADDRESS_INCREMENT[] = {
01991 {1 << 1, 0}, {0, 1}, // 0: x
01992 {2 << 1, 0}, {3 << 1, 0}, // 1: 0x
01993 {4 << 1, 0}, {5 << 1, 0}, // 2: 00x
01994 {0, 3}, {0, 2}, // 3: 01x
01995 {6 << 1, 0}, {7 << 1, 0}, // 4: 000x
01996 {0, 5}, {0, 4}, // 5: 001x
01997 {8 << 1, 0}, {9 << 1, 0}, // 6: 0000x
01998 {0, 7}, {0, 6}, // 7: 0001x
01999 {10 << 1, 0}, {11 << 1, 0}, // 8: 0000 0x
02000 {12 << 1, 0}, {13 << 1, 0}, // 9: 0000 1x
02001 {14 << 1, 0}, {15 << 1, 0}, // 10: 0000 00x
02002 {16 << 1, 0}, {17 << 1, 0}, // 11: 0000 01x
02003 {18 << 1, 0}, {19 << 1, 0}, // 12: 0000 10x
02004 {0, 9}, {0, 8}, // 13: 0000 11x

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01992 {-1, 0}, {20 « 1, 0}, // 14: 0000 000x
01993 {-1, 0}, {21 « 1, 0}, // 15: 0000 001x
01994 {22 « 1, 0}, {23 « 1, 0}, // 16: 0000 010x
01995 {0, 15}, {0, 14}, // 17: 0000 011x
01996 {0, 13}, {0, 12}, // 18: 0000 100x
01997 {0, 11}, {0, 10}, // 19: 0000 101x
01998 {24 « 1, 0}, {25 « 1, 0}, // 20: 0000 0001x
01999 {26 « 1, 0}, {27 « 1, 0}, // 21: 0000 0011x
02000 {28 « 1, 0}, {29 « 1, 0}, // 22: 0000 0100x
02001 {30 « 1, 0}, {31 « 1, 0}, // 23: 0000 0101x
02002 {32 « 1, 0}, {-1, 0}, // 24: 0000 0001 0x
02003 {-1, 0}, {33 « 1, 0}, // 25: 0000 0001 1x
02004 {34 « 1, 0}, {35 « 1, 0}, // 26: 0000 0011 0x
02005 {36 « 1, 0}, {37 « 1, 0}, // 27: 0000 0011 1x
02006 {38 « 1, 0}, {39 « 1, 0}, // 28: 0000 0100 0x
02007 {0, 21}, {0, 20}, // 29: 0000 0100 1x
02008 {0, 19}, {0, 18}, // 30: 0000 0101 0x
02009 {0, 17}, {0, 16}, // 31: 0000 0101 1x
02010 {0, 35}, {-1, 0}, // 32: 0000 0001 00x
02011 {-1, 0}, {0, 34}, // 33: 0000 0001 11x
02012 {0, 33}, {0, 32}, // 34: 0000 0011 00x
02013 {0, 31}, {0, 30}, // 35: 0000 0011 01x
02014 {0, 29}, {0, 28}, // 36: 0000 0011 10x
02015 {0, 27}, {0, 26}, // 37: 0000 0011 11x
02016 {0, 25}, {0, 24}, // 38: 0000 0100 00x
02017 {0, 23}, {0, 22}, // 39: 0000 0100 01x
02018 };
02019
02020 static const plm_vlc_t PLM_VIDEO_MACROBLOCK_TYPE_INTRA[] = {
02021 {1 « 1, 0},
02022 {0, 0x01}, // 0: x
02023 {-1, 0},
02024 {0, 0x11}, // 1: 0x
02025 };
02026
02027 static const plm_vlc_t PLM_VIDEO_MACROBLOCK_TYPE_PREDICTIVE[] = {
02028 {1 « 1, 0}, {0, 0x0a}, // 0: x
02029 {2 « 1, 0}, {0, 0x02}, // 1: 0x
02030 {3 « 1, 0}, {0, 0x08}, // 2: 00x
02031 {4 « 1, 0}, {15 « 1, 0}, // 3: 000x
02032 {6 « 1, 0}, {0, 0x12}, // 4: 0000x
02033 {0, 0x1a}, {0, 0x01}, // 5: 0001x
02034 {-1, 0}, {0, 0x11}, // 6: 0000 0x
02035 };
02036
02037 static const plm_vlc_t PLM_VIDEO_MACROBLOCK_TYPE_B[] = {
02038 {1 « 1, 0}, {2 « 1, 0}, // 0: x
02039 {3 « 1, 0}, {4 « 1, 0}, // 1: 0x
02040 {0, 0x0c}, {0, 0xe}, // 2: 1x
02041 {5 « 1, 0}, {6 « 1, 0}, // 3: 00x
02042 {0, 0x04}, {0, 0x06}, // 4: 01x
02043 {7 « 1, 0}, {8 « 1, 0}, // 5: 000x
02044 {0, 0x08}, {0, 0xa}, // 6: 001x
02045 {9 « 1, 0}, {10 « 1, 0}, // 7: 0000x
02046 {0, 0x1e}, {0, 0x01}, // 8: 0001x
02047 {-1, 0}, {0, 0x11}, // 9: 0000 0x
02048 {0, 0x16}, {0, 0x1a}, // 10: 0000 1x
02049 };
02050
02051 static const plm_vlc_t *PLM_VIDEO_MACROBLOCK_TYPE[] = {
02052 NUL, PLM_VIDEO_MACROBLOCK_TYPE_INTRA, PLM_VIDEO_MACROBLOCK_TYPE_PREDICTIVE,
PLM_VIDEO_MACROBLOCK_TYPE_B};
02053
02054 static const plm_vlc_t PLM_VIDEO_CODE_BLOCK_PATTERN[] = {
02055 {1 « 1, 0}, {2 « 1, 0}, // 0: x
02056 {3 « 1, 0}, {4 « 1, 0}, // 1: 0x
02057 {5 « 1, 0}, {6 « 1, 0}, // 2: 1x
02058 {7 « 1, 0}, {8 « 1, 0}, // 3: 00x
02059 {9 « 1, 0}, {10 « 1, 0}, // 4: 01x
02060 {11 « 1, 0}, {12 « 1, 0}, // 5: 10x
02061 {13 « 1, 0}, {0, 60}, // 6: 11x
02062 {14 « 1, 0}, {15 « 1, 0}, // 7: 000x
02063 {16 « 1, 0}, {17 « 1, 0}, // 8: 001x
02064 {18 « 1, 0}, {19 « 1, 0}, // 9: 010x
02065 {20 « 1, 0}, {21 « 1, 0}, // 10: 011x
02066 {22 « 1, 0}, {23 « 1, 0}, // 11: 100x
02067 {0, 32}, {0, 16}, // 12: 101x
02068 {0, 8}, {0, 4}, // 13: 110x
02069 {24 « 1, 0}, {25 « 1, 0}, // 14: 0000x
02070 {26 « 1, 0}, {27 « 1, 0}, // 15: 0001x
02071 {28 « 1, 0}, {29 « 1, 0}, // 16: 0010x
02072 {30 « 1, 0}, {31 « 1, 0}, // 17: 0011x
02073 {0, 62}, {0, 2}, // 18: 0100x
02074 {0, 61}, {0, 1}, // 19: 0101x
02075 {0, 56}, {0, 52}, // 20: 0110x
02076 {0, 44}, {0, 28}, // 21: 0111x
02077 {0, 40}, {0, 20}, // 22: 1000x

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02078 {0, 48}, {0, 12}, // 23: 1001x
02079 {32 « 1, 0}, {33 « 1, 0}, // 24: 0000 0x
02080 {34 « 1, 0}, {35 « 1, 0}, // 25: 0000 1x
02081 {36 « 1, 0}, {37 « 1, 0}, // 26: 0001 0x
02082 {38 « 1, 0}, {39 « 1, 0}, // 27: 0001 1x
02083 {40 « 1, 0}, {41 « 1, 0}, // 28: 0010 0x
02084 {42 « 1, 0}, {43 « 1, 0}, // 29: 0010 1x
02085 {0, 63}, {0, 3}, // 30: 0011 0x
02086 {0, 36}, {0, 24}, // 31: 0011 1x
02087 {44 « 1, 0}, {45 « 1, 0}, // 32: 0000 00x
02088 {46 « 1, 0}, {47 « 1, 0}, // 33: 0000 01x
02089 {48 « 1, 0}, {49 « 1, 0}, // 34: 0000 10x
02090 {50 « 1, 0}, {51 « 1, 0}, // 35: 0000 11x
02091 {52 « 1, 0}, {53 « 1, 0}, // 36: 0001 00x
02092 {54 « 1, 0}, {55 « 1, 0}, // 37: 0001 01x
02093 {56 « 1, 0}, {57 « 1, 0}, // 38: 0001 10x
02094 {58 « 1, 0}, {59 « 1, 0}, // 39: 0001 11x
02095 {0, 34}, {0, 18}, // 40: 0010 00x
02096 {0, 10}, {0, 6}, // 41: 0010 01x
02097 {0, 33}, {0, 17}, // 42: 0010 10x
02098 {0, 9}, {0, 5}, // 43: 0010 11x
02099 {-1, 0}, {60 « 1, 0}, // 44: 0000 000x
02100 {61 « 1, 0}, {62 « 1, 0}, // 45: 0000 001x
02101 {0, 58}, {0, 54}, // 46: 0000 010x
02102 {0, 46}, {0, 30}, // 47: 0000 011x
02103 {0, 57}, {0, 53}, // 48: 0000 100x
02104 {0, 45}, {0, 29}, // 49: 0000 101x
02105 {0, 38}, {0, 26}, // 50: 0000 110x
02106 {0, 37}, {0, 25}, // 51: 0000 111x
02107 {0, 43}, {0, 23}, // 52: 0001 000x
02108 {0, 51}, {0, 15}, // 53: 0001 001x
02109 {0, 42}, {0, 22}, // 54: 0001 010x
02110 {0, 50}, {0, 14}, // 55: 0001 011x
02111 {0, 41}, {0, 21}, // 56: 0001 100x
02112 {0, 49}, {0, 13}, // 57: 0001 101x
02113 {0, 35}, {0, 19}, // 58: 0001 110x
02114 {0, 11}, {0, 7}, // 59: 0001 111x
02115 {0, 39}, {0, 27}, // 60: 0000 0001x
02116 {0, 59}, {0, 55}, // 61: 0000 0010x
02117 {0, 47}, {0, 31}, // 62: 0000 0011x
02118 };
02119
02120 static const plm_vlc_t PLM_VIDEO_MOTION[] = {
02121 {1 « 1, 0}, {0, 0}, // 0: x
02122 {2 « 1, 0}, {3 « 1, 0}, // 1: 0x
02123 {4 « 1, 0}, {5 « 1, 0}, // 2: 00x
02124 {0, 1}, {0, -1}, // 3: 01x
02125 {6 « 1, 0}, {7 « 1, 0}, // 4: 000x
02126 {0, 2}, {0, -2}, // 5: 001x
02127 {8 « 1, 0}, {9 « 1, 0}, // 6: 0000x
02128 {0, 3}, {0, -3}, // 7: 0001x
02129 {10 « 1, 0}, {11 « 1, 0}, // 8: 0000 0x
02130 {12 « 1, 0}, {13 « 1, 0}, // 9: 0000 1x
02131 {-1, 0}, {14 « 1, 0}, // 10: 0000 00x
02132 {15 « 1, 0}, {16 « 1, 0}, // 11: 0000 01x
02133 {17 « 1, 0}, {18 « 1, 0}, // 12: 0000 10x
02134 {0, 4}, {0, -4}, // 13: 0000 11x
02135 {-1, 0}, {19 « 1, 0}, // 14: 0000 001x
02136 {20 « 1, 0}, {21 « 1, 0}, // 15: 0000 010x
02137 {0, 7}, {0, -7}, // 16: 0000 011x
02138 {0, 6}, {0, -6}, // 17: 0000 100x
02139 {0, 5}, {0, -5}, // 18: 0000 101x
02140 {22 « 1, 0}, {23 « 1, 0}, // 19: 0000 0011x
02141 {24 « 1, 0}, {25 « 1, 0}, // 20: 0000 0100x
02142 {26 « 1, 0}, {27 « 1, 0}, // 21: 0000 0101x
02143 {28 « 1, 0}, {29 « 1, 0}, // 22: 0000 0011 0x
02144 {30 « 1, 0}, {31 « 1, 0}, // 23: 0000 0011 1x
02145 {32 « 1, 0}, {33 « 1, 0}, // 24: 0000 0100 0x
02146 {0, 10}, {0, -10}, // 25: 0000 0100 1x
02147 {0, 9}, {0, -9}, // 26: 0000 0101 0x
02148 {0, 8}, {0, -8}, // 27: 0000 0101 1x
02149 {0, 16}, {0, -16}, // 28: 0000 0011 00x
02150 {0, 15}, {0, -15}, // 29: 0000 0011 01x
02151 {0, 14}, {0, -14}, // 30: 0000 0011 10x
02152 {0, 13}, {0, -13}, // 31: 0000 0011 11x
02153 {0, 12}, {0, -12}, // 32: 0000 0100 00x
02154 {0, 11}, {0, -11}, // 33: 0000 0100 01x
02155 };
02156
02157 static const plm_vlc_t PLM_VIDEO_DCT_SIZE_LUMINANCE[] = {
02158 {1 « 1, 0}, {2 « 1, 0}, // 0: x
02159 {0, 1}, {0, 2}, // 1: 0x
02160 {3 « 1, 0}, {4 « 1, 0}, // 2: 1x
02161 {0, 0}, {0, 3}, // 3: 10x
02162 {0, 4}, {5 « 1, 0}, // 4: 11x
02163 {0, 5}, {6 « 1, 0}, // 5: 111x
02164 {0, 6}, {7 « 1, 0}, // 6: 1111x

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02165     {0, 7},      {8 << 1, 0}, // 7: 1111 1x
02166     {0, 8},      {-1, 0},    // 8: 1111 1lx
02167 };
02168
02169 static const plm_vlc_t PLM_VIDEO_DCT_SIZE_CHROMINANCE[] = {
02170     {1 << 1, 0}, {2 << 1, 0}, // 0: x
02171     {0, 0},        {0, 1},      // 1: 0x
02172     {0, 2},        {3 << 1, 0}, // 2: 1x
02173     {0, 3},        {4 << 1, 0}, // 3: 11x
02174     {0, 4},        {5 << 1, 0}, // 4: 111x
02175     {0, 5},        {6 << 1, 0}, // 5: 1111x
02176     {0, 6},        {7 << 1, 0}, // 6: 1111 1x
02177     {0, 7},        {8 << 1, 0}, // 7: 1111 1lx
02178     {0, 8},        {-1, 0},    // 8: 1111 11x
02179 };
02180
02181 static const plm_vlc_t *PLM_VIDEO_DCT_SIZE[] = {PLM_VIDEO_DCT_SIZE_LUMINANCE,
02182                                         PLM_VIDEO_DCT_SIZE_CHROMINANCE,
02183
02184 //  dct_coeff bitmap:
02185 //  0xffff  run
02186 //  0x00ff  level
02187
02188 //  Decoded values are unsigned. Sign bit follows in the stream.
02189
02190 static const plm_vlc_uint_t PLM_VIDEO_DCT_COEFF[] = {
02191     {1 << 1, 0}, {0, 0x0001}, // 0: x
02192     {2 << 1, 0}, {3 << 1, 0}, // 1: 0x
02193     {4 << 1, 0}, {5 << 1, 0}, // 2: 00x
02194     {6 << 1, 0}, {0, 0x0101}, // 3: 01x
02195     {7 << 1, 0}, {8 << 1, 0}, // 4: 000x
02196     {9 << 1, 0}, {10 << 1, 0}, // 5: 001x
02197     {0, 0x0002}, {0, 0x0201}, // 6: 010x
02198     {11 << 1, 0}, {12 << 1, 0}, // 7: 0000x
02199     {13 << 1, 0}, {14 << 1, 0}, // 8: 0001x
02200     {15 << 1, 0}, {0, 0x0003}, // 9: 0010x
02201     {0, 0x0401}, {0, 0x0301}, // 10: 0011x
02202     {16 << 1, 0}, {0, 0xffff}, // 11: 0000 0x
02203     {17 << 1, 0}, {18 << 1, 0}, // 12: 0000 1x
02204     {0, 0x0701}, {0, 0x0601}, // 13: 0001 0x
02205     {0, 0x0102}, {0, 0x0501}, // 14: 0001 1x
02206     {19 << 1, 0}, {20 << 1, 0}, // 15: 0010 0x
02207     {21 << 1, 0}, {22 << 1, 0}, // 16: 0000 00x
02208     {0, 0x0202}, {0, 0x0901}, // 17: 0000 10x
02209     {0, 0x0004}, {0, 0x0801}, // 18: 0000 11x
02210     {23 << 1, 0}, {24 << 1, 0}, // 19: 0010 00x
02211     {25 << 1, 0}, {26 << 1, 0}, // 20: 0010 01x
02212     {27 << 1, 0}, {28 << 1, 0}, // 21: 0000 000x
02213     {29 << 1, 0}, {30 << 1, 0}, // 22: 0000 001x
02214     {0, 0xd01}, {0, 0x0006}, // 23: 0010 000x
02215     {0, 0x0c01}, {0, 0xb01}, // 24: 0010 001x
02216     {0, 0x0302}, {0, 0x0103}, // 25: 0010 010x
02217     {0, 0x0005}, {0, 0xa01}, // 26: 0010 011x
02218     {31 << 1, 0}, {32 << 1, 0}, // 27: 0000 0000x
02219     {33 << 1, 0}, {34 << 1, 0}, // 28: 0000 0001x
02220     {35 << 1, 0}, {36 << 1, 0}, // 29: 0000 0010x
02221     {37 << 1, 0}, {38 << 1, 0}, // 30: 0000 0011x
02222     {39 << 1, 0}, {40 << 1, 0}, // 31: 0000 0000 0x
02223     {41 << 1, 0}, {42 << 1, 0}, // 32: 0000 0000 1x
02224     {43 << 1, 0}, {44 << 1, 0}, // 33: 0000 0001 0x
02225     {45 << 1, 0}, {46 << 1, 0}, // 34: 0000 0001 1x
02226     {0, 0x1001}, {0, 0x0502}, // 35: 0000 0010 0x
02227     {0, 0x0007}, {0, 0x0203}, // 36: 0000 0010 1x
02228     {0, 0x0104}, {0, 0xf01}, // 37: 0000 0011 0x
02229     {0, 0xe01}, {0, 0x0402}, // 38: 0000 0011 1x
02230     {47 << 1, 0}, {48 << 1, 0}, // 39: 0000 0000 00x
02231     {49 << 1, 0}, {50 << 1, 0}, // 40: 0000 0000 01x
02232     {51 << 1, 0}, {52 << 1, 0}, // 41: 0000 0000 10x
02233     {53 << 1, 0}, {54 << 1, 0}, // 42: 0000 0000 11x
02234     {55 << 1, 0}, {56 << 1, 0}, // 43: 0000 0001 00x
02235     {57 << 1, 0}, {58 << 1, 0}, // 44: 0000 0001 01x
02236     {59 << 1, 0}, {60 << 1, 0}, // 45: 0000 0001 10x
02237     {61 << 1, 0}, {62 << 1, 0}, // 46: 0000 0001 11x
02238     {-1, 0},       {63 << 1, 0}, // 47: 0000 0000 000x
02239     {64 << 1, 0}, {65 << 1, 0}, // 48: 0000 0000 001x
02240     {66 << 1, 0}, {67 << 1, 0}, // 49: 0000 0000 010x
02241     {68 << 1, 0}, {69 << 1, 0}, // 50: 0000 0000 011x
02242     {70 << 1, 0}, {71 << 1, 0}, // 51: 0000 0000 100x
02243     {72 << 1, 0}, {73 << 1, 0}, // 52: 0000 0000 101x
02244     {74 << 1, 0}, {75 << 1, 0}, // 53: 0000 0000 110x
02245     {76 << 1, 0}, {77 << 1, 0}, // 54: 0000 0000 111x
02246     {0, 0x000b}, {0, 0x0802}, // 55: 0000 0001 000x
02247     {0, 0x0403}, {0, 0x000a}, // 56: 0000 0001 001x
02248     {0, 0x0204}, {0, 0x0702}, // 57: 0000 0001 010x
02249     {0, 0x1501}, {0, 0x1401}, // 58: 0000 0001 011x
02250     {0, 0x0009}, {0, 0x1301}, // 59: 0000 0001 100x

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02251 {0, 0x1201}, {0, 0x0105}, // 60: 0000 0001 101x
02252 {0, 0x0303}, {0, 0x008}, // 61: 0000 0001 110x
02253 {0, 0x0602}, {0, 0x1101}, // 62: 0000 0001 111x
02254 {78 « 1, 0}, {79 « 1, 0}, // 63: 0000 0000 0001x
02255 {80 « 1, 0}, {81 « 1, 0}, // 64: 0000 0000 0010x
02256 {82 « 1, 0}, {83 « 1, 0}, // 65: 0000 0000 0011x
02257 {84 « 1, 0}, {85 « 1, 0}, // 66: 0000 0000 0100x
02258 {86 « 1, 0}, {87 « 1, 0}, // 67: 0000 0000 0101x
02259 {88 « 1, 0}, {89 « 1, 0}, // 68: 0000 0000 0110x
02260 {90 « 1, 0}, {91 « 1, 0}, // 69: 0000 0000 0111x
02261 {0, 0x0a02}, {0, 0x0902}, // 70: 0000 0000 1000x
02262 {0, 0x0503}, {0, 0x0304}, // 71: 0000 0000 1001x
02263 {0, 0x0205}, {0, 0x0107}, // 72: 0000 0000 1010x
02264 {0, 0x0106}, {0, 0x000f}, // 73: 0000 0000 1011x
02265 {0, 0x000e}, {0, 0x000d}, // 74: 0000 0000 1100x
02266 {0, 0x000c}, {0, 0x1a01}, // 75: 0000 0000 1101x
02267 {0, 0x1901}, {0, 0x1801}, // 76: 0000 0000 1110x
02268 {0, 0x1701}, {0, 0x1601}, // 77: 0000 0000 1111x
02269 {92 « 1, 0}, {93 « 1, 0}, // 78: 0000 0000 0001 0x
02270 {94 « 1, 0}, {95 « 1, 0}, // 79: 0000 0000 0001 1x
02271 {96 « 1, 0}, {97 « 1, 0}, // 80: 0000 0000 0010 0x
02272 {98 « 1, 0}, {99 « 1, 0}, // 81: 0000 0000 0010 1x
02273 {100 « 1, 0}, {101 « 1, 0}, // 82: 0000 0000 0011 0x
02274 {102 « 1, 0}, {103 « 1, 0}, // 83: 0000 0000 0011 1x
02275 {0, 0x001f}, {0, 0x001e}, // 84: 0000 0000 0100 0x
02276 {0, 0x001d}, {0, 0x001c}, // 85: 0000 0000 0100 1x
02277 {0, 0x001b}, {0, 0x001a}, // 86: 0000 0000 0101 0x
02278 {0, 0x0019}, {0, 0x0018}, // 87: 0000 0000 0101 1x
02279 {0, 0x0017}, {0, 0x0016}, // 88: 0000 0000 0110 0x
02280 {0, 0x0015}, {0, 0x0014}, // 89: 0000 0000 0110 1x
02281 {0, 0x0013}, {0, 0x0012}, // 90: 0000 0000 0111 0x
02282 {0, 0x0011}, {0, 0x0010}, // 91: 0000 0000 0111 1x
02283 {104 « 1, 0}, {105 « 1, 0}, // 92: 0000 0000 0001 00x
02284 {106 « 1, 0}, {107 « 1, 0}, // 93: 0000 0000 0001 01x
02285 {108 « 1, 0}, {109 « 1, 0}, // 94: 0000 0000 0001 10x
02286 {110 « 1, 0}, {111 « 1, 0}, // 95: 0000 0000 0001 11x
02287 {0, 0x028}, {0, 0x027}, // 96: 0000 0000 0010 00x
02288 {0, 0x026}, {0, 0x025}, // 97: 0000 0000 0010 01x
02289 {0, 0x024}, {0, 0x023}, // 98: 0000 0000 0010 10x
02290 {0, 0x022}, {0, 0x021}, // 99: 0000 0000 0010 11x
02291 {0, 0x020}, {0, 0x010e}, // 100: 0000 0000 0011 00x
02292 {0, 0x010d}, {0, 0x010c}, // 101: 0000 0000 0011 01x
02293 {0, 0x010b}, {0, 0x010a}, // 102: 0000 0000 0011 10x
02294 {0, 0x0109}, {0, 0x0108}, // 103: 0000 0000 0011 11x
02295 {0, 0x0112}, {0, 0x0111}, // 104: 0000 0000 0001 000x
02296 {0, 0x0110}, {0, 0x010f}, // 105: 0000 0000 0001 001x
02297 {0, 0x0603}, {0, 0x1002}, // 106: 0000 0000 0001 010x
02298 {0, 0x0f02}, {0, 0x0e02}, // 107: 0000 0000 0001 011x
02299 {0, 0xd02}, {0, 0xc02}, // 108: 0000 0000 0001 100x
02300 {0, 0xb02}, {0, 0x1f01}, // 109: 0000 0000 0001 101x
02301 {0, 0x1e01}, {0, 0x1d01}, // 110: 0000 0000 0001 110x
02302 {0, 0x1c01}, {0, 0x1b01}, // 111: 0000 0000 0001 111x
02303 },
02304
02305 typedef struct {
02306     int full_px;
02307     int is_set;
02308     int r_size;
02309     int h;
02310     int v;
02311 } plm_video_motion_t;
02312
02313 struct plm_video_t {
02314     double framerate;
02315     double time;
02316     int frames_decoded;
02317     int width;
02318     int height;
02319     int mb_width;
02320     int mb_height;
02321     int mb_size;
02322
02323     int luma_width;
02324     int luma_height;
02325
02326     int chroma_width;
02327     int chroma_height;
02328
02329     int start_code;
02330     int picture_type;
02331
02332     plm_video_motion_t motion_forward;
02333     plm_video_motion_t motion_backward;
02334
02335     int has_sequence_header;
02336     int quantizer_scale;
02337

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```

02338     int slice_begin;
02339     int macroblock_address;
02340
02341     int mb_row;
02342     int mb_col;
02343
02344     int macroblock_type;
02345     int macroblock_intra;
02346
02347     int dc_predictor[3];
02348
02349     plm_buffer_t *buffer;
02350     int destroy_buffer_when_done;
02351
02352     plm_frame_t frame_current;
02353     plm_frame_t frame_forward;
02354     plm_frame_t frame_backward;
02355
02356     uint8_t *frames_data;
02357
02358     int block_data[64];
02359     uint8_t intra_quant_matrix[64];
02360     uint8_t non_intra_quant_matrix[64];
02361
02362     int has_reference_frame;
02363     int assume_no_b_frames;
02364 };
02365
02366 static inline uint8_t plm_clamp(int n) {
02367     if (n > 255) {
02368         n = 255;
02369     } else if (n < 0) {
02370         n = 0;
02371     }
02372     return n;
02373 }
02374
02375 int plm_video_decode_sequence_header(plm_video_t *self);
02376 void plm_video_init_frame(plm_video_t *self, plm_frame_t *frame, uint8_t *base);
02377 void plm_video_decode_picture(plm_video_t *self);
02378 void plm_video_decode_slice(plm_video_t *self, int slice);
02379 void plm_video_decode_macroblock(plm_video_t *self);
02380 void plm_video_decode_motion_vectors(plm_video_t *self);
02381 int plm_video_decode_motion_vector(plm_video_t *self, int r_size, int motion);
02382 void plm_video_predict_macroblock(plm_video_t *self);
02383 void plm_video_copy_macroblock(plm_video_t *self, plm_frame_t *s, int motion_h, int motion_v);
02384 void plm_video_interpolate_macroblock(plm_video_t *self, plm_frame_t *s, int motion_h, int motion_v);
02385 void plm_video_process_macroblock(plm_video_t *self, uint8_t *s, uint8_t *d, int mh, int mb, int bs,
02386     int interp);
02387 void plm_video_decode_block(plm_video_t *self, int block);
02388 void plm_video_idct(int *block);
02389
02390 plm_video_t *plm_video_create_with_buffer(plm_buffer_t *buffer, int destroy_when_done) {
02391     plm_video_t *self = (plm_video_t *)PLM_MALLOC(sizeof(plm_video_t));
02392     memset(self, 0, sizeof(plm_video_t));
02393
02394     self->buffer = buffer;
02395     self->destroy_buffer_when_done = destroy_when_done;
02396
02397     // Attempt to decode the sequence header
02398     self->start_code = plm_buffer_find_start_code(self->buffer, PLM_START_SEQUENCE);
02399     if (self->start_code != -1) {
02400         plm_video_decode_sequence_header(self);
02401     }
02402     return self;
02403 }
02404
02405 void plm_video_destroy(plm_video_t *self) {
02406     if (self->destroy_buffer_when_done) {
02407         plm_buffer_destroy(self->buffer);
02408     }
02409
02410     if (self->has_sequence_header) {
02411         PLM_FREE(self->frames_data);
02412     }
02413
02414     PLM_FREE(self);
02415 }
02416
02417 double plm_video_get_framerate(plm_video_t *self) { return plm_video_has_header(self) ?
02418     self->framerate : 0; }
02419
02420 int plm_video_get_width(plm_video_t *self) { return plm_video_has_header(self) ? self->width : 0; }
02421
02422 int plm_video_get_height(plm_video_t *self) { return plm_video_has_header(self) ? self->height : 0; }
02423
02424 void plm_video_set_no_delay(plm_video_t *self, int no_delay) { self->assume_no_b_frames = no_delay; }

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02423
02424     double plm_video_get_time(plm_video_t *self) { return self->time; }
02425
02426     void plm_video_set_time(plm_video_t *self, double time) {
02427         self->frames_decoded = self->framerate * time;
02428         self->time = time;
02429     }
02430
02431     void plm_video_rewind(plm_video_t *self) {
02432         plm_buffer_rewind(self->buffer);
02433         self->time = 0;
02434         self->frames_decoded = 0;
02435         self->has_reference_frame = FALSE;
02436         self->start_code = -1;
02437     }
02438
02439     int plm_video_has-ended(plm_video_t *self) { return plm_buffer_has-ended(self->buffer); }
02440
02441     plm_frame_t *plm_video_decode(plm_video_t *self) {
02442         if (!plm_video_has_header(self)) {
02443             return NULL;
02444         }
02445
02446         plm_frame_t *frame = NULL;
02447         do {
02448             if (self->start_code != PLM_START_PICTURE) {
02449                 self->start_code = plm_buffer_find_start_code(self->buffer, PLM_START_PICTURE);
02450
02451                 if (self->start_code == -1) {
02452                     // If we reached the end of the file and the previously decoded
02453                     // frame was a reference frame, we still have to return it.
02454                     if (self->has_reference_frame && !self->assume_no_b_frames &&
02455                         plm_buffer_has-ended(self->buffer) &&
02456                         (self->picture_type == PLM_VIDEO_PICTURE_TYPE_INTRA ||
02457                          self->picture_type == PLM_VIDEO_PICTURE_TYPE_PREDICTIVE)) {
02458                         self->has_reference_frame = FALSE;
02459                         frame = &self->frame_backward;
02460                         break;
02461                     }
02462                     return NULL;
02463                 }
02464             }
02465
02466             // Make sure we have a full picture in the buffer before attempting to
02467             // decode it. Sadly, this can only be done by seeking for the start code
02468             // of the next picture. Also, if we didn't find the start code for the
02469             // next picture, but the source has ended, we assume that this last
02470             // picture is in the buffer.
02471             if (plm_buffer_has_start_code(self->buffer, PLM_START_PICTURE) == -1 &&
02472                 !plm_buffer_has-ended(self->buffer)) {
02473                 return NULL;
02474             }
02475             plm_buffer_discard_read_bytes(self->buffer);
02476
02477             plm_video_decode_picture(self);
02478
02479             if (self->assume_no_b_frames) {
02480                 frame = &self->frame_backward;
02481             } else if (self->picture_type == PLM_VIDEO_PICTURE_TYPE_B) {
02482                 frame = &self->frame_current;
02483             } else if (self->has_reference_frame) {
02484                 frame = &self->frame_forward;
02485             } else {
02486                 self->has_reference_frame = TRUE;
02487             }
02488         } while (!frame);
02489
02490         frame->time = self->time;
02491         self->frames_decoded++;
02492         self->time = (double)self->frames_decoded / self->framerate;
02493
02494     return frame;
02495 }
02496
02497     int plm_video_has_header(plm_video_t *self) {
02498         if (self->has_sequence_header) {
02499             return TRUE;
02500         }
02501         if (self->start_code != PLM_START_SEQUENCE) {
02502             self->start_code = plm_buffer_find_start_code(self->buffer, PLM_START_SEQUENCE);
02503         }
02504         if (self->start_code == -1) {
02505             return FALSE;
02506         }
02507

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02508     if (!plm_video_decode_sequence_header(self)) {
02509         return FALSE;
02510     }
02511
02512     return TRUE;
02513 }
02514
02515 int plm_video_decode_sequence_header(plm_video_t *self) {
02516     int max_header_size = 64 + 2 * 64 * 8; // 64 bit header + 2x 64 byte matrix
02517     if (!plm_buffer_has(self->buffer, max_header_size)) {
02518         return FALSE;
02519     }
02520
02521     self->width = plm_buffer_read(self->buffer, 12);
02522     self->height = plm_buffer_read(self->buffer, 12);
02523
02524     if (self->width <= 0 || self->height <= 0) {
02525         return FALSE;
02526     }
02527
02528     // Skip pixel aspect ratio
02529     plm_buffer_skip(self->buffer, 4);
02530
02531     self->framerate = PLM_VIDEO_PICTURE_RATE[plm_buffer_read(self->buffer, 4)];
02532
02533     // Skip bit_rate, marker, buffer_size and constrained bit
02534     plm_buffer_skip(self->buffer, 18 + 1 + 10 + 1);
02535
02536     // Load custom intra quant matrix?
02537     if (plm_buffer_read(self->buffer, 1)) {
02538         for (int i = 0; i < 64; i++) {
02539             int idx = PLM_VIDEO_ZIG_ZAG[i];
02540             self->intra_quant_matrix[idx] = plm_buffer_read(self->buffer, 8);
02541         }
02542     } else {
02543         memcpy(self->intra_quant_matrix, PLM_VIDEO_INTRA_QUANT_MATRIX, 64);
02544     }
02545
02546     // Load custom non intra quant matrix?
02547     if (plm_buffer_read(self->buffer, 1)) {
02548         for (int i = 0; i < 64; i++) {
02549             int idx = PLM_VIDEO_ZIG_ZAG[i];
02550             self->non_intra_quant_matrix[idx] = plm_buffer_read(self->buffer, 8);
02551         }
02552     } else {
02553         memcpy(self->non_intra_quant_matrix, PLM_VIDEO_NON_INTRA_QUANT_MATRIX, 64);
02554     }
02555
02556     self->mb_width = (self->width + 15) >> 4;
02557     self->mb_height = (self->height + 15) >> 4;
02558     self->mb_size = self->mb_width * self->mb_height;
02559
02560     self->luma_width = self->mb_width << 4;
02561     self->luma_height = self->mb_height << 4;
02562
02563     self->chroma_width = self->mb_width << 3;
02564     self->chroma_height = self->mb_height << 3;
02565
02566     // Allocate one big chunk of data for all 3 frames = 9 planes
02567     size_t luma_plane_size = self->luma_width * self->luma_height;
02568     size_t chroma_plane_size = self->chroma_width * self->chroma_height;
02569     size_t frame_data_size = (luma_plane_size + 2 * chroma_plane_size);
02570
02571     self->frames_data = (uint8_t *)PLM_MALLOC(frame_data_size * 3);
02572     plm_video_init_frame(self, &self->frame_current, self->frames_data + frame_data_size * 0);
02573     plm_video_init_frame(self, &self->frame_forward, self->frames_data + frame_data_size * 1);
02574     plm_video_init_frame(self, &self->frame_backward, self->frames_data + frame_data_size * 2);
02575
02576     self->has_sequence_header = TRUE;
02577     return TRUE;
02578 }
02579
02580 void plm_video_init_frame(plm_video_t *self, plm_frame_t *frame, uint8_t *base) {
02581     size_t luma_plane_size = self->luma_width * self->luma_height;
02582     size_t chroma_plane_size = self->chroma_width * self->chroma_height;
02583
02584     frame->width = self->width;
02585     frame->height = self->height;
02586     frame->y.width = self->luma_width;
02587     frame->y.height = self->luma_height;
02588     frame->y.data = base;
02589
02590     frame->cr.width = self->chroma_width;
02591     frame->cr.height = self->chroma_height;
02592     frame->cr.data = base + luma_plane_size;
02593
02594     frame->cb.width = self->chroma_width;

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02595     frame->cb.height = self->chroma_height;
02596     frame->cb.data = base + luma_plane_size + chroma_plane_size;
02597 }
02598
02599 void plm_video_decode_picture(plm_video_t *self) {
02600     plm_buffer_skip(self->buffer, 10); // skip temporalReference
02601     self->picture_type = plm_buffer_read(self->buffer, 3);
02602     plm_buffer_skip(self->buffer, 16); // skip vbv_delay
02603
02604     // D frames or unknown coding type
02605     if (self->picture_type <= 0 || self->picture_type > PLM_VIDEO_PICTURE_TYPE_B) {
02606         return;
02607     }
02608
02609     // Forward full_px, f_code
02610     if (self->picture_type == PLM_VIDEO_PICTURE_TYPE_PREDICTIVE || self->picture_type ==
02611         PLM_VIDEO_PICTURE_TYPE_B) {
02612         self->motion_forward.full_px = plm_buffer_read(self->buffer, 1);
02613         int f_code = plm_buffer_read(self->buffer, 3);
02614         if (f_code == 0) {
02615             // Ignore picture with zero f_code
02616             return;
02617         }
02618         self->motion_forward.r_size = f_code - 1;
02619     }
02620
02621     // Backward full_px, f_code
02622     if (self->picture_type == PLM_VIDEO_PICTURE_TYPE_B) {
02623         self->motion_backward.full_px = plm_buffer_read(self->buffer, 1);
02624         int f_code = plm_buffer_read(self->buffer, 3);
02625         if (f_code == 0) {
02626             // Ignore picture with zero f_code
02627             return;
02628         }
02629         self->motion_backward.r_size = f_code - 1;
02630     }
02631
02632     plm_frame_t frame_temp = self->frame_forward;
02633     if (self->picture_type == PLM_VIDEO_PICTURE_TYPE_INTRA || self->picture_type ==
02634         PLM_VIDEO_PICTURE_TYPE_PREDICTIVE) {
02635         self->frame_forward = self->frame_backward;
02636     }
02637
02638     // Find first slice start code; skip extension and user data
02639     do {
02640         self->start_code = plm_buffer_next_start_code(self->buffer);
02641     } while (self->start_code == PLM_START_EXTENSION || self->start_code == PLM_START_USER_DATA);
02642
02643     // Decode all slices
02644     while (PLM_START_IS_SLICE(self->start_code)) {
02645         plm_video_decode_slice(self, self->start_code & 0x000000FF);
02646         if (self->macroblock_address >= self->mb_size - 2) {
02647             break;
02648         }
02649     }
02650
02651     // If this is a reference picture rotate the prediction pointers
02652     if (self->picture_type == PLM_VIDEO_PICTURE_TYPE_INTRA || self->picture_type ==
02653         PLM_VIDEO_PICTURE_TYPE_PREDICTIVE) {
02654         self->frame_backward = self->frame_current;
02655         self->frame_current = frame_temp;
02656     }
02657
02658 void plm_video_decode_slice(plm_video_t *self, int slice) {
02659     self->slice_begin = TRUE;
02660     self->macroblock_address = (slice - 1) * self->mb_width - 1;
02661
02662     // Reset motion vectors and DC predictors
02663     self->motion_backward.h = self->motion_forward.h = 0;
02664     self->motion_backward.v = self->motion_forward.v = 0;
02665     self->dc_predictor[0] = 128;
02666     self->dc_predictor[1] = 128;
02667     self->dc_predictor[2] = 128;
02668
02669     self->quantizer_scale = plm_buffer_read(self->buffer, 5);
02670
02671     // Skip extra
02672     while (plm_buffer_read(self->buffer, 1)) {
02673         plm_buffer_skip(self->buffer, 8);
02674     }
02675
02676     do {
02677         plm_video_decode_macroblock(self);
02678     } while (self->macroblock_address < self->mb_size - 1 && plm_buffer_peek_non_zero(self->buffer,
02679         23));

```

```

02678 }
02679
02680 void plm_video_decode_macroblock(plm_video_t *self) {
02681     // Decode increment
02682     int increment = 0;
02683     int t = plm_buffer_read_vlc(self->buffer, PLM_VIDEO_MACROBLOCK_ADDRESS_INCREMENT);
02684
02685     while (t == 34) {
02686         // macroblock_stuffing
02687         t = plm_buffer_read_vlc(self->buffer, PLM_VIDEO_MACROBLOCK_ADDRESS_INCREMENT);
02688     }
02689     while (t == 35) {
02690         // macroblock_escape
02691         increment += 33;
02692         t = plm_buffer_read_vlc(self->buffer, PLM_VIDEO_MACROBLOCK_ADDRESS_INCREMENT);
02693     }
02694     increment += t;
02695
02696     // Process any skipped macroblocks
02697     if (self->slice_begin) {
02698         // The first increment of each slice is relative to beginning of the
02699         // previous row, not the previous macroblock
02700         self->slice_begin = FALSE;
02701         self->macroblock_address += increment;
02702     } else {
02703         if (self->macroblock_address + increment >= self->mb_size) {
02704             return; // invalid
02705         }
02706         if (increment > 1) {
02707             // Skipped macroblocks reset DC predictors
02708             self->dc_predictor[0] = 128;
02709             self->dc_predictor[1] = 128;
02710             self->dc_predictor[2] = 128;
02711
02712             // Skipped macroblocks in P-pictures reset motion vectors
02713             if (self->picture_type == PLM_VIDEO_PICTURE_TYPE_PREDICTIVE) {
02714                 self->motion_forward.h = 0;
02715                 self->motion_forward.v = 0;
02716             }
02717         }
02718
02719         // Predict skipped macroblocks
02720         while (increment > 1) {
02721             self->macroblock_address++;
02722             self->mb_row = self->macroblock_address / self->mb_width;
02723             self->mb_col = self->macroblock_address % self->mb_width;
02724
02725             plm_video_predict_macroblock(self);
02726             increment--;
02727         }
02728         self->macroblock_address++;
02729     }
02730
02731     self->mb_row = self->macroblock_address / self->mb_width;
02732     self->mb_col = self->macroblock_address % self->mb_width;
02733
02734     if (self->mb_col >= self->mb_width || self->mb_row >= self->mb_height) {
02735         return; // corrupt stream;
02736     }
02737
02738     // Process the current macroblock
02739     const plm_vlc_t *table = PLM_VIDEO_MACROBLOCK_TYPE[self->picture_type];
02740     self->macroblock_type = plm_buffer_read_vlc(self->buffer, table);
02741
02742     self->macroblock_intra = (self->macroblock_type & 0x01);
02743     self->motion_forward.is_set = (self->macroblock_type & 0x08);
02744     self->motion_backward.is_set = (self->macroblock_type & 0x04);
02745
02746     // Quantizer scale
02747     if ((self->macroblock_type & 0x10) != 0) {
02748         self->quantizer_scale = plm_buffer_read(self->buffer, 5);
02749     }
02750
02751     if (self->macroblock_intra) {
02752         // Intra-coded macroblocks reset motion vectors
02753         self->motion_backward.h = self->motion_forward.h = 0;
02754         self->motion_backward.v = self->motion_forward.v = 0;
02755     } else {
02756         // Non-intra macroblocks reset DC predictors
02757         self->dc_predictor[0] = 128;
02758         self->dc_predictor[1] = 128;
02759         self->dc_predictor[2] = 128;
02760
02761         plm_video_decode_motion_vectors(self);
02762         plm_video_predict_macroblock(self);
02763     }
02764

```

```

02765 // Decode blocks
02766 int cbp = ((self->macroblock_type & 0x02) != 0) ? plm_buffer_read_vlc(self->buffer,
02767 PLM_VIDEO_CODE_BLOCK_PATTERN)
02768 : (self->macroblock_intra ? 0x3f : 0);
02769 for (int block = 0, mask = 0x20; block < 6; block++) {
02770     if ((cbp & mask) != 0) {
02771         plm_video_decode_block(self, block);
02772     }
02773     mask >>= 1;
02774 }
02775 }
02776
02777 void plm_video_decode_motion_vectors(plm_video_t *self) {
02778
02779 // Forward
02780 if (self->motion_forward.is_set) {
02781     int r_size = self->motion_forward.r_size;
02782     self->motion_forward.h = plm_video_decode_motion_vector(self, r_size, self->motion_forward.h);
02783     self->motion_forward.v = plm_video_decode_motion_vector(self, r_size, self->motion_forward.v);
02784 } else if (self->picture_type == PLM_VIDEO_PICTURE_TYPE_PREDICTIVE) {
02785     // No motion information in P-picture, reset vectors
02786     self->motion_forward.h = 0;
02787     self->motion_forward.v = 0;
02788 }
02789
02790 if (self->motion_backward.is_set) {
02791     int r_size = self->motion_backward.r_size;
02792     self->motion_backward.h = plm_video_decode_motion_vector(self, r_size, self->motion_backward.h);
02793     self->motion_backward.v = plm_video_decode_motion_vector(self, r_size, self->motion_backward.v);
02794 }
02795 }
02796
02797 int plm_video_decode_motion_vector(plm_video_t *self, int r_size, int motion) {
02798     int fscale = 1 « r_size;
02799     int m_code = plm_buffer_read_vlc(self->buffer, PLM_VIDEO_MOTION);
02800     int r = 0;
02801     int d;
02802
02803     if ((m_code != 0) && (fscale != 1)) {
02804         r = plm_buffer_read(self->buffer, r_size);
02805         d = ((abs(m_code) - 1) « r_size) + r + 1;
02806         if (m_code < 0)
02807             d = -d;
02808     }
02809 } else {
02810     d = m_code;
02811 }
02812
02813 motion += d;
02814 if (motion > (fscale « 4) - 1) {
02815     motion -= fscale « 5;
02816 } else if (motion < ((-fscale) « 4)) {
02817     motion += fscale « 5;
02818 }
02819
02820 return motion;
02821 }
02822
02823 void plm_video_predict_macroblock(plm_video_t *self) {
02824     int fw_h = self->motion_forward.h;
02825     int fw_v = self->motion_forward.v;
02826
02827     if (self->motion_forward.full_px) {
02828         fw_h <= 1;
02829         fw_v <= 1;
02830     }
02831
02832     if (self->picture_type == PLM_VIDEO_PICTURE_TYPE_B) {
02833         int bw_h = self->motion_backward.h;
02834         int bw_v = self->motion_backward.v;
02835
02836         if (self->motion_backward.full_px) {
02837             bw_h <= 1;
02838             bw_v <= 1;
02839         }
02840
02841         if (self->motion_forward.is_set) {
02842             plm_video_copy_macroblock(self, &self->frame_forward, fw_h, fw_v);
02843             if (self->motion_backward.is_set) {
02844                 plm_video_interpolate_macroblock(self, &self->frame_backward, bw_h, bw_v);
02845             }
02846         } else {
02847             plm_video_copy_macroblock(self, &self->frame_backward, bw_h, bw_v);
02848         }
02849     } else {
02850         plm_video_copy_macroblock(self, &self->frame_forward, fw_h, fw_v);
02851     }
02852 }

```

```

02851     }
02852 }
02853
02854 void plm_video_copy_macroblock(plm_video_t *self, plm_frame_t *s, int motion_h, int motion_v) {
02855     plm_frame_t *d = &self->frame_current;
02856     plm_video_process_macroblock(self, s->y.data, d->y.data, motion_h, motion_v, 16, FALSE);
02857     plm_video_process_macroblock(self, s->cr.data, d->cr.data, motion_h / 2, motion_v / 2, 8, FALSE);
02858     plm_video_process_macroblock(self, s->cb.data, d->cb.data, motion_h / 2, motion_v / 2, 8, FALSE);
02859 }
02860
02861 void plm_video_interpolate_macroblock(plm_video_t *self, plm_frame_t *s, int motion_h, int motion_v) {
02862     plm_frame_t *d = &self->frame_current;
02863     plm_video_process_macroblock(self, s->y.data, d->y.data, motion_h, motion_v, 16, TRUE);
02864     plm_video_process_macroblock(self, s->cr.data, d->cr.data, motion_h / 2, motion_v / 2, 8, TRUE);
02865     plm_video_process_macroblock(self, s->cb.data, d->cb.data, motion_h / 2, motion_v / 2, 8, TRUE);
02866 }
02867
02868 #define PLM_BLOCK_SET(DEST, DEST_INDEX, DEST_WIDTH, SOURCE_INDEX, SOURCE_WIDTH, BLOCK_SIZE, OP)
02869     do {
02870         int dest_scan = DEST_WIDTH - BLOCK_SIZE;
02871         int source_scan = SOURCE_WIDTH - BLOCK_SIZE;
02872         for (int y = 0; y < BLOCK_SIZE; y++) {
02873             for (int x = 0; x < BLOCK_SIZE; x++) {
02874                 DEST[DEST_INDEX] = OP;
02875                 SOURCE_INDEX++;
02876                 DEST_INDEX++;
02877             }
02878             SOURCE_INDEX += source_scan;
02879             DEST_INDEX += dest_scan;
02880         }
02881     } while (FALSE)
02882
02883 void plm_video_process_macroblock(plm_video_t *self, uint8_t *s, uint8_t *d, int motion_h, int motion_v, int block_size,
02884                                     int interpolate) {
02885     int dw = self->mb_width * block_size;
02886
02887     int hp = motion_h >> 1;
02888     int vp = motion_v >> 1;
02889     int odd_h = (motion_h & 1) == 1;
02890     int odd_v = (motion_v & 1) == 1;
02891
02892     unsigned int si = ((self->mb_row * block_size) + vp) * dw + (self->mb_col * block_size) + hp;
02893     unsigned int di = (self->mb_row * dw + self->mb_col) * block_size;
02894
02895     unsigned int max_address = (dw * (self->mb_height * block_size - block_size + 1) - block_size);
02896     if (si > max_address || di > max_address) {
02897         return; // corrupt video
02898     }
02899
02900 #define PLM_MB_CASE(INTERPOLATE, ODD_H, ODD_V, OP)
02901     case ((INTERPOLATE << 2) | (ODD_H << 1) | (ODD_V)):
02902         PLM_BLOCK_SET(d, di, dw, si, dw, block_size, OP);
02903     break
02904
02905     switch ((interpolate << 2) | (odd_h << 1) | (odd_v)) {
02906         PLM_MB_CASE(0, 0, 0, (s[si]));
02907         PLM_MB_CASE(0, 0, 1, (s[si] + s[si + dw] + 1) >> 1);
02908         PLM_MB_CASE(0, 1, 0, (s[si] + s[si + 1] + 1) >> 1);
02909         PLM_MB_CASE(0, 1, 1, (s[si] + s[si + 1] + s[si + dw] + s[si + dw + 1] + 2) >> 2);
02910
02911         PLM_MB_CASE(1, 0, 0, (d[di] + (s[si]) + 1) >> 1);
02912         PLM_MB_CASE(1, 0, 1, (d[di] + ((s[si] + s[si + dw] + 1) >> 1) + 1) >> 1);
02913         PLM_MB_CASE(1, 1, 0, (d[di] + ((s[si] + s[si + 1] + 1) >> 1) + 1) >> 1);
02914         PLM_MB_CASE(1, 1, 1, (d[di] + ((s[si] + s[si + 1] + s[si + dw] + s[si + dw + 1] + 2) >> 2) + 1) >
02915     );
02916 }
02917 #undef PLM_MB_CASE
02918 }
02919

```

```

02920 void plm_video_decode_block(plm_video_t *self, int block) {
02921     int n = 0;
02922     uint8_t *quant_matrix;
02923
02924     // Decode DC coefficient of intra-coded blocks
02925     if (self->macroblock_intra) {
02926         int predictor;
02927         int dct_size;
02928
02929         // DC prediction
02930         int plane_index = block > 3 ? block - 3 : 0;
02931         predictor = self->dc_predictor[plane_index];
02932         dct_size = plm_buffer_read_vlc(self->buffer, PLM_VIDEO_DCT_SIZE[plane_index]);
02933
02934         // Read DC coeff
02935         if (dct_size > 0) {
02936             int differential = plm_buffer_read(self->buffer, dct_size);
02937             if ((differential & (1 << (dct_size - 1))) != 0) {
02938                 self->block_data[0] = predictor + differential;
02939             } else {
02940                 self->block_data[0] = predictor + (-(1 << dct_size) | (differential + 1));
02941             }
02942         } else {
02943             self->block_data[0] = predictor;
02944         }
02945
02946         // Save predictor value
02947         self->dc_predictor[plane_index] = self->block_data[0];
02948
02949         // Dequantize + premultiply
02950         self->block_data[0] <= (3 + 5);
02951
02952         quant_matrix = self->intra_quant_matrix;
02953         n = 1;
02954     } else {
02955         quant_matrix = self->non_intra_quant_matrix;
02956     }
02957
02958     // Decode AC coefficients (+DC for non-intra)
02959     int level = 0;
02960     while (TRUE) {
02961         int run = 0;
02962         uint16_t coeff = plm_buffer_read_vlc_uint(self->buffer, PLM_VIDEO_DCT_COEFF);
02963
02964         if ((coeff == 0x0001) && (n > 0) && (plm_buffer_read(self->buffer, 1) == 0)) {
02965             // end_of_block
02966             break;
02967         }
02968         if (coeff == 0xffff) {
02969             // escape
02970             run = plm_buffer_read(self->buffer, 6);
02971             level = plm_buffer_read(self->buffer, 8);
02972             if (level == 0) {
02973                 level = plm_buffer_read(self->buffer, 8);
02974             } else if (level == 128) {
02975                 level = plm_buffer_read(self->buffer, 8) - 256;
02976             } else if (level > 128) {
02977                 level = level - 256;
02978             }
02979         } else {
02980             run = coeff >> 8;
02981             level = coeff & 0xff;
02982             if (plm_buffer_read(self->buffer, 1)) {
02983                 level = -level;
02984             }
02985         }
02986
02987         n += run;
02988         if (n < 0 || n >= 64) {
02989             return; // invalid
02990         }
02991
02992         int de_zig_zagged = PLM_VIDEO_ZIG_ZAG[n];
02993         n++;
02994
02995         // Dequantize, oddify, clip
02996         level <= 1;
02997         if (!self->macroblock_intra) {
02998             level += (level < 0 ? -1 : 1);
02999         }
03000         level = (level * self->quantizer_scale * quant_matrix[de_zig_zagged]) >> 4;
03001         if ((level & 1) == 0) {
03002             level -= level > 0 ? 1 : -1;
03003         }
03004         if (level > 2047) {
03005             level = 2047;

```

```

03007     } else if (level < -2048) {
03008         level = -2048;
03009     }
03010
03011     // Save premultiplied coefficient
03012     self->block_data[de_zig_zagged] = level * PLM_VIDEO_PREMULTIPLIER_MATRIX[de_zig_zagged];
03013 }
03014
03015 // Move block to its place
03016 uint8_t *d;
03017 int dw;
03018 int di;
03019
03020 if (block < 4) {
03021     d = self->frame_current.y.data;
03022     dw = self->luma_width;
03023     di = (self->mb_row * self->luma_width + self->mb_col) << 4;
03024     if ((block & 1) != 0) {
03025         di += 8;
03026     }
03027     if ((block & 2) != 0) {
03028         di += self->luma_width << 3;
03029     }
03030 } else {
03031     d = (block == 4) ? self->frame_current.cb.data : self->frame_current.cr.data;
03032     dw = self->chroma_width;
03033     di = ((self->mb_row * self->luma_width) << 2) + (self->mb_col << 3);
03034 }
03035
03036 int *s = self->block_data;
03037 int si = 0;
03038 if (self->macroblock_intra) {
03039     // Overwrite (no prediction)
03040     if (n == 1) {
03041         int clamped = plm_clamp((s[0] + 128) >> 8);
03042         PLM_BLOCK_SET(d, di, dw, si, 8, 8, clamped);
03043         s[0] = 0;
03044     } else {
03045         plm_video_idct(s);
03046         PLM_BLOCK_SET(d, di, dw, si, 8, 8, plm_clamp(s[si]));
03047         memset(self->block_data, 0, sizeof(self->block_data));
03048     }
03049 } else {
03050     // Add data to the predicted macroblock
03051     if (n == 1) {
03052         int value = (s[0] + 128) >> 8;
03053         PLM_BLOCK_SET(d, di, dw, si, 8, 8, plm_clamp(d[di] + value));
03054         s[0] = 0;
03055     } else {
03056         plm_video_idct(s);
03057         PLM_BLOCK_SET(d, di, dw, si, 8, 8, plm_clamp(d[di] + s[si]));
03058         memset(self->block_data, 0, sizeof(self->block_data));
03059     }
03060 }
03061 }
03062
03063 void plm_video_idct(int *block) {
03064     int b1, b3, b4, b6, b7, tmp1, tmp2, m0, x0, x1, x2, x3, x4, y3, y4, y5, y6, y7;
03065
03066     // Transform columns
03067     for (int i = 0; i < 8; ++i) {
03068         b1 = block[4 * 8 + i];
03069         b3 = block[2 * 8 + i] + block[6 * 8 + i];
03070         b4 = block[5 * 8 + i] - block[3 * 8 + i];
03071         tmp1 = block[1 * 8 + i] + block[7 * 8 + i];
03072         tmp2 = block[3 * 8 + i] + block[5 * 8 + i];
03073         b6 = block[1 * 8 + i] - block[7 * 8 + i];
03074         b7 = tmp1 + tmp2;
03075         m0 = block[0 * 8 + i];
03076         x4 = ((b6 * 473 - b4 * 196 + 128) >> 8) - b7;
03077         x0 = x4 - ((tmp1 - tmp2) * 362 + 128) >> 8;
03078         x1 = m0 - b1;
03079         x2 = ((block[2 * 8 + i] - block[6 * 8 + i]) * 362 + 128) >> 8) - b3;
03080         x3 = m0 + b1;
03081         y3 = x1 + x2;
03082         y4 = x3 + b3;
03083         y5 = x1 - x2;
03084         y6 = x3 - b3;
03085         y7 = -x0 - ((b4 * 473 + b6 * 196 + 128) >> 8);
03086         block[0 * 8 + i] = b7 + y4;
03087         block[1 * 8 + i] = x4 + y3;
03088         block[2 * 8 + i] = y5 - x0;
03089         block[3 * 8 + i] = y6 - y7;
03090         block[4 * 8 + i] = y6 + y7;
03091         block[5 * 8 + i] = x0 + y5;
03092         block[6 * 8 + i] = y3 - x4;
03093         block[7 * 8 + i] = y4 - b7;

```

```

03094    }
03095
03096 // Transform rows
03097 for (int i = 0; i < 64; i += 8) {
03098     b1 = block[4 + i];
03099     b3 = block[2 + i] + block[6 + i];
03100     b4 = block[5 + i] - block[3 + i];
03101     tmp1 = block[1 + i] + block[7 + i];
03102     tmp2 = block[3 + i] + block[5 + i];
03103     b6 = block[1 + i] - block[7 + i];
03104     b7 = tmp1 + tmp2;
03105     m0 = block[0 + i];
03106     x4 = ((b6 * 473 - b4 * 196 + 128) >> 8) - b7;
03107     x0 = x4 - (((tmp1 - tmp2) * 362 + 128) >> 8);
03108     x1 = m0 - b1;
03109     x2 = (((block[2 + i] - block[6 + i]) * 362 + 128) >> 8) - b3;
03110     x3 = m0 + b1;
03111     y3 = x1 + x2;
03112     y4 = x3 + b3;
03113     y5 = x1 - x2;
03114     y6 = x3 - b3;
03115     y7 = -x0 - ((b4 * 473 + b6 * 196 + 128) >> 8);
03116     block[0 + i] = (b7 + y4 + 128) >> 8;
03117     block[1 + i] = (x4 + y3 + 128) >> 8;
03118     block[2 + i] = (y5 - x0 + 128) >> 8;
03119     block[3 + i] = (y6 - y7 + 128) >> 8;
03120     block[4 + i] = (y6 + y7 + 128) >> 8;
03121     block[5 + i] = (x0 + y5 + 128) >> 8;
03122     block[6 + i] = (y3 - x4 + 128) >> 8;
03123     block[7 + i] = (y4 - b7 + 128) >> 8;
03124 }
03125 }
03126
03127 // YCbCr conversion following the BT.601 standard:
03128 // https://infogalactic.com/info/YCbCr#ITU-R_BT.601_conversion
03129
03130 #define PLM_PUT_PIXEL(RI, GI, BI, Y_OFFSET, DEST_OFFSET)
03131     \
03132     y = ((frame->y.data[y_index + Y_OFFSET] - 16) * 76309) >> 16;
03133     \
03134     dest[d_index + DEST_OFFSET + RI] = plm_clamp(y + r);
03135     \
03136     dest[d_index + DEST_OFFSET + GI] = plm_clamp(y - g);
03137     \
03138     dest[d_index + DEST_OFFSET + BI] = plm_clamp(y + b);
03139
03140 #define PLM_DEFINE_FRAME_CONVERT_FUNCTION(NAME, BYTES_PER_PIXEL, RI, GI, BI)
03141     \
03142     void NAME(plm_frame_t *frame, uint8_t *dest, int stride) {
03143         \
03144         int cols = frame->width >> 1;
03145         \
03146         int rows = frame->height >> 1;
03147         \
03148         int yw = frame->y.width;
03149         \
03150         int cw = frame->cb.width;
03151         \
03152         for (int row = 0; row < rows; row++) {
03153             \
03154             int c_index = row * cw;
03155             \
03156             int y_index = row * 2 * yw;
03157             \
03158             int d_index = row * 2 * stride;
03159             \
03160             for (int col = 0; col < cols; col++) {
03161                 \
03162                 int y;
03163                 \
03164                 int cr = frame->cr.data[c_index] - 128;
03165                 \
03166                 int cb = frame->cb.data[c_index] - 128;
03167                 \
03168                 int r = (cr * 104597) >> 16;
03169                 \
03170                 int g = (cb * 25674 + cr * 53278) >> 16;
03171                 \
03172                 int b = (cb * 132201) >> 16;
03173                 \
03174                 PLM_PUT_PIXEL(RI, GI, BI, 0, 0);
03175                 \
03176                 PLM_PUT_PIXEL(RI, GI, BI, 1, BYTES_PER_PIXEL);
03177                 \
03178                 PLM_PUT_PIXEL(RI, GI, BI, yw, stride);
03179                 \
03180                 PLM_PUT_PIXEL(RI, GI, BI, yw + 1, stride + BYTES_PER_PIXEL);

```

```

03157     \
03158         c_index += 1;
03159         y_index += 2;
03160         d_index += 2 * BYTES_PER_PIXEL;
03161     }
03162 }
03163
03164 PLM_DEFINE_FRAME_CONVERT_FUNCTION(plm_frame_to_rgb, 3, 0, 1, 2)
03165 PLM_DEFINE_FRAME_CONVERT_FUNCTION(plm_frame_to_bgr, 3, 2, 1, 0)
03166 PLM_DEFINE_FRAME_CONVERT_FUNCTION(plm_frame_to_rgba, 4, 0, 1, 2)
03167 PLM_DEFINE_FRAME_CONVERT_FUNCTION(plm_frame_to_bgra, 4, 2, 1, 0)
03168 PLM_DEFINE_FRAME_CONVERT_FUNCTION(plm_frame_to_argb, 4, 1, 2, 3)
03169 PLM_DEFINE_FRAME_CONVERT_FUNCTION(plm_frame_to_abgr, 4, 3, 2, 1)
03170
03171 #undef PLM_PUT_PIXEL
03172 #undef PLM_DEFINE_FRAME_CONVERT_FUNCTION
03173
03174 // -----
03175 // plm_audio implementation
03176
03177 // Based on kjmp2 by Martin J. Fiedler
03178 // http://keyj.emphy.de/kjmp2/
03179
03180 static const int PLM_AUDIO_FRAME_SYNC = 0x7ff;
03181
03182 static const int PLM_AUDIO_MPEG_2_5 = 0x0;
03183 static const int PLM_AUDIO_MPEG_2 = 0x2;
03184 static const int PLM_AUDIO_MPEG_1 = 0x3;
03185
03186 static const int PLM_AUDIO_LAYER_III = 0x1;
03187 static const int PLM_AUDIO_LAYER_II = 0x2;
03188 static const int PLM_AUDIO_LAYER_I = 0x3;
03189
03190 static const int PLM_AUDIO_MODE_STEREO = 0x0;
03191 static const int PLM_AUDIO_MODE_JOINT_STEREO = 0x1;
03192 static const int PLM_AUDIO_MODE_DUAL_CHANNEL = 0x2;
03193 static const int PLM_AUDIO_MODE_MONO = 0x3;
03194
03195 static const unsigned short PLM_AUDIO_SAMPLE_RATE[] = {
03196     44100, 48000, 32000, 0, // MPEG-1
03197     22050, 24000, 16000, 0 // MPEG-2
03198 };
03199
03200 static const short PLM_AUDIO_BIT_RATE[] = {
03201     32, 48, 56, 64, 80, 96, 112, 128, 160, 192, 224, 256, 320, 384, // MPEG-1
03202     8, 16, 24, 32, 40, 48, 56, 64, 80, 96, 112, 128, 144, 160 // MPEG-2
03203 };
03204
03205 static const int PLM_AUDIO_SCALEFACTOR_BASE[] = {0x02000000, 0x01965FEA, 0x01428A30};
03206
03207 static const float PLM_AUDIO_SYNTHESIS_WINDOW[] = {
03208     0.0, -0.5, -0.5, -0.5, -0.5, -0.5, -0.5, -0.5, -1.0, -1.0, -1.0,
03209     -1.0, -1.5, -1.5, -2.0, -2.0, -2.5, -2.5, -3.0, -3.5, -3.5, -4.0,
03210     -4.5, -5.0, -5.5, -6.5, -7.0, -8.0, -8.5, -9.5, -10.5, -12.0, -13.0,
03211     -14.5, -15.5, -17.5, -19.0, -20.5, -22.5, -24.5, -26.5, -29.0, -31.5, -34.0,
03212     -36.5, -39.5, -42.5, -45.5, -48.5, -52.0, -55.5, -58.5, -62.5, -66.0, -69.5,
03213     -73.5, -77.0, -80.5, -84.5, -88.0, -91.5, -95.0, -98.0, -101.0, -104.0, 106.5,
03214     109.0, 111.0, 112.5, 113.5, 114.0, 114.0, 113.5, 112.0, 110.5, 107.5, 104.0,
03215     100.0, 94.5, 88.5, 81.5, 73.0, 63.5, 53.0, 41.5, 28.5, 14.5, -1.0,
03216     -18.0, 36.0, -55.5, -76.5, -98.5, -122.0, -147.0, -173.5, -200.5, -229.5, -259.5,
03217     -290.5, -322.5, -355.5, -389.5, -424.0, -459.5, -495.5, -532.0, -568.5, -605.0, -641.5,
03218     -678.0, -714.0, -749.0, -783.5, -817.0, -849.0, -879.5, -908.5, -935.0, -959.5, -981.0,
03219     -1000.5, -1016.0, -1028.5, -1037.5, -1042.5, -1043.5, -1040.0, -1031.5, 1018.5, 1000.0, 976.0,
03220     946.5, 911.0, 869.5, 822.0, 767.5, 707.0, 640.0, 565.5, 485.0, 397.0, 302.5,
03221     201.0, 92.5, -22.5, -144.0, -272.5, -407.0, -547.5, -694.0, -846.0, -1003.0, -1165.0,
03222     -1331.5, -1502.0, -1675.5, -1852.5, -2031.5, -2212.5, -2394.0, -2576.5, -2758.5, -2939.5, -3118.5,
03223     -3294.5,

```

```

03223     -3467.5,   -3635.5,   -3798.5,   -3955.0,   -4104.5,   -4245.5,   -4377.5,   -4499.0,   -4609.5,   -4708.0,
03224     -4792.5,   -4863.5,   -4919.0,   -4958.0,   -4979.5,   -4983.0,   -4967.5,   -4931.5,   -4875.0,   -4796.0,   -4694.5,
03225     -4569.5,
03226     -4420.0,   -4246.0,   -4046.0,   -3820.0,   -3567.0,   3287.0,   2979.5,   2644.0,   2280.5,   1888.0,
1467.5,
03227     1018.5,    541.0,    35.0,    -499.0,   -1061.0,   -1650.0,   -2266.5,   -2909.0,   -3577.0,   -4270.0,
-4987.5,
03228     -5727.5,   -6490.0,   -7274.0,   -8077.5,   -8899.5,   -9739.0,   -10594.5,   -11464.5,   -12347.0,
-13241.0,   -14144.5,
03229     -15056.0,   -15973.5,   -16895.5,   -17820.0,   -18744.5,   -19668.0,   -20588.0,   -21503.0,   -22410.5,
-23308.5,   -24195.0,
03230     -25068.5,   -25926.5,   -26767.0,   -27589.0,   -28389.0,   -29166.5,   -29919.0,   -30644.5,   -31342.0,
-32009.5,   -32645.0,
03231     -33247.0,   -33814.5,   -34346.0,   -34839.5,   -35295.0,   -35710.0,   -36084.5,   -36417.5,   -36707.5,
-36954.0,   -37156.5,
03232     -37315.0,   -37428.0,   -37496.0,   37519.0,   37496.0,   37428.0,   37315.0,   37156.5,   36954.0,   36707.5,
36417.5,
03233     36084.5,   35710.0,   35295.0,   34839.5,   34346.0,   33814.5,   33247.0,   32645.0,   32009.5,   31342.0,
30644.5,
03234     29919.0,   29166.5,   28389.0,   27589.0,   26767.0,   25926.5,   25068.5,   24195.0,   23308.5,   22410.5,
21503.0,
03235     20588.0,   19668.0,   18744.5,   17820.0,   16895.5,   15973.5,   15056.0,   14144.5,   13241.0,   12347.0,
11464.5,
03236     10594.5,   9739.0,   8899.5,   8077.5,   7274.0,   6490.0,   5727.5,   4987.5,   4270.0,   3577.0,
2909.0,
03237     2266.5,    1650.0,    1061.0,    499.0,    -35.0,    -541.0,   -1018.5,   -1467.5,   -1888.0,   -2280.5,
-2644.0,
03238     -2979.5,   3287.0,   3567.0,   3820.0,   4046.0,   4246.0,   4420.0,   4569.5,   4694.5,   4796.0,
4875.0,
03239     4931.5,    4967.5,    4983.0,    4979.5,    4958.0,    4919.0,    4863.5,    4792.5,    4708.0,    4609.5,
4499.0,
03240     4377.5,    4245.5,    4104.5,    3955.0,    3798.5,    3635.5,    3467.5,    3294.5,    3118.5,    2939.5,
2758.5,
03241     2576.5,    2394.0,    2212.5,    2031.5,    1852.5,    1675.5,    1502.0,    1331.5,    1165.0,    1003.0,
846.0,
03242     694.0,     547.5,     407.0,     272.5,     144.0,     22.5,     -92.5,    -201.0,    -302.5,    -397.0,
-485.0,
03243     1018.5,   1031.5,   1040.0,   1043.5,   1042.5,   1037.5,   1028.5,   1016.0,   1000.5,   981.0,   959.5,
935.0,
03244     568.5,     908.5,     879.5,     849.0,     817.0,     783.5,     749.0,     714.0,     678.0,     641.5,     605.0,
532.0,
03245     200.5,     495.5,     459.5,     424.0,     389.5,     355.5,     322.5,     290.5,     259.5,     229.5,
173.5,
03246     -28.5,     147.0,     122.0,     98.5,     76.5,     55.5,     36.0,     18.0,     1.0,     -14.5,
-41.5,
03247     -110.5,   -53.0,    -63.5,    -73.0,    -81.5,    -88.5,    -94.5,    -100.0,   -104.0,   -107.5,
-112.0,
03248     101.0,    -113.5,   -114.0,   -114.0,   -113.5,   -112.5,   -111.0,   -109.0,   106.5,    104.0,
98.0,
03249     62.5,     95.0,     91.5,     88.0,     84.5,     80.5,     77.0,     73.5,     69.5,     66.0,
58.5,
03250     29.0,     55.5,     52.0,     48.5,     45.5,     42.5,     39.5,     36.5,     34.0,     31.5,
26.5,
03251     10.5,     24.5,     22.5,     20.5,     19.0,     17.5,     15.5,     14.5,     13.0,     12.0,
9.5,
03252     3.5,      8.5,      8.0,      7.0,      6.5,      5.5,      5.0,      4.5,      4.0,      3.5,
3.0,
03253     1.0,      2.5,      2.5,      2.0,      2.0,      1.5,      1.5,      1.0,      1.0,      1.0,
0.5,
03254     0.5,      0.5,      0.5,      0.5,      0.5,      0.5};

03255 // Quantizer lookup, step 1: bitrate classes
03256 static const uint8_t PLM_AUDIO_QUANT_LUT_STEP_1[2][16] = {
03257     // 32, 48, 56, 64, 80, 96, 112, 128, 160, 192, 224, 256, 320, 384 <- bitrate
03258     {0, 0, 1, 1, 1, 2, 2, 2, 2, 2, 2, 2}, // mono
03259     {0, 16, 24, 28, 32, 40, 48, 56, 64, 80, 96, 112, 128, 160, 192 <- bitrate / chan
03260     {0, 0, 0, 0, 1, 1, 2, 2, 2, 2} // stereo
03261 };
03262 };

03263 // Quantizer lookup, step 2: bitrate class, sample rate -> B2 table idx, sblimit
03264 #define PLM_AUDIO_QUANT_TAB_A (27 | 64) // Table 3-B.2a: high-rate, sblimit = 27
03265 #define PLM_AUDIO_QUANT_TAB_B (30 | 64) // Table 3-B.2b: high-rate, sblimit = 30
03266 #define PLM_AUDIO_QUANT_TAB_C 8           // Table 3-B.2c: low-rate, sblimit = 8
03267 #define PLM_AUDIO_QUANT_TAB_D 12          // Table 3-B.2d: low-rate, sblimit = 12
03268
03269 static const uint8_t QUANT_LUT_STEP_2[3][3] = {
03270     // 44.1 kHz,      48 kHz,      32 kHz
03271     {PLM_AUDIO_QUANT_TAB_C, PLM_AUDIO_QUANT_TAB_C, PLM_AUDIO_QUANT_TAB_D}, // 32 - 48 kbit/sec/ch
03272     {PLM_AUDIO_QUANT_TAB_A, PLM_AUDIO_QUANT_TAB_A, PLM_AUDIO_QUANT_TAB_A}, // 56 - 80 kbit/sec/ch
03273     {PLM_AUDIO_QUANT_TAB_B, PLM_AUDIO_QUANT_TAB_A, PLM_AUDIO_QUANT_TAB_B} // 96+ kbit/sec/ch
03274 };
03275 };
03276
03277 // Quantizer lookup, step 3: B2 table, subband -> nbal, row index
03278 // (upper 4 bits: nbal, lower 4 bits: row index)

```



```

03362     self->buffer = buffer;
03363     self->destroy_buffer_when_done = destroy_when_done;
03364     self->samplerate_index = 3; // Indicates 0
03365
03366     memcpy(self->D, PLM_AUDIO_SYNTHESIS_WINDOW, 512 * sizeof(float));
03367     memcpy(self->D + 512, PLM_AUDIO_SYNTHESIS_WINDOW, 512 * sizeof(float));
03368
03369     // Attempt to decode first header
03370     self->next_frame_data_size = plm_audio_decode_header(self);
03371
03372     return self;
03373 }
03374
03375 void plm_audio_destroy(plm_audio_t *self) {
03376     if (self->destroy_buffer_when_done) {
03377         plm_buffer_destroy(self->buffer);
03378     }
03379     PLM_FREE(self);
03380 }
03381
03382 int plm_audio_has_header(plm_audio_t *self) {
03383     if (self->has_header) {
03384         return TRUE;
03385     }
03386
03387     self->next_frame_data_size = plm_audio_decode_header(self);
03388     return self->has_header;
03389 }
03390
03391 int plm_audio_get_samplerate(plm_audio_t *self) {
03392     return plm_audio_has_header(self) ? PLM_AUDIO_SAMPLE_RATE[self->samplerate_index] : 0;
03393 }
03394
03395 double plm_audio_get_time(plm_audio_t *self) { return self->time; }
03396
03397 void plm_audio_set_time(plm_audio_t *self, double time) {
03398     self->samples_decoded = time * (double)PLM_AUDIO_SAMPLE_RATE[self->samplerate_index];
03399     self->time = time;
03400 }
03401
03402 void plm_audio_rewind(plm_audio_t *self) {
03403     plm_buffer_rewind(self->buffer);
03404     self->time = 0;
03405     self->samples_decoded = 0;
03406     self->next_frame_data_size = 0;
03407 }
03408
03409 int plm_audio_has-ended(plm_audio_t *self) { return plm_buffer_has-ended(self->buffer); }
03410
03411 plm_samples_t *plm_audio_decode(plm_audio_t *self) {
03412     // Do we have at least enough information to decode the frame header?
03413     if (!self->next_frame_data_size) {
03414         if (!plm_buffer_has(self->buffer, 48)) {
03415             return NULL;
03416         }
03417         self->next_frame_data_size = plm_audio_decode_header(self);
03418     }
03419
03420     if (self->next_frame_data_size == 0 || !plm_buffer_has(self->buffer, self->next_frame_data_size << 3)) {
03421         return NULL;
03422     }
03423
03424     plm_audio_decode_frame(self);
03425     self->next_frame_data_size = 0;
03426
03427     self->samples.time = self->time;
03428
03429     self->samples_decoded += PLM_AUDIO_SAMPLES_PER_FRAME;
03430     self->time = (double)self->samples_decoded / (double)PLM_AUDIO_SAMPLE_RATE[self->samplerate_index];
03431
03432     return &self->samples;
03433 }
03434
03435 int plm_audio_find_frame_sync(plm_audio_t *self) {
03436     size_t i;
03437     for (i = self->buffer->bit_index >> 3; i < self->buffer->length - 1; i++) {
03438         if (self->buffer->bytes[i] == 0xFF && (self->buffer->bytes[i + 1] & 0xFE) == 0xFC) {
03439             self->buffer->bit_index = ((i + 1) << 3) + 3;
03440             return TRUE;
03441         }
03442     }
03443     self->buffer->bit_index = (i + 1) << 3;
03444     return FALSE;
03445 }
03446
03447 int plm_audio_decode_header(plm_audio_t *self) {

```

```

03448 if (!plm_buffer_has(self->buffer, 48)) {
03449     return 0;
03450 }
03451
03452 plm_buffer_skip_bytes(self->buffer, 0x00);
03453 int sync = plm_buffer_read(self->buffer, 11);
03454
03455 // Attempt to resync if no syncword was found. This sucks balls. The MP2
03456 // stream contains a syncword just before every frame (11 bits set to 1).
03457 // However, this syncword is not guaranteed to not occur elsewhere in the
03458 // stream. So, if we have to resync, we also have to check if the header
03459 // (samplerate, bitrate) differs from the one we had before. This all
03460 // may still lead to garbage data being decoded :/
03461
03462 if (sync != PLM_AUDIO_FRAME_SYNC && !plm_audio_find_frame_sync(self)) {
03463     return 0;
03464 }
03465
03466 self->version = plm_buffer_read(self->buffer, 2);
03467 self->layer = plm_buffer_read(self->buffer, 2);
03468 int hasCRC = !plm_buffer_read(self->buffer, 1);
03469
03470 if (self->version != PLM_AUDIO_MPEG_1 || self->layer != PLM_AUDIO_LAYER_II) {
03471     return 0;
03472 }
03473
03474 int bitrate_index = plm_buffer_read(self->buffer, 4) - 1;
03475 if (bitrate_index > 13) {
03476     return 0;
03477 }
03478
03479 int samplerate_index = plm_buffer_read(self->buffer, 2);
03480 if (samplerate_index == 3) {
03481     return 0;
03482 }
03483
03484 int padding = plm_buffer_read(self->buffer, 1);
03485 plm_buffer_skip(self->buffer, 1); // f_private
03486 int mode = plm_buffer_read(self->buffer, 2);
03487
03488 // If we already have a header, make sure the samplerate, bitrate and mode
03489 // are still the same, otherwise we might have missed sync.
03490 if (self->has_header &&
03491     (self->bitrate_index != bitrate_index || self->samplerate_index != samplerate_index ||
03492      self->mode != mode)) {
03493     return 0;
03494 }
03495 self->bitrate_index = bitrate_index;
03496 self->samplerate_index = samplerate_index;
03497 self->mode = mode;
03498 self->has_header = TRUE;
03499
03500 // Parse the mode_extension, set up the stereo bound
03501 if (mode == PLM_AUDIO_MODE_JOINT_STEREO) {
03502     self->bound = (plm_buffer_read(self->buffer, 2) + 1) « 2;
03503 } else {
03504     plm_buffer_skip(self->buffer, 2);
03505     self->bound = (mode == PLM_AUDIO_MODE_MONO) ? 0 : 32;
03506 }
03507
03508 // Discard the last 4 bits of the header and the CRC value, if present
03509 plm_buffer_skip(self->buffer, 4); // copyright(1), original(1), emphasis(2)
03510 if (hasCRC) {
03511     plm_buffer_skip(self->buffer, 16);
03512 }
03513
03514 // Compute frame size, check if we have enough data to decode the whole
03515 // frame.
03516 int bitrate = PLM_AUDIO_BIT_RATE[bitrate_index];
03517 int samplerate = PLM_AUDIO_SAMPLE_RATE[samplerate_index];
03518 int frame_size = (144000 * bitrate / samplerate) + padding;
03519 return frame_size - (hasCRC ? 6 : 4);
03520 }
03521
03522 void plm_audio_decode_frame(plm_audio_t *self) {
03523     // Prepare the quantizer table lookups
03524     int tab3 = 0;
03525     int sbllimit = 0;
03526
03527     int tab1 = (self->mode == PLM_AUDIO_MODE_MONO) ? 0 : 1;
03528     int tab2 = PLM_AUDIO_QUANT_LUT_STEP_1[tab1][self->bitrate_index];
03529     tab3 = QUANT_LUT_STEP_2[tab2][self->samplerate_index];
03530     sbllimit = tab3 & 63;
03531     tab3 »= 6;
03532
03533     if (self->bound > sbllimit) {

```

```

03534     self->bound = sblimit;
03535 }
03536
03537 // Read the allocation information
03538 for (int sb = 0; sb < self->bound; sb++) {
03539     self->allocation[0][sb] = plm_audio_read_allocation(self, sb, tab3);
03540     self->allocation[1][sb] = plm_audio_read_allocation(self, sb, tab3);
03541 }
03542
03543 for (int sb = self->bound; sb < sblimit; sb++) {
03544     self->allocation[0][sb] = self->allocation[1][sb] = plm_audio_read_allocation(self, sb, tab3);
03545 }
03546
03547 // Read scale factor selector information
03548 int channels = (self->mode == PLM_AUDIO_MODE_MONO) ? 1 : 2;
03549 for (int sb = 0; sb < sblimit; sb++) {
03550     for (int ch = 0; ch < channels; ch++) {
03551         if (self->allocation[ch][sb]) {
03552             self->scale_factor_info[ch][sb] = plm_buffer_read(self->buffer, 2);
03553         }
03554     }
03555     if (self->mode == PLM_AUDIO_MODE_MONO) {
03556         self->scale_factor_info[1][sb] = self->scale_factor_info[0][sb];
03557     }
03558 }
03559
03560 // Read scale factors
03561 for (int sb = 0; sb < sblimit; sb++) {
03562     for (int ch = 0; ch < channels; ch++) {
03563         if (self->allocation[ch][sb]) {
03564             int *sf = self->scale_factor[ch][sb];
03565             switch (self->scale_factor_info[ch][sb]) {
03566                 case 0:
03567                     sf[0] = plm_buffer_read(self->buffer, 6);
03568                     sf[1] = plm_buffer_read(self->buffer, 6);
03569                     sf[2] = plm_buffer_read(self->buffer, 6);
03570                     break;
03571                 case 1:
03572                     sf[0] = sf[1] = plm_buffer_read(self->buffer, 6);
03573                     sf[2] = plm_buffer_read(self->buffer, 6);
03574                     break;
03575                 case 2:
03576                     sf[0] = sf[1] = sf[2] = plm_buffer_read(self->buffer, 6);
03577                     break;
03578                 case 3:
03579                     sf[0] = plm_buffer_read(self->buffer, 6);
03580                     sf[1] = sf[2] = plm_buffer_read(self->buffer, 6);
03581                     break;
03582             }
03583         }
03584     }
03585     if (self->mode == PLM_AUDIO_MODE_MONO) {
03586         self->scale_factor[1][sb][0] = self->scale_factor[0][sb][0];
03587         self->scale_factor[1][sb][1] = self->scale_factor[0][sb][1];
03588         self->scale_factor[1][sb][2] = self->scale_factor[0][sb][2];
03589     }
03590 }
03591
03592 // Coefficient input and reconstruction
03593 int out_pos = 0;
03594 for (int part = 0; part < 3; part++) {
03595     for (int granule = 0; granule < 4; granule++) {
03596
03597     // Read the samples
03598     for (int sb = 0; sb < self->bound; sb++) {
03599         plm_audio_read_samples(self, 0, sb, part);
03600         plm_audio_read_samples(self, 1, sb, part);
03601     }
03602     for (int sb = self->bound; sb < sblimit; sb++) {
03603         plm_audio_read_samples(self, 0, sb, part);
03604         self->sample[1][sb][0] = self->sample[0][sb][0];
03605         self->sample[1][sb][1] = self->sample[0][sb][1];
03606         self->sample[1][sb][2] = self->sample[0][sb][2];
03607     }
03608     for (int sb = sblimit; sb < 32; sb++) {
03609         self->sample[0][sb][0] = 0;
03610         self->sample[0][sb][1] = 0;
03611         self->sample[0][sb][2] = 0;
03612         self->sample[1][sb][0] = 0;
03613         self->sample[1][sb][1] = 0;
03614         self->sample[1][sb][2] = 0;
03615     }
03616
03617     // Synthesis loop
03618     for (int p = 0; p < 3; p++) {
03619         // Shifting step
03620         self->v_pos = (self->v_pos - 64) & 1023;

```

```

03621     for (int ch = 0; ch < 2; ch++) {
03622         plm_audio_idct36(self->sample[ch], p, self->V[ch], self->v_pos);
03623
03624         // Build U, windowing, calculate output
03625         memset(self->U, 0, sizeof(self->U));
03626
03627         int d_index = 512 - (self->v_pos >> 1);
03628         int v_index = (self->v_pos % 128) >> 1;
03629         while (v_index < 1024) {
03630             for (int i = 0; i < 32; ++i) {
03631                 self->U[i] += self->D[d_index++] * self->V[ch][v_index++];
03632             }
03633
03634             v_index += 128 - 32;
03635             d_index += 64 - 32;
03636         }
03637
03638         d_index -= (512 - 32);
03639         v_index = (128 - 32 + 1024) - v_index;
03640         while (v_index < 1024) {
03641             for (int i = 0; i < 32; ++i) {
03642                 self->U[i] += self->D[d_index++] * self->V[ch][v_index++];
03643             }
03644
03645             v_index += 128 - 32;
03646             d_index += 64 - 32;
03647         }
03648     }
03649
03650     // Output samples
03651 #ifdef PLM_AUDIO_SEPARATE_CHANNELS
03652     float *out_channel = ch == 0 ? self->samples.left : self->samples.right;
03653     for (int j = 0; j < 32; j++) {
03654         out_channel[out_pos + j] = self->U[j] / 2147418112.0f;
03655     }
03656 #else
03657     for (int j = 0; j < 32; j++) {
03658         self->samples.interleaved[((out_pos + j) << 1) + ch] = self->U[j] / 2147418112.0f;
03659     }
03660 #endif
03661     } // End of synthesis channel loop
03662     out_pos += 32;
03663 } // End of synthesis sub-block loop
03664
03665 } // Decoding of the granule finished
03666 }
03667
03668     plm_buffer_align(self->buffer);
03669 }
03670
03671 const plm_quantizer_spec_t *plm_audio_read_allocation(plm_audio_t *self, int sb, int tab3) {
03672     int tab4 = PLM_AUDIO_QUANT_LUT_STEP_3[tab3][sb];
03673     int qtab = PLM_AUDIO_QUANT_LUT_STEP_4[tab4 & 15][plm_buffer_read(self->buffer, tab4 >> 4)];
03674     return qtab ? (&PLM_AUDIO_QUANT_TAB[qtab - 1]) : 0;
03675 }
03676
03677 void plm_audio_read_samples(plm_audio_t *self, int ch, int sb, int part) {
03678     const plm_quantizer_spec_t *q = self->allocation[ch][sb];
03679     int sf = self->scale_factor[ch][sb][part];
03680     int *sample = self->sample[ch][sb];
03681     int val = 0;
03682
03683     if (!q) {
03684         // No bits allocated for this subband
03685         sample[0] = sample[1] = sample[2] = 0;
03686         return;
03687     }
03688
03689     // Resolve scalefactor
03690     if (sf == 63) {
03691         sf = 0;
03692     } else {
03693         int shift = (sf / 3) | 0;
03694         sf = (PLM_AUDIO_SCALEFACTOR_BASE[sf % 3] + ((1 << shift) >> 1)) >> shift;
03695     }
03696
03697     // Decode samples
03698     int adj = q->levels;
03699     if (q->group) {
03700         // Decode grouped samples
03701         val = plm_buffer_read(self->buffer, q->bits);
03702         sample[0] = val % adj;
03703         val /= adj;
03704         sample[1] = val % adj;
03705         sample[2] = val / adj;
03706     } else {
03707         // Decode direct samples

```

```

03708     sample[0] = plm_buffer_read(self->buffer, q->bits);
03709     sample[1] = plm_buffer_read(self->buffer, q->bits);
03710     sample[2] = plm_buffer_read(self->buffer, q->bits);
03711 }
03712
03713 // Postmultiply samples
03714 int scale = 65536 / (adj + 1);
03715 adj = ((adj + 1) >> 1) - 1;
03716
03717 val = (adj - sample[0]) * scale;
03718 sample[0] = (val * (sf >> 12) + ((val * (sf & 4095) + 2048) >> 12)) >> 12;
03719
03720 val = (adj - sample[1]) * scale;
03721 sample[1] = (val * (sf >> 12) + ((val * (sf & 4095) + 2048) >> 12)) >> 12;
03722
03723 val = (adj - sample[2]) * scale;
03724 sample[2] = (val * (sf >> 12) + ((val * (sf & 4095) + 2048) >> 12)) >> 12;
03725 }
03726
03727 void plm_audio_idct36(int s[32][3], int ss, float *d, int dp) {
03728     float t01, t02, t03, t04, t05, t06, t07, t08, t09, t10, t11, t12, t13, t14, t15, t16, t17, t18, t19,
03729     t20, t21, t22,
03730     t23, t24, t25, t26, t27, t28, t29, t30, t31, t32, t33;
03731     t01 = (float)(s[0][ss] + s[31][ss]);
03732     t02 = (float)(s[0][ss] - s[31][ss]) * 0.500602998235f;
03733     t03 = (float)(s[1][ss] + s[30][ss]);
03734     t04 = (float)(s[1][ss] - s[30][ss]) * 0.505470959898f;
03735     t05 = (float)(s[2][ss] + s[29][ss]);
03736     t06 = (float)(s[2][ss] - s[29][ss]) * 0.515447309923f;
03737     t07 = (float)(s[3][ss] + s[28][ss]);
03738     t08 = (float)(s[3][ss] - s[28][ss]) * 0.53104259109f;
03739     t09 = (float)(s[4][ss] + s[27][ss]);
03740     t10 = (float)(s[4][ss] - s[27][ss]) * 0.553103896034f;
03741     t11 = (float)(s[5][ss] + s[26][ss]);
03742     t12 = (float)(s[5][ss] - s[26][ss]) * 0.582934968206f;
03743     t13 = (float)(s[6][ss] + s[25][ss]);
03744     t14 = (float)(s[6][ss] - s[25][ss]) * 0.622504123036f;
03745     t15 = (float)(s[7][ss] + s[24][ss]);
03746     t16 = (float)(s[7][ss] - s[24][ss]) * 0.674808341455f;
03747     t17 = (float)(s[8][ss] + s[23][ss]);
03748     t18 = (float)(s[8][ss] - s[23][ss]) * 0.744536271002f;
03749     t19 = (float)(s[9][ss] + s[22][ss]);
03750     t20 = (float)(s[9][ss] - s[22][ss]) * 0.839349645416f;
03751     t21 = (float)(s[10][ss] + s[21][ss]);
03752     t22 = (float)(s[10][ss] - s[21][ss]) * 0.972568237862f;
03753     t23 = (float)(s[11][ss] + s[20][ss]);
03754     t24 = (float)(s[11][ss] - s[20][ss]) * 1.16943993343f;
03755     t25 = (float)(s[12][ss] + s[19][ss]);
03756     t26 = (float)(s[12][ss] - s[19][ss]) * 1.48416461631f;
03757     t27 = (float)(s[13][ss] + s[18][ss]);
03758     t28 = (float)(s[13][ss] - s[18][ss]) * 2.05778100995f;
03759     t29 = (float)(s[14][ss] + s[17][ss]);
03760     t30 = (float)(s[14][ss] - s[17][ss]) * 3.40760841847f;
03761     t31 = (float)(s[15][ss] + s[16][ss]);
03762     t32 = (float)(s[15][ss] - s[16][ss]) * 10.1900081235f;
03763
03764     t33 = t01 + t31;
03765     t31 = (t01 - t31) * 0.502419286188f;
03766     t01 = t03 + t29;
03767     t29 = (t03 - t29) * 0.52249861494f;
03768     t03 = t05 + t27;
03769     t27 = (t05 - t27) * 0.566944034816f;
03770     t05 = t07 + t25;
03771     t25 = (t07 - t25) * 0.64682178336f;
03772     t07 = t09 + t23;
03773     t23 = (t09 - t23) * 0.788154623451f;
03774     t09 = t11 + t21;
03775     t21 = (t11 - t21) * 1.06067768599f;
03776     t11 = t13 + t19;
03777     t19 = (t13 - t19) * 1.72244709824f;
03778     t13 = t15 + t17;
03779     t17 = (t15 - t17) * 5.10114861869f;
03780     t15 = t33 + t13;
03781     t13 = (t33 - t13) * 0.509795579104f;
03782     t33 = t01 + t11;
03783     t01 = (t01 - t11) * 0.601344886935f;
03784     t11 = t03 + t09;
03785     t09 = (t03 - t09) * 0.899976223136f;
03786     t03 = t05 + t07;
03787     t07 = (t05 - t07) * 2.56291544774f;
03788     t05 = t15 + t03;
03789     t15 = (t15 - t03) * 0.541196100146f;
03790     t03 = t33 + t11;
03791     t11 = (t33 - t11) * 1.30656296488f;
03792     t33 = t05 + t03;
03793     t05 = (t05 - t03) * 0.707106781187f;

```

```
03794 t03 = t15 + t11;
03795 t15 = (t15 - t11) * 0.707106781187f;
03796 t03 += t15;
03797 t11 = t13 + t07;
03798 t13 = (t13 - t07) * 0.541196100146f;
03799 t07 = t01 + t09;
03800 t09 = (t01 - t09) * 1.30656296488f;
03801 t01 = t11 + t07;
03802 t07 = (t11 - t07) * 0.707106781187f;
03803 t11 = t13 + t09;
03804 t13 = (t13 - t09) * 0.707106781187f;
03805 t11 += t13;
03806 t01 += t11;
03807 t11 += t07;
03808 t07 += t13;
03809 t09 = t31 + t17;
03810 t31 = (t31 - t17) * 0.509795579104f;
03811 t17 = t29 + t19;
03812 t29 = (t29 - t19) * 0.601344886935f;
03813 t19 = t27 + t21;
03814 t21 = (t27 - t21) * 0.899976223136f;
03815 t27 = t25 + t23;
03816 t23 = (t25 - t23) * 2.56291544774f;
03817 t25 = t09 + t27;
03818 t09 = (t09 - t27) * 0.541196100146f;
03819 t27 = t17 + t19;
03820 t19 = (t17 - t19) * 1.30656296488f;
03821 t17 = t25 + t27;
03822 t27 = (t25 - t27) * 0.707106781187f;
03823 t25 = t09 + t19;
03824 t19 = (t09 - t19) * 0.707106781187f;
03825 t25 += t19;
03826 t09 = t31 + t23;
03827 t31 = (t31 - t23) * 0.541196100146f;
03828 t23 = t29 + t21;
03829 t21 = (t29 - t21) * 1.30656296488f;
03830 t29 = t09 + t23;
03831 t23 = (t09 - t23) * 0.707106781187f;
03832 t09 = t31 + t21;
03833 t31 = (t31 - t21) * 0.707106781187f;
03834 t09 += t31;
03835 t29 += t09;
03836 t09 += t23;
03837 t23 += t31;
03838 t17 += t29;
03839 t29 += t25;
03840 t25 += t09;
03841 t09 += t27;
03842 t27 += t23;
03843 t23 += t19;
03844 t19 += t31;
03845 t21 = t02 + t32;
03846 t02 = (t02 - t32) * 0.502419286188f;
03847 t32 = t04 + t30;
03848 t04 = (t04 - t30) * 0.52249861494f;
03849 t30 = t06 + t28;
03850 t28 = (t06 - t28) * 0.566944034816f;
03851 t06 = t08 + t26;
03852 t08 = (t08 - t26) * 0.64682178336f;
03853 t26 = t10 + t24;
03854 t10 = (t10 - t24) * 0.788154623451f;
03855 t24 = t12 + t22;
03856 t22 = (t12 - t22) * 1.06067768599f;
03857 t12 = t14 + t20;
03858 t20 = (t14 - t20) * 1.72244709824f;
03859 t14 = t16 + t18;
03860 t16 = (t16 - t18) * 5.10114861869f;
03861 t18 = t21 + t14;
03862 t14 = (t21 - t14) * 0.509795579104f;
03863 t21 = t32 + t12;
03864 t32 = (t32 - t12) * 0.601344886935f;
03865 t12 = t30 + t24;
03866 t24 = (t30 - t24) * 0.899976223136f;
03867 t30 = t06 + t26;
03868 t26 = (t06 - t26) * 2.56291544774f;
03869 t06 = t18 + t30;
03870 t18 = (t18 - t30) * 0.541196100146f;
03871 t30 = t21 + t12;
03872 t12 = (t21 - t12) * 1.30656296488f;
03873 t21 = t06 + t30;
03874 t30 = (t06 - t30) * 0.707106781187f;
03875 t06 = t18 + t12;
03876 t12 = (t18 - t12) * 0.707106781187f;
03877 t06 += t12;
03878 t18 = t14 + t26;
03879 t26 = (t14 - t26) * 0.541196100146f;
03880 t14 = t32 + t24;
```

```
03881 t24 = (t32 - t24) * 1.30656296488f;
03882 t32 = t18 + t14;
03883 t14 = (t18 - t14) * 0.707106781187f;
03884 t18 = t26 + t24;
03885 t24 = (t26 - t24) * 0.707106781187f;
03886 t18 += t24;
03887 t32 += t18;
03888 t18 += t14;
03889 t26 = t14 + t24;
03890 t14 = t02 + t16;
03891 t02 = (t02 - t16) * 0.509795579104f;
03892 t16 = t04 + t20;
03893 t04 = (t04 - t20) * 0.601344886935f;
03894 t20 = t28 + t22;
03895 t22 = (t28 - t22) * 0.899976223136f;
03896 t28 = t08 + t10;
03897 t10 = (t08 - t10) * 2.56291544774f;
03898 t08 = t14 + t28;
03899 t14 = (t14 - t28) * 0.541196100146f;
03900 t28 = t16 + t20;
03901 t20 = (t16 - t20) * 1.30656296488f;
03902 t16 = t08 + t28;
03903 t28 = (t08 - t28) * 0.707106781187f;
03904 t08 = t14 + t20;
03905 t20 = (t14 - t20) * 0.707106781187f;
03906 t08 += t20;
03907 t14 = t02 + t10;
03908 t02 = (t02 - t10) * 0.541196100146f;
03909 t10 = t04 + t22;
03910 t22 = (t04 - t22) * 1.30656296488f;
03911 t04 = t14 + t10;
03912 t10 = (t14 - t10) * 0.707106781187f;
03913 t14 = t02 + t22;
03914 t02 = (t02 - t22) * 0.707106781187f;
03915 t14 += t02;
03916 t04 += t14;
03917 t14 += t10;
03918 t10 += t02;
03919 t16 += t04;
03920 t04 += t08;
03921 t08 += t14;
03922 t14 += t28;
03923 t28 += t10;
03924 t10 += t20;
03925 t20 += t02;
03926 t21 += t16;
03927 t16 += t32;
03928 t32 += t04;
03929 t04 += t06;
03930 t06 += t08;
03931 t08 += t18;
03932 t18 += t14;
03933 t14 += t30;
03934 t30 += t28;
03935 t28 += t26;
03936 t26 += t10;
03937 t10 += t12;
03938 t12 += t20;
03939 t20 += t24;
03940 t24 += t02;
03941
03942 d[dp + 48] = -t33;
03943 d[dp + 49] = d[dp + 47] = -t21;
03944 d[dp + 50] = d[dp + 46] = -t17;
03945 d[dp + 51] = d[dp + 45] = -t16;
03946 d[dp + 52] = d[dp + 44] = -t01;
03947 d[dp + 53] = d[dp + 43] = -t32;
03948 d[dp + 54] = d[dp + 42] = -t29;
03949 d[dp + 55] = d[dp + 41] = -t04;
03950 d[dp + 56] = d[dp + 40] = -t03;
03951 d[dp + 57] = d[dp + 39] = -t06;
03952 d[dp + 58] = d[dp + 38] = -t25;
03953 d[dp + 59] = d[dp + 37] = -t08;
03954 d[dp + 60] = d[dp + 36] = -t11;
03955 d[dp + 61] = d[dp + 35] = -t18;
03956 d[dp + 62] = d[dp + 34] = -t09;
03957 d[dp + 63] = d[dp + 33] = -t14;
03958 d[dp + 32] = -t05;
03959 d[dp + 0] = t05;
03960 d[dp + 31] = -t30;
03961 d[dp + 1] = t30;
03962 d[dp + 30] = -t27;
03963 d[dp + 2] = t27;
03964 d[dp + 29] = -t28;
03965 d[dp + 3] = t28;
03966 d[dp + 28] = -t07;
03967 d[dp + 4] = t07;
```

```

03968 d[dp + 27] = -t26;
03969 d[dp + 5] = t26;
03970 d[dp + 26] = -t23;
03971 d[dp + 6] = t23;
03972 d[dp + 25] = -t10;
03973 d[dp + 7] = t10;
03974 d[dp + 24] = -t15;
03975 d[dp + 8] = t15;
03976 d[dp + 23] = -t12;
03977 d[dp + 9] = t12;
03978 d[dp + 22] = -t19;
03979 d[dp + 10] = t19;
03980 d[dp + 21] = -t20;
03981 d[dp + 11] = t20;
03982 d[dp + 20] = -t13;
03983 d[dp + 12] = t13;
03984 d[dp + 19] = -t24;
03985 d[dp + 13] = t24;
03986 d[dp + 18] = -t31;
03987 d[dp + 14] = t31;
03988 d[dp + 17] = -t02;
03989 d[dp + 15] = t02;
03990 d[dp + 16] = 0.0;
03991 }
03992
03993 #endif // PL_MPEG_IMPLEMENTATION

```

## 6.5 video.h

```

00001 #include "../core/include/subsystems/screen.h"
00002 #include "pl_mpeg.h"
00003 #include <string>
00004
00006 void set_video(const std::string &filename);
00008 void video_restart();
00009 // plays the video set by set_video()
00010 // because of memory constraints we're limited to one video at a time
00011 class VideoPlayer : public screen::Page {
00012 public:
00013 VideoPlayer();
00014 void update(bool was_pressed, int x, int y) override;
00015
00016 void draw(vex::brain::lcd &screen, bool first_draw, unsigned int frame_number) override;
00017 };

```

## 6.6 layout.h

```

00001 #include <cmath>
00002 #include <functional>
00003
00004 struct SliderCfg {
00005 double &val;
00006 double min;
00007 double max;
00008 };

```

## 6.7 lift.h

```

00001 #pragma once
00002
00003 #include "../core/include/utils/controls/pid.h"
00004 #include "vex.h"
00005 #include <atomic>
00006 #include <iostream>
00007 #include <map>
00008 #include <vector>
00009
00010 using namespace vex;
00011 using namespace std;
00012
00021 template <typename T> class Lift {
00022 public:
00029 struct lift_cfg_t {
00030     double up_speed, down_speed;
00031     double softstop_up, softstop_down;

```

```
00032
00033     PID::pid_config_t lift_pid_cfg;
00034 };
00035
00060     Lift(motor_group &lift_motors, lift_cfg_t &lift_cfg, map<T, double> &setpoint_map, limit
00061     *homing_switch = NULL)
00061     : lift_motors(lift_motors), cfg(lift_cfg), lift_pid(cfg.lift_pid_cfg),
00062     setpoint_map(setpoint_map),
00062     homing_switch(homing_switch) {
00063
00064     is_async = true;
00065     setpoint = 0;
00066
00067     // Create a background task that is constantly updating the lift PID, if
00068     // requested. Set once, and forget.
00069     task t(
00070         [](void *ptr) {
00071             Lift &lift = *((Lift *)ptr);
00072
00073             while (true) {
00074                 if (lift.get_async())
00075                     lift.hold();
00076
00077                 vexDelay(50);
00078             }
00079
00080             return 0;
00081         },
00082         this);
00083     }
00084
00093 void control_continuous(bool up_ctrl, bool down_ctrl) {
00094     static timer tmr;
00095
00096     double cur_pos = 0;
00097
00098     // Check if there's a hook for a custom sensor. If not, use the motors.
00099     if (get_sensor == NULL)
00100         cur_pos = lift_motors.position(rev);
00101     else
00102         cur_pos = get_sensor();
00103
00104     if (up_ctrl && cur_pos < cfg.softstop_up) {
00105         lift_motors.spin(directionType::fwd, cfg.up_speed, volt);
00106         setpoint = cur_pos + .3;
00107
00108         // std::cout << "DEBUG OUT: UP " << setpoint << ", " << tmr.time(sec) <<
00109         // ", " << cfg.down_speed << "\n";
00110
00111         // Disable the PID while going UP.
00112         is_async = false;
00113     } else if (down_ctrl && cur_pos > cfg.softstop_down) {
00114         // Lower the lift slowly, at a rate defined by down_speed
00115         if (setpoint > cfg.softstop_down)
00116             setpoint = setpoint - (tmr.time(sec) * cfg.down_speed);
00117         // std::cout << "DEBUG OUT: DOWN " << setpoint << ", " << tmr.time(sec) <<
00118         // ", " << cfg.down_speed << "\n";
00119         is_async = true;
00120     } else {
00121         // Hold the lift at the last setpoint
00122         is_async = true;
00123     }
00124
00125     tmr.reset();
00126 }
00127
00136 void control_manual(bool up_btn, bool down_btn, int volt_up, int volt_down) {
00137     static bool down_hold = false;
00138     static bool init = true;
00139
00140     // Allow for setting position while still calling this function
00141     if (init || up_btn || down_btn) {
00142         init = false;
00143         is_async = false;
00144     }
00145
00146     double rev = lift_motors.position(rotationUnits::rev);
00147
00148     if (rev < cfg.softstop_down && down_btn)
00149         down_hold = true;
00150     else if (!down_btn)
00151         down_hold = false;
00152
00153     if (up_btn && rev < cfg.softstop_up)
00154         lift_motors.spin(directionType::fwd, volt_up, voltageUnits::volt);
00155     else if (down_btn && rev > cfg.softstop_down && !down_hold)
00156         lift_motors.spin(directionType::rev, volt_down, voltageUnits::volt);
```

```

00157     else
00158         lift_motors.spin(directionType::fwd, 0, voltageUnits::volt);
00159     }
00160
00173 void control_setpoints(bool up_step, bool down_step, vector<T> pos_list) {
00174     // Make sure inputs are only processed on the rising edge of the button
00175     static bool up_last = up_step, down_last = down_step;
00176
00177     bool up_rising = up_step && !up_last;
00178     bool down_rising = down_step && !down_last;
00179
00180     up_last = up_step;
00181     down_last = down_step;
00182
00183     static int cur_index = 0;
00184
00185     // Avoid an index overflow. Shouldn't happen unless the user changes
00186     // pos_list between calls.
00187     if (cur_index >= pos_list.size())
00188         cur_index = pos_list.size() - 1;
00189
00190     // Increment or decrement the index of the list, bringing it up or down.
00191     if (up_rising && cur_index < (pos_list.size() - 1))
00192         cur_index++;
00193     else if (down_rising && cur_index > 0)
00194         cur_index--;
00195
00196     // Set the lift to hold the position in the background with the PID loop
00197     set_position(pos_list[cur_index]);
00198     is_async = true;
00199 }
00200
00209 bool set_position(T pos) {
00210     this->setpoint = setpoint_map[pos];
00211     is_async = true;
00212
00213     return (lift_pid.get_target() == this->setpoint) && lift_pid.is_on_target();
00214 }
00215
00223 bool set_setpoint(double val) {
00224     this->setpoint = val;
00225     return (lift_pid.get_target() == this->setpoint) && lift_pid.is_on_target();
00226 }
00227
00231 double get_setpoint() { return this->setpoint; }
00232
00237 void hold() {
00238     lift_pid.set_target(setpoint);
00239     // std::cout << "DEBUG OUT: SETPOINT " << setpoint << "\n";
00240
00241     if (get_sensor != NULL)
00242         lift_pid.update(get_sensor());
00243     else
00244         lift_pid.update(lift_motors.position(rev));
00245
00246     // std::cout << "DEBUG OUT: ROTATION " << lift_motors.rotation(rev) <<
00247     // "\n\n";
00248
00249     lift_motors.spin(fwd, lift_pid.get(), volt);
00250 }
00251
00257 void home() {
00258     static timer tmr;
00259     tmr.reset();
00260
00261     while (tmr.time(sec) < 3) {
00262         lift_motors.spin(directionType::rev, 6, volt);
00263
00264         if (homing_switch == NULL && lift_motors.current(currentUnits::amp) > 1.5)
00265             break;
00266         else if (homing_switch != NULL && homing_switch->pressing())
00267             break;
00268     }
00269
00270     if (reset_sensor != NULL)
00271         reset_sensor();
00272
00273     lift_motors.resetPosition();
00274     lift_motors.stop();
00275 }
00276
00280 bool get_async() { return is_async; }
00281
00288 void set_async(bool val) { this->is_async = val; }
00289
00298 void set_sensor_function(double (*fn_ptr)(void)) { this->get_sensor = fn_ptr; }
00299

```

```

00305     void set_sensor_reset(void (*fn_ptr)(void)) { this->reset_sensor = fn_ptr; }
00306
00307 private:
00308     motor_group &lift_motors;
00309     lift_cfg_t &cfg;
00310     PID lift_pid;
00311     map<T, double> &setpoint_map;
00312     limit *homing_switch;
00313
00314     atomic<double> setpoint;
00315     atomic<bool> is_async;
00316
00317     double (*get_sensor)(void) = NULL;
00318     void (*reset_sensor)(void) = NULL;
00319 };

```

## 6.8 mecanum\_drive.h

```

00001 #pragma once
00002
00003 #include "../core/include/utils/controls/pid.h"
00004 #include "vex.h"
00005
00006 #ifndef PI
00007 #define PI 3.141592654
00008 #endif
00009
00015 class MecanumDrive {
00016
00017 public:
00021     struct mecanumdrive_config_t {
00022         // PID configurations for autonomous driving
00023         PID::pid_config_t drive_pid_conf;
00024         PID::pid_config_t drive_gyro_pid_conf;
00025         PID::pid_config_t turn_pid_conf;
00026
00027         // Diameter of the mecanum wheels
00028         double drive_wheel_diam;
00029
00030         // Diameter of the perpendicular undriven encoder wheel
00031         double lateral_wheel_diam;
00032
00033         // Width between the center of the left and right wheels
00034         double wheelbase_width;
00035     };
00036
00040     MecanumDrive(vex::motor &left_front, vex::motor &right_front, vex::motor &left_rear, vex::motor
00041         &right_rear,
00042             vex::rotation *lateral_wheel = NULL, vex::inertial *imu = NULL, mecanumdrive_config_t
00043             *config = NULL);
00044
00053     void drive_raw(double direction_deg, double magnitude, double rotation);
00054
00067     void drive(double left_y, double left_x, double right_x, int power = 2);
00068
00084     bool auto_drive(double inches, double direction, double speed, bool gyro_correction = true);
00085
00097     bool auto_turn(double degrees, double speed, bool ignore_imu = false);
00098
00099 private:
00100     vex::motor &left_front, &right_front, &left_rear, &right_rear;
00101
00102     mecanumdrive_config_t *config;
00103     vex::rotation *lateral_wheel;
00104     vex::inertial *imu;
00105
00106     PID *drive_pid = NULL;
00107     PID *drive_gyro_pid = NULL;
00108     PID *turn_pid = NULL;
00109
00110     bool init = true;
00111 };

```

## 6.9 odometry\_3wheel.h

```

00001 #pragma once
00002 #include "../core/include/subsystems/custom_encoder.h"
00003 #include "../core/include/subsystems/odometry/odometry_base.h"
00004 #include "../core/include/subsystems/tank_drive.h"

```

```

00005
00034 class Odometry3Wheel : public OdometryBase {
00035 public:
00041     typedef struct {
00042         double wheelbase_dist;
00044         double off_axis_center_dist;
00046         double wheel_diam;
00048     } odometry3wheel_cfg_t;
00049
00059     Odometry3Wheel(CustomEncoder &lside_fwd, CustomEncoder &rside_fwd, CustomEncoder &off_axis,
00060             odometry3wheel_cfg_t &cfg,
00061             bool is_async = true);
00068     pose_t update() override;
00069
00078     void tune(vex::controller &con, TankDrive &drive);
00079
00080 private:
00097     static pose_t calculate_new_pos(double lside_delta_deg, double rside_delta_deg, double
00098             offax_delta_deg,
00099             pose_t old_pos, odometry3wheel_cfg_t cfg);
00100
00101     CustomEncoder &lside_fwd, &rside_fwd, &off_axis;
00101     odometry3wheel_cfg_t &cfg;
00102 };

```

## 6.10 odometry\_base.h

```

00001 #pragma once
00002
00003 #include "../core/include/robot_specs.h"
00004 #include "../core/include/utils/command_structure/auto_command.h"
00005 #include "../core/include/utils/geometry.h"
00006 #include "vex.h"
00007
00008 #ifndef PI
00009 #define PI 3.141592654
00010 #endif
00011
00026 class OdometryBase {
00027 public:
00034     OdometryBase(bool is_async);
00035
00040     pose_t get_position(void);
00041
00046     virtual void set_position(const pose_t &newpos = zero_pos);
00047     AutoCommand *SetPositionCmd(const pose_t &newpos = zero_pos);
00053     virtual pose_t update() = 0;
00054
00062     static int background_task(void *ptr);
00063
00069     void end_async();
00070
00077     static double pos_diff(pose_t start_pos, pose_t end_pos);
00078
00085     static double rot_diff(pose_t pos1, pose_t pos2);
00086
00096     static double smallest_angle(double start_deg, double end_deg);
00097
00099     bool end_task = false;
00100
00105     double get_speed();
00106
00111     double get_accel();
00112
00117     double get_angular_speed_deg();
00118
00123     double get_angular_accel_deg();
00124
00128     inline static constexpr pose_t zero_pos = {.x = 0.0L, .y = 0.0L, .rot = 90.0L};
00129
00130 protected:
00134     vex::task *handle;
00135
00139     vex::mutex mut;
00140
00144     pose_t current_pos;
00145
00146     double speed;
00147     double accel;
00148     double ang_speed_deg;
00149     double ang_accel_deg;
00151 };

```

## 6.11 odometry\_tank.h

```

00001 #pragma once
00002
00003 #include "../core/include/subsystems/custom_encoder.h"
00004 #include "../core/include/subsystems/odometry/odometry_base.h"
00005 #include "../core/include/utils/geometry.h"
00006 #include "../core/include/utils/moving_average.h"
00007 #include "../core/include/utils/vector2d.h"
00008
00009 #include "../core/include/robot_specs.h"
00010
00011 static int background_task(void *odom_obj);
00012
00020 class OdometryTank : public OdometryBase {
00021 public:
00033     OdometryTank(vex::motor_group &left_side, vex::motor_group &right_side, robot_specs_t &config,
00034             vex::inertial *imu = NULL, bool is_async = true);
00035
00048     OdometryTank(CustomEncoder &left_custom_enc, CustomEncoder &right_custom_enc, robot_specs_t &config,
00049             vex::inertial *imu = NULL, bool is_async = true);
00050
00063     OdometryTank(vex::encoder &left_vex_enc, vex::encoder &right_vex_enc, robot_specs_t &config,
00064             vex::inertial *imu = NULL, bool is_async = true);
00065
00070     pose_t update() override;
00071
00076     void set_position(const pose_t &newpos = zero_pos) override;
00077
00078 private:
00083     static pose_t calculate_new_pos(robot_specs_t &config, pose_t &stored_info, double lside_diff,
00084         double rside_diff,
00085             double angle_deg);
00086
00087     vex::motor_group *left_side, *right_side;
00088     CustomEncoder *left_custom_enc, *right_custom_enc;
00089     vex::encoder *left_vex_enc, *right_vex_enc;
00090     vex::inertial *imu;
00091     robot_specs_t &config;
00092
00092     double rotation_offset = 0;
00093     ExponentialMovingAverage ema = ExponentialMovingAverage(3);
00094 };

```

## 6.12 screen.h

```

00001 #pragma once
00002 #include "../core/include/subsystems/odometry/odometry_base.h"
00003 #include "../core/include/utils/controls/pid.h"
00004 #include "../core/include/utils/controls/pidff.h"
00005 #include "../core/include/utils/graph_drawer.h"
00006 #include "vex.h"
00007 #include <cassert>
00008 #include <functional>
00009 #include <map>
00010 #include <vector>
00011
00012 namespace screen {
00015 class ButtonWidget {
00016 public:
00021     ButtonWidget(std::function<void(void)> onpress, Rect rect, std::string name)
00022         : onpress(onpress), rect(rect), name(name) {}
00027     ButtonWidget(void (*onpress)(), Rect rect, std::string name) : onpress(onpress), rect(rect),
00028         name(name) {}
00028
00034     bool update(bool was_pressed, int x, int y);
00036     void draw(vex::brain::lcd &, bool first_draw, unsigned int frame_number);
00037
00038 private:
00039     std::function<void(void)> onpress;
00040     Rect rect;
00041     std::string name = "";
00042     bool was_pressed_last = false;
00043 };
00044
00047 class SliderWidget {
00048 public:
00055     SliderWidget(double &val, double low, double high, Rect rect, std::string name)
00056         : value(val), low(low), high(high), rect(rect), name(name) {}
00057
00063     bool update(bool was_pressed, int x, int y);
00065     void draw(vex::brain::lcd &, bool first_draw, unsigned int frame_number);
00066

```

```
00067 private:
00068     double &value;
00069
00070     double low;
00071     double high;
00072
00073     Rect rect;
00074     std::string name = "";
00075 };
00076
00077 struct WidgetConfig;
00078
00079 struct SliderConfig {
00080     double &val;
00081     double low;
00082     double high;
00083 };
00084 struct ButtonConfig {
00085     std::function<void()> onclick;
00086 };
00087 struct CheckboxConfig {
00088     std::function<void(bool)> onupdate;
00089 };
00090 struct LabelConfig {
00091     std::string label;
00092 };
00093
00094 struct TextConfig {
00095     std::function<std::string()> text;
00096 };
00097 struct SizedWidget {
00098     int size;
00099     WidgetConfig &widget;
00100 };
00101 struct WidgetConfig {
00102     enum Type {
00103         Col,
00104         Row,
00105         Slider,
00106         Button,
00107         Checkbox,
00108         Label,
00109         Text,
00110         Graph,
00111     };
00112     Type type;
00113     union {
00114         std::vector<SizedWidget> widgets;
00115         SliderConfig slider;
00116         ButtonConfig button;
00117         CheckboxConfig checkbox;
00118         LabelConfig label;
00119         TextConfig text;
00120         GraphDrawer *graph;
00121     } config;
00122 };
00123
00124 class Page;
00125 class Page {
00126     public:
00127     virtual void update(bool was_pressed, int x, int y);
00128     virtual void draw(vex::brain::lcd &screen, bool first_draw, unsigned int frame_number);
00129 };
00130
00131 struct ScreenRect {
00132     uint32_t x1;
00133     uint32_t y1;
00134     uint32_t x2;
00135     uint32_t y2;
00136 };
00137 void draw_widget(WidgetConfig &widget, ScreenRect rect);
00138
00139 class WidgetPage : public Page {
00140     public:
00141         WidgetPage(WidgetConfig &cfg) : base_widget(cfg) {}
00142         void update(bool was_pressed, int x, int y) override;
00143
00144         void draw(vex::brain::lcd &, bool first_draw, unsigned int frame_number) override {
00145             draw_widget(base_widget, {.x1 = 20, .y1 = 0, .x2 = 440, .y2 = 240});
00146         }
00147
00148         private:
00149             WidgetConfig &base_widget;
00150 };
00151
00152 void start_screen(vex::brain::lcd &screen, std::vector<Page *> pages, int first_page = 0);
00153
```

```
00177 void next_page();
00178 void prev_page();
00179 void goto_page(size_t page);
00180
00183 void stop_screen();
00184
00186 using update_func_t = std::function<void(bool, int, int)>;
00187
00189 using draw_func_t = std::function<void(vex::brain::lcd &screen, bool, unsigned int)>;
00190
00192 class StatsPage : public Page {
00193 public:
00196     StatsPage(std::map<std::string, vex::motor &> motors);
00198     void update(bool was_pressed, int x, int y) override;
00200     void draw(vex::brain::lcd &, bool first_draw, unsigned int frame_number) override;
00201
00202 private:
00203     void draw_motor_stats(const std::string &name, vex::motor &mot, unsigned int frame, int x, int y,
00204                           vex::brain::lcd &scr);
00205
00206     std::map<std::string, vex::motor &> motors;
00207     static const int y_start = 0;
00208     static const int per_column = 4;
00209     static const int row_height = 20;
00210     static const int row_width = 200;
00211 };
00212
00217 class OdometryPage : public Page {
00218 public:
00219     OdometryPage(OdometryBase &odom, double robot_width, double robot_height, bool do_trail);
00220     void update(bool was_pressed, int x, int y) override;
00222     void draw(vex::brain::lcd &, bool first_draw, unsigned int frame_number) override;
00223
00234 private:
00235     static const int path_len = 40;
00236     static constexpr char const *field_filename = "vex_field_240p.png";
00237
00238     OdometryBase &odom;
00239     double robot_width;
00240     double robot_height;
00241     uint8_t *buf = nullptr;
00242     int buf_size = 0;
00243     pose_t path[path_len];
00244     int path_index = 0;
00245     bool do_trail;
00246     GraphDrawer velocity_graph;
00247 };
00248
00251 class FunctionPage : public Page {
00252 public:
00253     FunctionPage(update_func_t update_f, draw_func_t draw_t);
00255     void update(bool was_pressed, int x, int y) override;
00261     void draw(vex::brain::lcd &, bool first_draw, unsigned int frame_number) override;
00262
00263 private:
00264     update_func_t update_f;
00265     draw_func_t draw_f;
00266 };
00267
00269 class PIDPage : public Page {
00270 public:
00278     PIDPage(
00279         PID &pid, std::string name, std::function<void(void)> onchange = []() {});
00280     PIDPage(
00281         PIDFF &pidff, std::string name, std::function<void(void)> onchange = []() {});
00282
00284     void update(bool was_pressed, int x, int y) override;
00286     void draw(vex::brain::lcd &, bool first_draw, unsigned int frame_number) override;
00287
00288 private:
00290     void zero_d_f() { cfg.d = 0; }
00292     void zero_i_f() { cfg.i = 0; }
00293
00294     PID::pid_config_t &cfg;
00295     PID &pid;
00296     const std::string name;
00297     std::function<void(void)> onchange;
00298
00299     SliderWidget p_slider;
00300     SliderWidget i_slider;
00301     SliderWidget d_slider;
00302     ButtonWidget zero_i;
00303     ButtonWidget zero_d;
00304
00305     GraphDrawer graph;
00306 };
00307
```

```
00308 } // namespace screen
```

## 6.13 tank\_drive.h

```
00001 #pragma once
00002
00003 #ifndef PI
00004 #define PI 3.141592654
00005 #endif
00006
00007 #include "../core/include/robot_specs.h"
00008 #include "../core/include/subsystems/odometry/odometry_tank.h"
00009 #include "../core/include/utils/command_structure/auto_command.h"
00010 #include "../core/include/utils/controls/feedback_base.h"
00011 #include "../core/include/utils/controls/pid.h"
00012 #include "../core/include/utils/pure_pursuit.h"
00013 #include "vex.h"
00014 #include <vector>
00015
00016 using namespace vex;
00017
00023 class TankDrive {
00024 public:
00025     enum class BrakeType {
00026         None,
00027         ZeroVelocity,
00028         Smart,
00029     };
00031 };
00041 TankDrive(motor_group &left_motors, motor_group &right_motors, robot_specs_t &config, OdometryBase
*odom = NULL);
00042
00043     AutoCommand *DriveToPointCmd(point_t pt, vex::directionType dir = vex::forward, double max_speed =
1.0,
00044                                     double end_speed = 0.0);
00045     AutoCommand *DriveToPointCmd(Feedback &fb, point_t pt, vex::directionType dir = vex::forward, double
max_speed = 1.0,
00046                                     double end_speed = 0.0);
00047
00048     AutoCommand *DriveForwardCmd(double dist, vex::directionType dir = vex::forward, double max_speed =
1.0,
00049                                     double end_speed = 0.0);
00050     AutoCommand *DriveForwardCmd(Feedback &fb, double dist, vex::directionType dir = vex::forward,
double
max_speed = 1.0,
00051                                     double end_speed = 0.0);
00052
00053     AutoCommand *TurnToHeadingCmd(double heading, double max_speed = 1.0, double end_speed = 0.0);
00054     AutoCommand *TurnToHeadingCmd(Feedback &fb, double heading, double max_speed = 1.0, double end_speed
= 0.0);
00055
00056     AutoCommand *TurnToPointCmd(double x, double y, vex::directionType dir = vex::directionType::fwd,
00057                                     double max_speed = 1.0, double end_speed = 0.0);
00058
00059     AutoCommand *TurnDegreesCmd(double degrees, double max_speed = 1.0, double start_speed = 0.0);
00060     AutoCommand *TurnDegreesCmd(Feedback &fb, double degrees, double max_speed = 1.0, double end_speed =
0.0);
00061
00062     AutoCommand *PurePursuitCmd(PurePursuit::Path path, directionType dir, double max_speed = 1, double
end_speed = 0);
00063     AutoCommand *PurePursuitCmd(Feedback &feedback, PurePursuit::Path path, directionType dir, double
max_speed = 1,
00064                                     double end_speed = 0);
00065     Condition *DriveStalledCondition(double stall_time);
00066     AutoCommand *DriveTankCmd(double left, double right);
00067
00071     void stop();
00072
00083     void drive_tank(double left, double right, int power = 1, BrakeType bt = BrakeType::None);
00089     void drive_tank_raw(double left, double right);
00090
00102     void drive_arcade(double forward_back, double left_right, int power = 1, BrakeType bt =
BrakeType::None);
00103
00119     bool drive_forward(double inches, directionType dir, Feedback &feedback, double max_speed = 1,
double end_speed = 0);
00120
00133     bool drive_forward(double inches, directionType dir, double max_speed = 1, double end_speed = 0);
00134
00148     bool turn_degrees(double degrees, Feedback &feedback, double max_speed = 1, double end_speed = 0);
00149
00163     bool turn_degrees(double degrees, double max_speed = 1, double end_speed = 0);
00164
00180     bool drive_to_point(double x, double y, vex::directionType dir, Feedback &feedback, double max_speed
= 1,
```

```

00181             double end_speed = 0);
00182
00197     bool drive_to_point(double x, double y, vex::directionType dir, double max_speed = 1, double
00198     end_speed = 0);
00199
00211     bool turn_to_heading(double heading_deg, Feedback &feedback, double max_speed = 1, double end_speed
00212     = 0);
00222     bool turn_to_heading(double heading_deg, double max_speed = 1, double end_speed = 0);
00223
00227     void reset_auto();
00228
00239     static double modify_inputs(double input, int power = 2);
00240
00255     bool pure_pursuit(PurePursuit::Path path, directionType dir, Feedback &feedback, double max_speed =
00256     1,
00257             double end_speed = 0);
00257
00273     bool pure_pursuit(PurePursuit::Path path, directionType dir, double max_speed = 1, double end_speed
00274     = 0);
00274
00275     private:
00276     motor_group &left_motors;
00277     motor_group &right_motors;
00278
00279     PID correction_pid;
00281     Feedback *drive_default_feedback = NULL;
00282     Feedback *turn_default_feedback = NULL;
00283
00284     OdometryBase *odometry;
00286
00287     robot_specs_t &config;
00289
00290     bool func_initialized = false;
00293     bool is_pure_pursuit = false;
00294 };

```

## 6.14 auto\_chooser.h

```

00001 #pragma once
00002 #include "../core/include/subsystems/screen.h"
00003 #include "../core/include/utils/geometry.h"
00004 #include "vex.h"
00005 #include <string>
00006 #include <vector>
00007
00017 class AutoChooser : public screen::Page {
00018 public:
00024     AutoChooser(std::vector<std::string> paths, size_t def = 0);
00025
00026     void update(bool was_pressed, int x, int y);
00027     void draw(vex::brain::lcd &, bool first_draw, unsigned int frame_number);
00028
00033     size_t get_choice();
00034
00035 protected:
00040     struct entry_t {
00041         Rect rect;
00042         std::string name;
00043     };
00044
00045     static const size_t width = 380;
00046     static const size_t height = 220;
00047
00048     size_t choice;
00049     std::vector<entry_t> list ;
00050 };

```

## 6.15 auto\_command.h

```

00001
00007 #pragma once
00008
00009 #include "vex.h"
00010 #include <atomic>
00011 #include <functional>
00012 #include <queue>
00013 #include <vector>
00014
00024 class Condition {

```

```

00025 public:
00026     Condition *Or(Condition *b);
00027     Condition *And(Condition *b);
00028     virtual bool test() = 0;
00029 };
00030
00031 class AutoCommand {
00032 public:
00033     static constexpr double default_timeout = 10.0;
00034     virtual bool run() { return true; }
00044     virtual void on_timeout() {}
00045     AutoCommand *withTimeout(double t_seconds) {
00046         if (this->timeout_seconds < 0) {
00047             // should never be timed out
00048             return this;
00049         }
00050         this->timeout_seconds = t_seconds;
00051         return this;
00052     }
00053     AutoCommand *withCancelCondition(Condition *true_to_end) {
00054         this->true_to_end = true_to_end;
00055         return this;
00056     }
00068     double timeout_seconds = default_timeout;
00069     Condition *true_to_end = nullptr;
00070 };
00071
00076 class FunctionCommand : public AutoCommand {
00077 public:
00078     FunctionCommand(std::function<bool(void)> f) : f(f) {}
00079     bool run() { return f(); }
00080
00081 private:
00082     std::function<bool(void)> f;
00083 };
00084
00085 // Times tested 3
00086 // Test 1 -> false
00087 // Test 2 -> false
00088 // Test 3 -> true
00089 // Returns false until the Nth time that it is called
00090 // This is pretty much only good for implementing RepeatUntil
00091 class TimesTestedCondition : public Condition {
00092 public:
00093     TimesTestedCondition(size_t N) : max(N) {}
00094     bool test() override {
00095         count++;
00096         if (count >= max) {
00097             return true;
00098         }
00099         return false;
00100     }
00101
00102 private:
00103     size_t count = 0;
00104     size_t max;
00105 };
00106
00109 class FunctionCondition : public Condition {
00110 public:
00111     FunctionCondition(
00112         std::function<bool(void)> cond, std::function<void(void)> timeout = []() {})
00113         : cond(cond), timeout(timeout) {}
00114     bool test() override;
00115
00116 private:
00117     std::function<bool(void)> cond;
00118     std::function<void(void)> timeout;
00119 };
00120
00123 class IfTimePassed : public Condition {
00124 public:
00125     IfTimePassed(double time_s);
00126     bool test() override;
00127
00128 private:
00129     double time_s;
00130     vex::timer tmr;
00131 };
00132
00134 class WaitUntilCondition : public AutoCommand {
00135 public:
00136     WaitUntilCondition(Condition *cond) : cond(cond) {}
00137     bool run() override { return cond->test(); }
00138
00139 private:
00140     Condition *cond;

```

```

00141 };
00142
00146
00150 class InOrder : public AutoCommand {
00151 public:
00152     InOrder(const InOrder &other) = default;
00153     InOrder(std::queue<AutoCommand *> cmdqs);
00154     InOrder(std::initializer_list<AutoCommand *> cmdqs);
00155     bool run() override;
00156     void on_timeout() override;
00157
00158 private:
00159     AutoCommand *current_command = nullptr;
00160     std::queue<AutoCommand *> cmdqs;
00161     vex::timer tmr;
00162 };
00163
00167 class Parallel : public AutoCommand {
00168 public:
00169     Parallel(std::initializer_list<AutoCommand *> cmdqs);
00170     bool run() override;
00171     void on_timeout() override;
00172
00173 private:
00174     std::vector<AutoCommand *> cmdqs;
00175     std::vector<vex::task *> runners;
00176 };
00177
00182 class Branch : public AutoCommand {
00183 public:
00184     Branch(Condition *cond, AutoCommand *false_choice, AutoCommand *true_choice);
00185     ~Branch();
00186     bool run() override;
00187     void on_timeout() override;
00188
00189 private:
00190     AutoCommand *false_choice;
00191     AutoCommand *true_choice;
00192     Condition *cond;
00193     bool choice = false;
00194     bool chosen = false;
00195     vex::timer tmr;
00196 };
00197
00201 class Async : public AutoCommand {
00202 public:
00203     Async(AutoCommand *cmd) : cmd(cmd) {}
00204     bool run() override;
00205
00206 private:
00207     AutoCommand *cmd = nullptr;
00208 };
00209
00210 class RepeatUntil : public AutoCommand {
00211 public:
00215     RepeatUntil(InOrder cmdqs, size_t repeats);
00219     RepeatUntil(InOrder cmdqs, Condition *true_to_end);
00220     bool run() override;
00221     void on_timeout() override;
00222
00223 private:
00224     const InOrder cmdqs;
00225     InOrder *working_cmdqs;
00226     Condition *cond;
00227 };

```

## 6.16 basic\_command.h

```

00001
00014 #pragma once
00015
00016 #include "../core/include/utils/command_structure/auto_command.h"
00017
00018 // Basic Motor Classes-----
00019
00024 class BasicSpinCommand : public AutoCommand {
00025 public:
00026     // Enumerator for the type of power setting in the motor
00027     enum type { percent, voltage, velocity };
00028
00037     BasicSpinCommand(vex::motor &motor, vex::directionType dir, BasicSpinCommand::type setting, double
power);
00038

```

```

00045     bool run() override;
00046
00047 private:
00048     vex::motor &motor;
00049     type setting;
00051
00052     vex::directionType dir;
00053
00054     double power;
00055 };
00060 class BasicStopCommand : public AutoCommand {
00061 public:
00062     BasicStopCommand(vex::motor &motor, vex::brakeType setting);
00069
00076     bool run() override;
00077
00078 private:
00079     vex::motor &motor;
00080
00081     vex::brakeType setting;
00082 };
00083
00084 // Basic Solenoid Commands-----
00085
00090 class BasicSolenoidSet : public AutoCommand {
00091 public:
00092     BasicSolenoidSet(vex::pneumatics &solenoid, bool setting);
00099
00106     bool run() override;
00107
00108 private:
00109     vex::pneumatics &solenoid;
00110
00111     bool setting;
00112 };

```

## 6.17 command\_controller.h

```

00001
00010 #pragma once
00011 #include "../core/include/utils/command_structure/auto_command.h"
00012 #include <queue>
00013 #include <vector>
00014
00015 class CommandController {
00016 public:
00019     [[deprecated("Empty constructor is bad. Use list constructor "
00020                 "instead.")]] CommandController()
00021         : command_queue({}) {}
00022
00026     CommandController(std::initializer_list<AutoCommand *> cmdqs) : command_queue(cmdqs) {}
00034     [[deprecated("Use list constructor instead. If you need to make a decision "
00035                 "before adding new commands, use Branch "
00036                 "(https://github.com/RIT-VEX-U/Core/wiki/"
00037                 "3-%7C-Utilites#commandcontroller)")]] void
00038     add(std::vector<AutoCommand *> cmdqs);
00039     void add(AutoCommand *cmd, double timeout_seconds = 10.0);
00040
00052     [[deprecated("Use list constructor instead. If you need to make a decision "
00053                 "before adding new commands, use Branch "
00054                 "(https://github.com/RIT-VEX-U/Core/wiki/"
00055                 "3-%7C-Utilites#commandcontroller)")]] void
00056     add(std::vector<AutoCommand *> cmdqs, double timeout_sec);
00063     void add_delay(int ms);
00064
00069     void add_cancel_func(std::function<bool(void)> true_if_cancel);
00070
00075     void run();
00076
00084     bool last_command_timed_out();
00085
00086 private:
00087     std::queue<AutoCommand *> command_queue;
00088     bool command_timed_out = false;
00089     std::function<bool()> should_cancel = []() { return false; };
00090 };

```

## 6.18 delay\_command.h

```
00001
```

```

00008 #pragma once
00009
00010 #include "../core/include/utils/command_structure/auto_command.h"
00011
00012 class DelayCommand : public AutoCommand {
00013 public:
00014     DelayCommand(int ms) : ms(ms) {}
00015
00016     bool run() override {
00017         vexDelay(ms);
00018         return true;
00019     }
00020
00021 private:
00022     // amount of milliseconds to wait
00023     int ms;
00024 };

```

## 6.19 drive\_commands.h

```

00001
00020 #pragma once
00021
00022 #include "../core/include/subsystems/tank_drive.h"
00023 #include "../core/include/utils/command_structure/auto_command.h"
00024 #include "../core/include/utils/geometry.h"
00025 #include "vex.h"
00026
00027 using namespace vex;
00028
00029 // ===== DRIVING =====
00030
00036 class DriveForwardCommand : public AutoCommand {
00037 public:
00038     DriveForwardCommand(TankDrive &drive_sys, Feedback &feedback, double inches, directionType dir,
00039                          double max_speed = 1,
00040                          double end_speed = 0);
00041
00046     bool run() override;
00050     void on_timeout() override;
00051
00052 private:
00053     // drive system to run the function on
00054     TankDrive &drive_sys;
00055
00056     // feedback controller to use
00057     Feedback &feedback;
00058
00059     // parameters for drive_forward
00060     double inches;
00061     directionType dir;
00062     double max_speed;
00063     double end_speed;
00064 };
00065
00070 class TurnDegreesCommand : public AutoCommand {
00071 public:
00072     TurnDegreesCommand(TankDrive &drive_sys, Feedback &feedback, double degrees, double max_speed = 1,
00073                          double end_speed = 0);
00074
00080     bool run() override;
00084     void on_timeout() override;
00085
00086 private:
00087     // drive system to run the function on
00088     TankDrive &drive_sys;
00089
00090     // feedback controller to use
00091     Feedback &feedback;
00092
00093     // parameters for turn_degrees
00094     double degrees;
00095     double max_speed;
00096     double end_speed;
00097 };
00098
00103 class DriveToPointCommand : public AutoCommand {
00104 public:
00105     DriveToPointCommand(TankDrive &drive_sys, Feedback &feedback, double x, double y, directionType dir,
00106                          double max_speed = 1, double end_speed = 0);
00107     DriveToPointCommand(TankDrive &drive_sys, Feedback &feedback, point_t point, directionType dir,
00108                          double max_speed = 1,
00109                          double end_speed = 0);

```

```

00109
00115     bool run() override;
00116
00117 private:
00118     // drive system to run the function on
00119     TankDrive &drive_sys;
00120
00124     void on_timeout() override;
00125
00126     // feedback controller to use
00127     Feedback &feedback;
00128
00129     // parameters for drive_to_point
00130     double x;
00131     double y;
00132     directionType dir;
00133     double max_speed;
00134     double end_speed;
00135 };
00136
00142 class TurnToHeadingCommand : public AutoCommand {
00143 public:
00144     TurnToHeadingCommand(TankDrive &drive_sys, Feedback &feedback, double heading_deg, double speed = 1,
00145                         double end_speed = 0);
00146
00152     bool run() override;
00156     void on_timeout() override;
00157
00158 private:
00159     // drive system to run the function on
00160     TankDrive &drive_sys;
00161
00162     // feedback controller to use
00163     Feedback &feedback;
00164
00165     // parameters for turn_to_heading
00166     double heading_deg;
00167     double max_speed;
00168     double end_speed;
00169 };
00170
00174 class PurePursuitCommand : public AutoCommand {
00175 public:
00184     PurePursuitCommand(TankDrive &drive_sys, Feedback &feedback, PurePursuit::Path path, directionType
00185         dir,
00186         double max_speed = 1, double end_speed = 0);
00186
00190     bool run() override;
00191
00195     void on_timeout() override;
00196
00197 private:
00198     TankDrive &drive_sys;
00199     PurePursuit::Path path;
00200     directionType dir;
00201     Feedback &feedback;
00202     double max_speed;
00203     double end_speed;
00204 };
00205
00210 class DriveStopCommand : public AutoCommand {
00211 public:
00212     DriveStopCommand(TankDrive &drive_sys);
00213
00219     bool run() override;
00220     void on_timeout() override;
00221
00222 private:
00223     // drive system to run the function on
00224     TankDrive &drive_sys;
00225 };
00226
00227 // ===== ODOMETRY =====
00228
00233 class OdomSetPosition : public AutoCommand {
00234 public:
00241     OdomSetPosition(OdometryBase &odom, const pose_t &newpos = OdometryBase::zero_pos);
00242
00248     bool run() override;
00249
00250 private:
00251     // drive system with an odometry config
00252     OdometryBase &odom;
00253     pose_t newpos;
00254 };

```

## 6.20 flywheel\_commands.h

```

00001
00007 #pragma once
00008
00009 #include "../core/include/subsystems/flywheel.h"
00010 #include "../core/include/utils/command_structure/auto_command.h"
00011
00017 class SpinRPMCommand : public AutoCommand {
00018 public:
00024     SpinRPMCommand(Flywheel &flywheel, int rpm);
00025
00031     bool run() override;
00032
00033 private:
00034     // Flywheel instance to run the function on
00035     Flywheel &flywheel;
00036
00037     // parameters for spin_rpm
00038     int rpm;
00039 };
00040
00046 class WaitUntilUpToSpeedCommand : public AutoCommand {
00047 public:
00054     WaitUntilUpToSpeedCommand(Flywheel &flywheel, int threshold_rpm);
00055
00061     bool run() override;
00062
00063 private:
00064     // Flywheel instance to run the function on
00065     Flywheel &flywheel;
00066
00067     // if the actual speed is equal to the desired speed +/- this value, we are
00068     // ready to fire
00069     int threshold_rpm;
00070 };
00071
00077 class FlywheelStopCommand : public AutoCommand {
00078 public:
00083     FlywheelStopCommand(Flywheel &flywheel);
00084
00090     bool run() override;
00091
00092 private:
00093     // Flywheel instance to run the function on
00094     Flywheel &flywheel;
00095 };
00096
00102 class FlywheelStopMotorsCommand : public AutoCommand {
00103 public:
00108     FlywheelStopMotorsCommand(Flywheel &flywheel);
00109
00115     bool run() override;
00116
00117 private:
00118     // Flywheel instance to run the function on
00119     Flywheel &flywheel;
00120 };
00121
00127 class FlywheelStopNonTasksCommand : public AutoCommand {
00128     FlywheelStopNonTasksCommand(Flywheel &flywheel);
00129
00135     bool run() override;
00136
00137 private:
00138     // Flywheel instance to run the function on
00139     Flywheel &flywheel;
00140 };

```

## 6.21 bang\_bang.h

```

00001 #include "../core/include/utils/controls/feedback_base.h"
00002
00003 class BangBang : public Feedback {
00004
00005 public:
00006     BangBang(double threshold, double low, double high);
00015     void init(double start_pt, double set_pt, double start_vel [[maybe_unused]] = 0.0,
00016                 double end_vel [[maybe_unused]] = 0.0) override;
00017
00024     double update(double val) override;
00025
00029     double get() override;

```

```

00030
00038     void set_limits(double lower, double upper) override;
00039
00043     bool is_on_target() override;
00044
00045 private:
00046     double setpt;
00047     double sensor_val;
00048     double lower_bound, upper_bound;
00049     double last_output;
00050     double threshhold;
00051 };

```

## 6.22 feedback\_base.h

```

00001 #pragma once
00002
00010 class Feedback {
00011 public:
00020     virtual void init(double start_pt, double set_pt, double start_vel = 0.0, double end_vel = 0.0) = 0;
00021
00028     virtual double update(double val) = 0;
00029
00033     virtual double get() = 0;
00034
00042     virtual void set_limits(double lower, double upper) = 0;
00043
00047     virtual bool is_on_target() = 0;
00048 };

```

## 6.23 feedforward.h

```

00001 #pragma once
00002
00003 #include "../core/include/utils/math_util.h"
00004 #include "../core/include/utils/moving_average.h"
00005 #include "vex.h"
00006 #include <math.h>
00007 #include <vector>
00008
00029 class FeedForward {
00030 public:
00039     typedef struct {
00040         double kS;
00042         double kV;
00044         double kA;
00046         double kG;
00048     } ff_config_t;
00049
00054     FeedForward(ff_config_t &cfg) : cfg(cfg) {}
00055
00067     double calculate(double v, double a, double pid_ref = 0.0) {
00068         double ks_sign = 0;
00069         if (v != 0)
00070             ks_sign = sign(v);
00071         else if (pid_ref != 0)
00072             ks_sign = sign(pid_ref);
00073
00074         return (cfg.kS * ks_sign) + (cfg.kV * v) + (cfg.kA * a) + cfg.kG;
00075     }
00076
00077 private:
00078     ff_config_t &cfg;
00079 };
00080
00089 FeedForward::ff_config_t tune_feedforward(vex::motor_group &motor, double pct, double duration);

```

## 6.24 motion\_controller.h

```

00001 #pragma once
00002 #include "../core/include/subsystems/screen.h"
00003 #include "../core/include/subsystems/tank_drive.h"
00004 #include "../core/include/utils/controls/feedback_base.h"
00005 #include "../core/include/utils/controls/feedforward.h"
00006 #include "../core/include/utils/controls/pid.h"

```

```

00007 #include "../core/include/utils/controls/trapezoid_profile.h"
00008
00009 #include "vex.h"
0010
00130 class MotionController : public Feedback {
00131 public:
00139     typedef struct {
00140         double max_v;
00141         double accel;
00142         PID::pid_config_t pid_cfg;
00143         FeedForward::ff_config_t ff_cfg;
00144     } m_profile_cfg_t;
00145
00155 MotionController(m_profile_cfg_t &config);
00156
00161 void init(double start_pt, double end_pt, double start_vel, double end_vel) override;
00162
00169 double update(double sensor_val) override;
00170
00174 double get() override;
00175
00184 void set_limits(double lower, double upper) override;
00185
00190 bool is_on_target() override;
00191
00195 motion_t get_motion() const;
00196
00197 screen::Page *Page();
00198
00200 static FeedForward::ff_config_t tune_feedforward(TankDrive &drive, OdometryTank &odometry, double
00201     pct = 0.6,
00202                                         double duration = 2);
0021
0022
0023 private:
0024     m_profile_cfg_t config;
0025
0026     PID pid;
0027     FeedForward ff;
0028     TrapezoidProfile profile;
0029
0030     double current_pos;
0031     double end_pt;
0032
0033     double lower_limit = 0, upper_limit = 0;
0034     double out = 0;
0035     motion_t cur_motion;
0036
0037     vex::timer tmr;
0038     friend class MotionControllerPage;
0039 };

```

## 6.25 pid.h

```

00001 #pragma once
00002
00003 #include "../core/include/utils/controls/feedback_base.h"
00004 #include "vex.h"
00005 #include <cmath>
00006
00007 using namespace vex;
00008
00023 class PID : public Feedback {
00024 public:
00029     enum ERROR_TYPE {
00030         LINEAR,
00031         ANGULAR // assumes degrees
00032     };
00043     struct pid_config_t {
00044         double p;
00045         double i;
00046         double d;
00047         double deadband;
00048         double on_target_time;
00050         ERROR_TYPE error_method;
00052     };
00053
00058     PID(pid_config_t &config);
00059
00072     void init(double start_pt, double set_pt, double start_vel = 0, double end_vel = 0) override;
00073
00081     double update(double sensor_val) override;
00082
00087     double get_sensor_val() const;

```

```

00088
00094     double get() override;
00095
00104     void set_limits(double lower, double upper) override;
00105
00110     bool is_on_target() override;
00111
00115     void reset();
00116
00122     double get_error();
00123
00128     double get_target() const;
00129
00134     void set_target(double target);
00135
00136     pid_config_t &config;
00138
00139 private:
00140     double last_error = 0;
00141     double accum_error = 0;
00142
00143     double last_time = 0;
00144     double on_target_last_time = 0;
00145
00146     double lower_limit = 0;
00147     double upper_limit = 0;
00148
00149     double target = 0;
00150     double target_vel = 0;
00153     double sensor_val = 0;
00155     double out = 0;
00158
00159     bool is_checking_on_target = false;
00160
00161     timer pid_timer;
00164 };

```

## 6.26 pidff.h

```

00001 #pragma once
00002 #include "../core/include/utils/controls/feedback_base.h"
00003 #include "../core/include/utils/controls/feedforward.h"
00004 #include "../core/include/utils/controls/pid.h"
00005
00006 class PIDFF : public Feedback {
00007 public:
00008     PIDFF(PID::pid_config_t &pid_cfg, FeedForward::ff_config_t &ff_cfg);
00009
00018     void init(double start_pt, double set_pt, double start_vel, double end_vel) override;
00019
00024     void set_target(double set_pt);
00025
00026     double get_target() const;
00027     double get_sensor_val() const;
00035     double update(double val) override;
00036
00045     double update(double val, double vel_setpt, double a_setpt = 0);
00046
00050     double get() override;
00051
00059     void set_limits(double lower, double upper) override;
00060
00064     bool is_on_target() override;
00065
00066     void reset();
00067
00068     PID pid;
00069
00070 private:
00071     FeedForward::ff_config_t &ff_cfg;
00072
00073     FeedForward ff;
00074
00075     double out;
00076     double lower_lim, upper_lim;
00077 };

```

## 6.27 take\_back\_half.h

```
00001 #pragma once
```

```

00002 #include "../core/include/utils/controls/feedback_base.h"
00003
00006 class TakeBackHalf : public Feedback {
00007
00008 public:
00009     TakeBackHalf(double TBH_gain, double first_cross_split, double on_target_threshold);
00018     void init(double start_pt, double set_pt, double, double);
00025     double update(double val) override;
00026
00030     double get() override;
00031
00039     void set_limits(double lower, double upper) override;
00040
00044     bool is_on_target() override;
00045
00046     double TBH_gain;
00047     double first_cross_split;
00048
00049 private:
00050     double on_target_threshhold;
00051
00052     double target = 0.0;
00053
00054     bool first_cross = true;
00055     double tbh = 0.0;
00056     double prev_error = 0.0;
00057
00058     double output = 0.0;
00059     double lower = 0.0, upper = 0.0;
00060 };

```

## 6.28 trapezoid\_profile.h

```

00001 #pragma once
00002
00003 const int MAX_TRAPEZOID_PROFILE_SEGMENTS = 4;
00004
00008 typedef struct {
00009     double pos;
00010     double vel;
00011     double accel;
00012
00013 } motion_t;
00014
00019 typedef struct {
00020     double pos_after;
00021     double vel_after;
00022     double accel;
00023     double duration;
00024 } trapezoid_profile_segment_t;
00025
00063 class TrapezoidProfile {
00064 public:
00071     TrapezoidProfile(double max_v, double accel);
00072
00081     motion_t calculate(double time_s, double pos_s);
00082
00089     motion_t calculate_time_based(double time_s);
00090
00097     void set_endpts(double start, double end);
00098
00105     void set_vel_endpts(double start, double end);
00106
00113     void set_accel(double accel);
00114
00121     void set_max_v(double max_v);
00122
00129     double get_movement_time() const;
00130
00131     double get_max_v() const;
00132     double get_accel() const;
00133
00134 private:
00135     double si, sf;
00136     double vi, vf;
00137     double max_v;
00138     double accel;
00139     double duration;
00140
00141     trapezoid_profile_segment_t segments[MAX_TRAPEZOID_PROFILE_SEGMENTS];
00142     int num_acceleration_phases;
00143
00144     bool precalculated;

```

```

00145     bool precalculate();
00151
00152     trapezoid_profile_segment_t calculate_kinetic_motion(double si, double vi, double v_target);
00163
00164     trapezoid_profile_segment_t calculate_next_segment(double s, double v);
00172
00173 };

```

## 6.29 generic\_auto.h

```

00001 #pragma once
00002
00003 #include "vex.h"
00004 #include <functional>
00005 #include <map>
00006 #include <queue>
00007
00008 typedef std::function<bool(void)> state_ptr;
00009
00015 class GenericAuto {
00016 public:
00030     [[deprecated("Use CommandController instead.")]] bool run(bool blocking);
00031
00037     [[deprecated("Use CommandController instead.")]] void add(state_ptr new_state);
00038
00044     [[deprecated("Use CommandController instead.")]] void add_async(state_ptr async_state);
00045
00051     [[deprecated("Use CommandController instead.")]] void add_delay(int ms);
00052
00053 private:
00054     std::queue<state_ptr> state_list;
00055 };

```

## 6.30 geometry.h

```

00001 #pragma once
00002 #include <cmath>
00003
00007 struct point_t {
00008     double x;
00009     double y;
00010
00017     double dist(const point_t other) const {
00018         return std::sqrt(std::pow(this->x - other.x, 2) + std::pow(this->y - other.y, 2));
00019     }
00020
00026     point_t operator+(const point_t &other) const {
00027         point_t p{.x = this->x + other.x, .y = this->y + other.y};
00028         return p;
00029     }
00030
00036     point_t operator-(const point_t &other) const {
00037         point_t p{.x = this->x - other.x, .y = this->y - other.y};
00038         return p;
00039     }
00040
00041     point_t operator*(double s) const { return {x * s, y * s}; }
00042     point_t operator/(double s) const { return {x / s, y / s}; }
00043
00044     point_t operator-() const { return {-x, -y}; }
00045     point_t operator+() const { return {x, y}; }
00046
00047     bool operator==(const point_t &rhs) { return x == rhs.x && y == rhs.y; }
00048 };
00049
00053 struct pose_t {
00054     double x;
00055     double y;
00056     double rot;
00057
00058     point_t get_point() { return point_t{x = x, .y = y}; }
00059 };
00060
00061 struct Rect {
00062     point_t min;
00063     point_t max;
00064     static Rect from_min_and_size(point_t min, point_t size) { return {min, min + size}; }
00065     point_t dimensions() const { return max - min; }
00066     point_t center() const { return (min + max) / 2; }

```

```

00067     double width() const { return max.x - min.x; }
00068     double height() const { return max.y - min.y; }
00069     bool contains(point_t p) const {
00070         bool xin = p.x > min.x && p.x < max.x;
00071         bool yin = p.y > min.y && p.y < max.y;
00072         return xin && yin;
00073     }
00074 };
00075
00076 struct Mat2 {
00077     double X11, X12;
00078     double X21, X22;
00079     point_t operator*(const point_t p) const {
00080         double outx = p.x * X11 + p.y * X12;
00081         double outy = p.x * X21 + p.y * X22;
00082         return {outx, outy};
00083     }
00084
00085     static Mat2 FromRotationDegrees(double degrees) {
00086         double rad = degrees * (M_PI / 180.0);
00087         double c = cos(rad);
00088         double s = sin(rad);
00089         return {c, -s, s, c};
00090     }
00091 };

```

## 6.31 graph\_drawer.h

```

00001 #pragma once
00002
00003 #include "../core/include/utils/geometry.h"
00004 #include "../core/include/utils/vector2d.h"
00005 #include "vex.h"
00006 #include <cmath>
00007 #include <stdio.h>
00008 #include <string>
00009 #include <vector>
00010
00011 class GraphDrawer {
00012 public:
00013     GraphDrawer(int num_samples, double lower_bound, double upper_bound, std::vector<vex::color> colors,
00014                 size_t num_series = 1);
00029     void add_samples(std::vector<point_t> sample);
00030
00036     void add_samples(std::vector<double> sample);
00037
00045     void draw(vex::brain::lcd &screen, int x, int y, int width, int height);
00046
00047 private:
00048     std::vector<std::vector<point_t>> series;
00049     int sample_index = 0;
00050     std::vector<vex::color> cols;
00051     vex::color bgcol = vex::transparent;
00052     bool border;
00053     double upper;
00054     double lower;
00055     bool auto_fit = false;
00056 };

```

## 6.32 logger.h

```

00001 #pragma once
00002
00003 #include "vex.h"
00004 #include <cstdarg>
00005 #include <cstdio>
00006 #include <string>
00007
00009 enum LogLevel { DEBUG, NOTICE, WARNING, ERROR, CRITICAL, TIME };
00010
00012 class Logger {
00013 private:
00014     const std::string filename;
00015     vex::brain::sdcard sd;
00016     void write_level(LogLevel l);
00017
00018 public:
00020     static constexpr int MAX_FORMAT_LEN = 512;
00023     explicit Logger(const std::string &filename);

```

```

00024
00026     Logger(const Logger &l) = delete;
00028     Logger &operator=(const Logger &l) = delete;
00029
00032     void Log(const std::string &s);
00033
00038     void Log(LogLevel level, const std::string &s);
00039
00042     void Logln(const std::string &s);
00043
00048     void Logln(LogLevel level, const std::string &s);
00049
00053     void Logf(const char *fmt, ...);
00054
00060     void Logf(LogLevel level, const char *fmt, ...);
00061 };

```

## 6.33 math\_util.h

```

00001 #pragma once
00002 #include "../core/include/utils/geometry.h"
00003 #include "math.h"
00004 #include "vex.h"
00005 #include <vector>
00006
00014 double clamp(double value, double low, double high);
00015
00022 double lerp(double a, double b, double t);
00029 double sign(double x);
00030
00031 double wrap_angle_deg(double input);
00032 double wrap_angle_rad(double input);
00033
00034 /*
00035 Calculates the variance of a set of numbers (needed for linear regression)
00036 https://en.wikipedia.org/wiki/Variance
00037 @param values the values for which the variance is taken
00038 @param mean the average of values
00039 */
00040 double variance(std::vector<double> const &values, double mean);
00041
00042 /*
00043 Calculates the average of a vector of doubles
00044 @param values the list of values for which the average is taken
00045 */
00046 double mean(std::vector<double> const &values);
00047
00048 /*
00049 Calculates the covariance of a set of points (needed for linear regression)
00050 https://en.wikipedia.org/wiki/Covariance
00051
00052 @param points the points for which the covariance is taken
00053 @param meanx the mean value of all x coordinates in points
00054 @param meany the mean value of all y coordinates in points
00055 */
00056 double covariance(std::vector<std::pair<double, double> const &points, double meanx, double meany);
00057
00058 /*
00059 Calculates the slope and y intercept of the line of best fit for the data
00060 @param points the points for the data
00061 */
00062 std::pair<double, double> calculate_linear_regression(std::vector<std::pair<double, double> const &points);
00063
00064 double estimate_path_length(const std::vector<point_t> &points);

```

## 6.34 moving\_average.h

```

00001 #pragma once
00002 #include <vector>
00003
00008 class Filter {
00009 public:
00010     virtual void add_entry(double n) = 0;
00011     virtual double get_value() const = 0;
00012 };
00013
00031 class MovingAverage : public Filter {
00032 public:

```

```

00033  /*
00034   * Create a moving average calculator with 0 as the default value
00035   *
00036   * @param buffer_size    The size of the buffer. The number of samples that
00037   * constitute a valid reading
00038   */
00039 MovingAverage(int buffer_size);
00040 /*
00041   * Create a moving average calculator with a specified default value
00042   * @param buffer_size    The size of the buffer. The number of samples that
00043   * constitute a valid reading
00044   * @param starting_value The value that the average will be before any data is
00045   * added
00046   */
00047 MovingAverage(int buffer_size, double starting_value);
00048 /*
00049   * Add a reading to the buffer
00050   * Before:
00051   * [ 1 1 2 2 3 3 ] => 2
00052   * ^
00053   * After:
00054   * [ 2 1 2 2 3 3 ] => 2.16
00055   * ^
00056   * @param n  the sample that will be added to the moving average.
00057   */
00058 void add_entry(double n) override;
00059 double get_value() const override;
00060 int get_size() const;
00061
00062 private:
00063     int buffer_index;           // index of the next value to be overridden
00064     std::vector<double> buffer; // all current data readings we've taken
00065     double current_avg;        // the current value of the data
00066 };
00067
00068 class ExponentialMovingAverage : public Filter {
00069 public:
00070 /*
00071   * Create a moving average calculator with 0 as the default value
00072   *
00073   * @param buffer_size    The size of the buffer. The number of samples that
00074   * constitute a valid reading
00075   */
00076 ExponentialMovingAverage(int buffer_size);
00077 /*
00078   * Create a moving average calculator with a specified default value
00079   * @param buffer_size    The size of the buffer. The number of samples that
00080   * constitute a valid reading
00081   * @param starting_value The value that the average will be before any data is
00082   * added
00083   */
00084 ExponentialMovingAverage(int buffer_size, double starting_value);
00085
00086 /*
00087   * Add a reading to the buffer
00088   * Before:
00089   * [ 1 1 2 2 3 3 ] => 2
00090   * ^
00091   * After:
00092   * [ 2 1 2 2 3 3 ] => 2.16
00093   * ^
00094   * @param n  the sample that will be added to the moving average.
00095   */
00096 void add_entry(double n) override;
00097
00098 double get_value() const override;
00099 int get_size();
00100
00101 private:
00102     int buffer_index;           // index of the next value to be overridden
00103     std::vector<double> buffer; // all current data readings we've taken
00104     double current_avg;        // the current value of the data
00105 };
00106
00107
00108
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00110
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00119
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00121
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00127
00128
00129
00130
00131
00132
00133
00134
00135
00136
00137
00138
00139
00140
00141
00142 };

```

## 6.35 pure\_pursuit.h

```

00001 #pragma once
00002
00003 #include "../core/include/utils/geometry.h"

```

```

00004 #include "../core/include/utils/vector2d.h"
00005 #include "vex.h"
00006 #include <vector>
00007
00008 using namespace vex;
00009
00010 namespace PurePursuit {
00015 class Path {
00016 public:
00022     Path(std::vector<point_t> points, double radius);
00023
00027     std::vector<point_t> get_points();
00028
00032     double get_radius();
00033
00037     bool is_valid();
00038
00039 private:
00040     std::vector<point_t> points;
00041     double radius;
00042     bool valid;
00043 };
00048 struct spline {
00049     double a, b, c, d, x_start, x_end;
00050
00051     double getY(double x) { return a * pow((x - x_start), 3) + b * pow((x - x_start), 2) + c * (x - x_start) + d; }
00052 };
00058 struct hermite_point {
00059     double x;
00060     double y;
00061     double dir;
00062     double mag;
00063
00064     point_t getPoint() const { return {x, y}; }
00065
00066     Vector2D getTangent() const { return Vector2D(dir, mag); }
00067 };
00068
00074 extern std::vector<point_t> line_circle_intersections(point_t center, double r, point_t point1,
00075 point_t point2);
00078 extern point_t get_looking_ahead(const std::vector<point_t> &path, pose_t robot_loc, double radius);
00079
00084 extern std::vector<point_t> inject_path(const std::vector<point_t> &path, double spacing);
00085
00098 extern std::vector<point_t> smooth_path(const std::vector<point_t> &path, double weight_data, double
00100 weight_smooth,
00101                                     double tolerance);
00100
00101 extern std::vector<point_t> smooth_path_cubic(const std::vector<point_t> &path, double res);
00102
00111 extern std::vector<point_t> smooth_path_hermite(const std::vector<hermite_point> &path, double step);
00112
00124 extern double estimate_remaining_dist(const std::vector<point_t> &path, pose_t robot_pose, double
00125 radius);
00125
00126 } // namespace PurePursuit

```

## 6.36 serializer.h

```

00001 #pragma once
00002 #include <algorithm>
00003 #include <map>
00004 #include <stdio.h>
00005 #include <string>
00006 #include <vector>
00007 #include <vex.h>
00008
00010 const char serialization_separator = '$';
00012 const std::size_t MAX_FILE_SIZE = 4096;
00013
00015 class Serializer {
00016 private:
00017     bool flush_always;
00018     std::string filename;
00019     std::map<std::string, int> ints;
00020     std::map<std::string, bool> bools;
00021     std::map<std::string, double> doubles;
00022     std::map<std::string, std::string> strings;
00023
00025     bool read_from_disk();
00026
00027 public:

```

```

00030 ~Serializer() {
00031     save_to_disk();
00032     printf("Saving %s\n", filename.c_str());
00033     fflush(stdout);
00034 }
00035
00041 explicit Serializer(const std::string &filename, bool flush_always = true)
00042     : flush_always(flush_always), filename(filename), ints({}), bools({}), doubles({}),
00043     strings({})
00044 {
00045     read_from_disk();
00046 }
00047
00049 void save_to_disk() const;
00050
00052
00057 void set_int(const std::string &name, int i);
00058
00063 void set_bool(const std::string &name, bool b);
00064
00069 void set_double(const std::string &name, double d);
00070
00075 void set_string(const std::string &name, std::string str);
00076
00079
00085 int int_or(const std::string &name, int otherwise);
00086
00092 bool bool_or(const std::string &name, bool otherwise);
00093
00099 double double_or(const std::string &name, double otherwise);
00100
00106 std::string string_or(const std::string &name, std::string otherwise);
00107 };

```

## 6.37 state\_machine.h

```

00001 #pragma once
00002 #include <string>
00003 #include <type_traits>
00004 #include <utility>
00005
00034 template <typename System, typename IDType, typename Message, int32_t delay_ms, bool do_log = false>
00035 class StateMachine {
00036     static_assert(std::is_enum<Message>::value, "Message should be an enum (it's easier that way)");
00037     static_assert(std::is_enum<IDType>::value, "IDType should be an enum (it's easier that way)");
00038
00039 public:
00046     class MaybeMessage {
00047     public:
00051         MaybeMessage() : exists(false) {}
00056         MaybeMessage(Message msg) : exists(true), thing(msg) {}
00061         bool has_message() { return exists; }
00067         Message message() { return thing; }
00068
00069     private:
00070         bool exists;
00071         Message thing;
00072     };
00078     struct State {
00079         // run once when we enter the state
00080         virtual void entry(System &) {}
00081         // run continuously while in the state
00082         virtual MaybeMessage work(System &) { return {}; }
00083         // run once when we exit the state
00084         virtual void exit(System &) {}
00085         // respond to a message when one comes in
00086         virtual State *respond(System &s, Message m) = 0;
00087         // Identify
00088         virtual IDType id() const = 0;
00089
00090         // virtual destructor cuz c++
00091         virtual ~State() {}
00092     };
00093
00094     // Data that gets passed to the runner thread. Don't worry too much about
00095     // this
00096     using thread_data = std::pair<State *, StateMachine *>;
00097
00102     StateMachine(State *initial) : runner(thread_runner, new thread_data{initial, this}) {}
00103
00109     IDType current_state() const {
00110         mut.lock();
00111         auto t = cur_type;

```

```

00112     mut.unlock();
00113     return t;
00114 }
00120 void send_message(Message msg) {
00121     mut.lock();
00122     incoming_msg = msg;
00123     mut.unlock();
00124 }
00125
00126 private:
00127     vex::task runner;
00128     mutable vex::mutex mut;
00129     MaybeMessage incoming_msg;
00130     IDType cur_type;
00131
00138     static int thread_runner(void *vptr) {
00139         thread_data *ptr = static_cast<thread_data *>(vptr);
00140         State *cur_state = ptr->first;
00141
00142         StateMachine &sys = *ptr->second;
00143         System &derived = static_cast<System *>(&sys);
00144
00145         cur_state->entry(derived);
00146
00147         sys.cur_type = cur_state->id();
00148
00149         auto respond_to_message = [&] (Message msg) {
00150             if (do_log) {
00151                 printf("responding to msg: %s\n", to_string(msg).c_str());
00152                 fflush(stdout);
00153             }
00154
00155             State *next_state = cur_state->respond(derived, msg);
00156
00157             if (cur_state != next_state) {
00158                 // switched states
00159                 sys.mut.lock();
00160
00161                 cur_state->exit(derived);
00162                 next_state->entry(derived);
00163
00164                 delete cur_state;
00165
00166                 cur_state = next_state;
00167                 sys.cur_type = cur_state->id();
00168
00169                 sys.mut.unlock();
00170             }
00171         };
00172
00173         while (true) {
00174             if (do_log) {
00175                 std::string str = to_string(cur_state->id());
00176                 std::string str2 = to_string(sys.cur_type);
00177
00178                 printf("state: %s %s\n", str.c_str(), str2.c_str());
00179             }
00180
00181             // Internal Message passed
00182             MaybeMessage internal_msg = cur_state->work(derived);
00183
00184             if (internal_msg.has_message()) {
00185                 respond_to_message(internal_msg.message());
00186             }
00187
00188             // External Message passed
00189             sys.mut.lock();
00190             MaybeMessage incoming = sys.incoming_msg;
00191             sys.incoming_msg = {};
00192             sys.mut.unlock();
00193
00194             if (incoming.has_message()) {
00195                 respond_to_message(incoming.message());
00196             }
00197
00198             vexDelay(delay_ms);
00199         }
00200     return 0;
00201 }
00202 };

```

## 6.38 vector2d.h

```
00001 #pragma once
```

```
00002
00003 #include "../core/include/utils/geometry.h"
00004 #include <cmath>
00005
00006 #ifndef PI
00007 #define PI 3.141592654
00008 #endif
00014 class Vector2D {
00015 public:
00023     Vector2D(double dir, double mag);
00024
00030     Vector2D(point_t p);
00031
00039     double get_dir() const;
00040
00044     double get_mag() const;
00045
00049     double get_x() const;
00050
00054     double get_y() const;
00055
00060     Vector2D normalize();
00061
00066     point_t point();
00067
00073     Vector2D operator*(const double &x);
00080     Vector2D operator+(const Vector2D &other);
00087     Vector2D operator-(const Vector2D &other);
00088
00089 private:
00090     double dir, mag;
00091 };
00092
00098 double deg2rad(double deg);
00099
00106 double rad2deg(double r);
```



# Index

accel  
    OdometryBase, 102  
add  
    CommandController, 31, 32  
    GenericAuto, 66  
add\_async  
    GenericAuto, 66  
add\_cancel\_func  
    CommandController, 32  
add\_delay  
    CommandController, 33  
    GenericAuto, 66  
add\_entry  
    ExponentialMovingAverage, 46  
    Filter, 53  
    MovingAverage, 92  
add\_samples  
    GraphDrawer, 68  
AndCondition, 13  
    test, 13  
ang\_accel\_deg  
    OdometryBase, 102  
ang\_speed\_deg  
    OdometryBase, 102  
Async, 14  
    run, 15  
auto\_drive  
    MecanumDrive, 83  
auto\_turn  
    MecanumDrive, 83  
AutoChooser, 15  
    AutoChooser, 16  
    choice, 17  
    draw, 16  
    get\_choice, 16  
    list, 17  
    update, 17  
AutoChooser::entry\_t, 44  
    name, 44  
AutoCommand, 18  
    on\_timeout, 19  
    run, 19  
    timeout\_seconds, 19  
background\_task  
    OdometryBase, 99  
BangBang, 20  
    get, 20  
    init, 20  
    is\_on\_target, 21  
set\_limits, 21  
    update, 21  
BasicSolenoidSet, 22  
    BasicSolenoidSet, 22  
    run, 23  
BasicSpinCommand, 23  
    BasicSpinCommand, 24  
    run, 25  
BasicStopCommand, 25  
    BasicStopCommand, 26  
    run, 26  
bool\_or  
    Serializer, 138  
BrakeType  
    TankDrive, 154  
Branch, 27  
    on\_timeout, 28  
    run, 28  
ButtonWidget  
    screen::ButtonWidget, 29  
calculate  
    FeedForward, 50  
    TrapezoidProfile, 167  
calculate\_time\_based  
    TrapezoidProfile, 167  
choice  
    AutoChooser, 17  
CommandController, 30  
    add, 31, 32  
    add\_cancel\_func, 32  
    add\_delay, 33  
    CommandController, 31  
    last\_command\_timed\_out, 33  
    run, 33  
Condition, 33  
config  
    PID, 120  
control\_continuous  
    Lift< T >, 73  
control\_manual  
    Lift< T >, 73  
control\_setpoints  
    Lift< T >, 74  
Core, 1  
correction\_pid  
    robot\_specs\_t, 135  
current\_pos  
    OdometryBase, 102  
current\_state

StateMachine< System, IDType, Message, de-  
 lay\_ms, do\_log >, 148  
 CustomEncoder, 34  
 CustomEncoder, 34  
 position, 35  
 rotation, 35  
 setPosition, 35  
 setRotation, 36  
 velocity, 36  
  
 DelayCommand, 36  
 DelayCommand, 37  
 run, 37  
 dist  
 point\_t, 128  
 dist\_between\_wheels  
 robot\_specs\_t, 135  
 double\_or  
 Serializer, 138  
 draw  
 AutoChooser, 16  
 FlywheelPage, 57  
 GraphDrawer, 68  
 MotionControllerPage, 90  
 screen::FunctionPage, 65  
 screen::OdometryPage, 104  
 screen::Page, 111  
 screen::PIDPage, 126  
 screen::StatsPage, 149  
 screen::WidgetPage, 181  
 VideoPlayer, 176  
 drive  
 MecanumDrive, 84  
 drive\_arcade  
 TankDrive, 154  
 drive\_correction\_cutoff  
 robot\_specs\_t, 135  
 drive\_forward  
 TankDrive, 155  
 drive\_raw  
 MecanumDrive, 84  
 drive\_tank  
 TankDrive, 156  
 drive\_tank\_raw  
 TankDrive, 157  
 drive\_to\_point  
 TankDrive, 157, 158  
 DriveForwardCommand, 38  
 DriveForwardCommand, 39  
 on\_timeout, 39  
 run, 40  
 DriveStopCommand, 40  
 DriveStopCommand, 41  
 on\_timeout, 41  
 run, 41  
 DriveToPointCommand, 42  
 DriveToPointCommand, 43  
 run, 44  
  
 end\_async  
 OdometryBase, 99  
 error\_method  
 PID::pid\_config\_t, 120  
 ERROR\_TYPE  
 PID, 116  
 ExponentialMovingAverage, 45  
 add\_entry, 46  
 ExponentialMovingAverage, 45  
 get\_size, 46  
 get\_value, 46  
  
 Feedback, 47  
 get, 48  
 init, 48  
 is\_on\_target, 48  
 set\_limits, 48  
 update, 49  
 FeedForward, 49  
 calculate, 50  
 FeedForward, 50  
 FeedForward::ff\_config\_t, 51  
 kA, 51  
 kG, 51  
 kS, 52  
 kV, 52  
 Filter, 52  
 add\_entry, 53  
 get\_value, 53  
 Flywheel, 53  
 Flywheel, 54  
 get\_motors, 54  
 get\_target, 54  
 getRPM, 54  
 is\_on\_target, 55  
 Page, 55  
 spin\_manual, 55  
 spin\_rpm, 56  
 SpinRpmCmd, 56  
 spinRPMTask, 57  
 stop, 56  
 WaitUntilUpToSpeedCmd, 56  
 FlywheelPage, 57  
 draw, 57  
 update, 57  
 FlywheelStopCommand, 58  
 FlywheelStopCommand, 59  
 run, 59  
 FlywheelStopMotorsCommand, 59  
 FlywheelStopMotorsCommand, 60  
 run, 60  
 FlywheelStopNonTasksCommand, 61  
 FunctionCommand, 62  
 run, 63  
 FunctionCondition, 63  
 test, 64  
 FunctionPage  
 screen::FunctionPage, 64

GenericAuto, 65  
add, 66  
add\_async, 66  
add\_delay, 66  
run, 67  
get  
    BangBang, 20  
    Feedback, 48  
    MotionController, 88  
    PID, 117  
    PIDFF, 121  
    TakeBackHalf, 151  
get\_accel  
    OdometryBase, 99  
get\_angular\_accel\_deg  
    OdometryBase, 99  
get\_angular\_speed\_deg  
    OdometryBase, 99  
get\_async  
    Lift< T >, 74  
get\_choice  
    AutoChooser, 16  
get\_dir  
    Vector2D, 174  
get\_error  
    PID, 117  
get\_mag  
    Vector2D, 174  
get\_motion  
    MotionController, 88  
get\_motors  
    Flywheel, 54  
get\_movement\_time  
    TrapezoidProfile, 167  
get\_points  
    PurePursuit::Path, 115  
get\_position  
    OdometryBase, 100  
get\_radius  
    PurePursuit::Path, 115  
get\_sensor\_val  
    PID, 117  
get\_setpoint  
    Lift< T >, 74  
get\_size  
    ExponentialMovingAverage, 46  
    MovingAverage, 93  
get\_speed  
    OdometryBase, 100  
get\_target  
    Flywheel, 54  
    PID, 117  
get\_value  
    ExponentialMovingAverage, 46  
    Filter, 53  
    MovingAverage, 93  
get\_x  
    Vector2D, 174  
get\_y  
    Vector2D, 174  
getRPM  
    Flywheel, 54  
GraphDrawer, 67  
    add\_samples, 68  
    draw, 68  
    GraphDrawer, 67  
handle  
    OdometryBase, 103  
has\_message  
    StateMachine< System, IDType, Message, delay\_ms, do\_log >::MaybeMessage, 81  
hold  
    Lift< T >, 74  
home  
    Lift< T >, 74  
IfTimePassed, 69  
    test, 70  
include/robot\_specs.h, 183  
include/subsystems/custom\_encoder.h, 183  
include/subsystems/flywheel.h, 183  
include/subsystems/fun/pl\_mpeg.h, 184  
include/subsystems/fun/video.h, 232  
include/subsystems/layout.h, 232  
include/subsystems/lift.h, 232  
include/subsystems/mecanum\_drive.h, 235  
include/subsystems/odometry/odometry\_3wheel.h, 235  
include/subsystems/odometry/odometry\_base.h, 236  
include/subsystems/odometry/odometry\_tank.h, 237  
include/subsystems/screen.h, 237  
include/subsystems/tank\_drive.h, 240  
include/utils/auto\_chooser.h, 241  
include/utils/command\_structure/auto\_command.h, 241  
include/utils/command\_structure/basic\_command.h, 243  
include/utils/command\_structure/command\_controller.h, 244  
include/utils/command\_structure/delay\_command.h, 244  
include/utils/command\_structure/drive\_commands.h, 245  
include/utils/command\_structure/flywheel\_commands.h, 247  
include/utils/controls/bang\_bang.h, 247  
include/utils/controls/feedback\_base.h, 248  
include/utils/controls/feedforward.h, 248  
include/utils/controls/motion\_controller.h, 248  
include/utils/controls/pid.h, 249  
include/utils/controls/pidff.h, 250  
include/utils/controls/take\_back\_half.h, 250  
include/utils/controls/trapezoid\_profile.h, 251  
include/utils/generic\_auto.h, 252  
include/utils/geometry.h, 252  
include/utils/graph\_drawer.h, 253  
include/utils/logger.h, 253  
include/utils/math\_util.h, 254

include/utils/moving\_average.h, 254  
 include/utils/pure\_pursuit.h, 255  
 include/utils/serializer.h, 256  
 include/utils/state\_machine.h, 257  
 include/utils/vector2d.h, 258  
 init  
     BangBang, 20  
     Feedback, 48  
     MotionController, 88  
     PID, 118  
     PIDFF, 121  
     TakeBackHalf, 151  
 InOrder, 70  
     on\_timeout, 71  
     run, 71  
 int\_or  
     Serializer, 138  
 is\_on\_target  
     BangBang, 21  
     Feedback, 48  
     Flywheel, 55  
     MotionController, 88  
     PID, 118  
     PIDFF, 123  
     TakeBackHalf, 151  
 is\_valid  
     PurePursuit::Path, 115  
  
 kA  
     FeedForward::ff\_config\_t, 51  
 kG  
     FeedForward::ff\_config\_t, 51  
 kS  
     FeedForward::ff\_config\_t, 52  
 kV  
     FeedForward::ff\_config\_t, 52  
  
 last\_command\_timed\_out  
     CommandController, 33  
 Lift  
     Lift< T >, 73  
 Lift< T >, 72  
     control\_continuous, 73  
     control\_manual, 73  
     control\_setpoints, 74  
     get\_async, 74  
     get\_setpoint, 74  
     hold, 74  
     home, 74  
 Lift, 73  
     set\_async, 75  
     set\_position, 75  
     set\_sensor\_function, 75  
     set\_sensor\_reset, 76  
     set\_setpoint, 76  
 Lift< T >::lift\_cfg\_t, 76  
 list  
     AutoChooser, 17  
 Log  
     Logger, 78  
 Logf  
     Logger, 78  
 Logger, 77  
     Log, 78  
     Logf, 78  
     Logger, 77  
     LogIn, 79  
 LogIn  
     Logger, 79  
  
 Mat2, 80  
 MaybeMessage  
     StateMachine< System, IDType, Message, delay\_ms, do\_log >::MaybeMessage, 81  
 MecanumDrive, 82  
     auto\_drive, 83  
     auto\_turn, 83  
     drive, 84  
     drive\_raw, 84  
     MecanumDrive, 82  
 MecanumDrive::mecanumdrive\_config\_t, 85  
 message  
     StateMachine< System, IDType, Message, delay\_ms, do\_log >::MaybeMessage, 81  
 modify\_inputs  
     TankDrive, 159  
 motion\_t, 85  
 MotionController, 86  
     get, 88  
     get\_motion, 88  
     init, 88  
     is\_on\_target, 88  
     MotionController, 87  
     set\_limits, 88  
     tune\_feedforward, 89  
     update, 89  
 MotionController::m\_profile\_cfg\_t, 79  
 MotionControllerPage, 90  
     draw, 90  
     update, 91  
 MovingAverage, 91  
     add\_entry, 92  
     get\_size, 93  
     get\_value, 93  
     MovingAverage, 92  
 mut  
     OdometryBase, 103  
  
 name  
     AutoChooser::entry\_t, 44  
 None  
     TankDrive, 154  
 normalize  
     Vector2D, 174  
  
 odom\_gear\_ratio  
     robot\_specs\_t, 135  
 Odometry3Wheel, 93

Odometry3Wheel, 95  
tune, 95  
update, 96  
Odometry3Wheel::odometry3wheel\_cfg\_t, 96  
off\_axis\_center\_dist, 97  
wheel\_diam, 97  
wheelbase\_dist, 97  
OdometryBase, 97  
accel, 102  
ang\_accel\_deg, 102  
ang\_speed\_deg, 102  
background\_task, 99  
current\_pos, 102  
end\_async, 99  
get\_accel, 99  
get\_angular\_accel\_deg, 99  
get\_angular\_speed\_deg, 99  
get\_position, 100  
get\_speed, 100  
handle, 103  
mut, 103  
OdometryBase, 98  
pos\_diff, 100  
rot\_diff, 101  
set\_position, 101  
smallest\_angle, 101  
speed, 103  
update, 102  
zero\_pos, 103  
OdometryPage  
screen::OdometryPage, 104  
OdometryTank, 105  
OdometryTank, 106, 107  
set\_position, 108  
update, 108  
OdomSetPosition, 108  
OdomSetPosition, 109  
run, 110  
off\_axis\_center\_dist  
Odometry3Wheel::odometry3wheel\_cfg\_t, 97  
on\_target\_time  
PID::pid\_config\_t, 120  
on\_timeout  
AutoCommand, 19  
Branch, 28  
DriveForwardCommand, 39  
DriveStopCommand, 41  
InOrder, 71  
Parallel, 113  
PurePursuitCommand, 131  
RepeatUntil, 134  
TurnDegreesCommand, 170  
TurnToHeadingCommand, 172  
operator+  
point\_t, 128  
Vector2D, 175  
operator-  
point\_t, 129  
Vector2D, 175  
operator\*  
Vector2D, 175  
OrCondition, 110  
test, 110  
Page  
Flywheel, 55  
Parallel, 112  
on\_timeout, 113  
run, 113  
parallel\_runner\_info, 114  
Path  
PurePursuit::Path, 114  
PID, 115  
config, 120  
ERROR\_TYPE, 116  
get, 117  
get\_error, 117  
get\_sensor\_val, 117  
get\_target, 117  
init, 118  
is\_on\_target, 118  
PID, 116  
reset, 118  
set\_limits, 118  
set\_target, 119  
update, 119  
PID::pid\_config\_t, 120  
error\_method, 120  
on\_target\_time, 120  
PIDFF, 121  
get, 121  
init, 121  
is\_on\_target, 123  
set\_limits, 123  
set\_target, 123  
update, 124  
PIDPage  
screen::PIDPage, 125  
plm\_frame\_t, 126  
plm\_packet\_t, 127  
plm\_plane\_t, 127  
plm\_samples\_t, 127  
point  
Vector2D, 176  
point\_t, 127  
dist, 128  
operator+, 128  
operator-, 129  
pos\_diff  
OdometryBase, 100  
pose\_t, 129  
position  
CustomEncoder, 35  
pure\_pursuit  
TankDrive, 159, 160  
PurePursuit::hermite\_point, 69  
PurePursuit::Path, 114

get\_points, 115  
 get\_radius, 115  
 is\_valid, 115  
 Path, 114  
 PurePursuit::spline, 146  
 PurePursuitCommand, 130  
     on\_timeout, 131  
     PurePursuitCommand, 131  
     run, 131  
  
 Rect, 131  
 RepeatUntil, 132  
     on\_timeout, 134  
     RepeatUntil, 133, 134  
     run, 134  
  
 reset  
     PID, 118  
 reset\_auto  
     TankDrive, 161  
 robot\_radius  
     robot\_specs\_t, 136  
 robot\_specs\_t, 135  
     correction\_pid, 135  
     dist\_between\_wheels, 135  
     drive\_correction\_cutoff, 135  
     odom\_gear\_ratio, 135  
     robot\_radius, 136  
 rot\_diff  
     OdometryBase, 101  
 rotation  
     CustomEncoder, 35  
 run  
     Async, 15  
     AutoCommand, 19  
     BasicSolenoidSet, 23  
     BasicSpinCommand, 25  
     BasicStopCommand, 26  
     Branch, 28  
     CommandController, 33  
     DelayCommand, 37  
     DriveForwardCommand, 40  
     DriveStopCommand, 41  
     DriveToPointCommand, 44  
     FlywheelStopCommand, 59  
     FlywheelStopMotorsCommand, 60  
     FunctionCommand, 63  
     GenericAuto, 67  
     InOrder, 71  
     OdomSetPosition, 110  
     Parallel, 113  
     PurePursuitCommand, 131  
     RepeatUntil, 134  
     SpinRPMCommand, 145  
     TurnDegreesCommand, 170  
     TurnToHeadingCommand, 172  
     WaitUntilCondition, 178  
     WaitUntilUpToSpeedCommand, 180  
  
 save\_to\_disk  
  
 Serializer, 140  
 screen::ButtonConfig, 28  
 screen::ButtonWidget, 28  
     ButtonWidget, 29  
     update, 30  
 screen::CheckboxConfig, 30  
 screen::FunctionPage, 64  
     draw, 65  
     FunctionPage, 64  
     update, 65  
 screen::LabelConfig, 72  
 screen::OdometryPage, 103  
     draw, 104  
     OdometryPage, 104  
     update, 104  
 screen::Page, 111  
     draw, 111  
     update, 112  
 screen::PIDPage, 125  
     draw, 126  
     PIDPage, 125  
     update, 126  
 screen::ScreenData, 136  
 screen::ScreenRect, 136  
 screen::SizedWidget, 142  
 screen::SliderConfig, 142  
 screen::SliderWidget, 142  
     SliderWidget, 143  
     update, 143  
 screen::StatsPage, 149  
     draw, 149  
     StatsPage, 149  
     update, 150  
 screen::TextConfig, 164  
 screen::WidgetConfig, 180  
 screen::WidgetPage, 181  
     draw, 181  
     update, 181  
 send\_message  
     StateMachine< System, IDType, Message, delay\_ms, do\_log >, 148  
 Serializer, 137  
     bool\_or, 138  
     double\_or, 138  
     int\_or, 138  
     save\_to\_disk, 140  
     Serializer, 137  
     set\_bool, 140  
     set\_double, 140  
     set\_int, 140  
     set\_string, 141  
     string\_or, 141  
 set\_accel  
     TrapezoidProfile, 168  
 set\_async  
     Lift< T >, 75  
 set\_bool  
     Serializer, 140

set\_double  
    Serializer, 140  
set\_endpts  
    TrapezoidProfile, 168  
set\_int  
    Serializer, 140  
set\_limits  
    BangBang, 21  
    Feedback, 48  
    MotionController, 88  
    PID, 118  
    PIDFF, 123  
    TakeBackHalf, 152  
set\_max\_v  
    TrapezoidProfile, 168  
set\_position  
    Lift< T >, 75  
    OdometryBase, 101  
    OdometryTank, 108  
set\_sensor\_function  
    Lift< T >, 75  
set\_sensor\_reset  
    Lift< T >, 76  
set\_setpoint  
    Lift< T >, 76  
set\_string  
    Serializer, 141  
set\_target  
    PID, 119  
    PIDFF, 123  
set\_vel\_endpts  
    TrapezoidProfile, 168  
setPosition  
    CustomEncoder, 35  
setRotation  
    CustomEncoder, 36  
SliderCfg, 142  
SliderWidget  
    screen::SliderWidget, 143  
smallest\_angle  
    OdometryBase, 101  
Smart  
    TankDrive, 154  
speed  
    OdometryBase, 103  
spin\_manual  
    Flywheel, 55  
spin\_rpm  
    Flywheel, 56  
SpinRpmCmd  
    Flywheel, 56  
SpinRPMCommand, 144  
    run, 145  
    SpinRPMCommand, 145  
spinRPMTask  
    Flywheel, 57  
StateMachine  
    StateMachine< System, IDType, Message, delay\_ms, do\_log >, 148  
    StateMachine< System, IDType, Message, delay\_ms, do\_log >, 147  
        current\_state, 148  
        send\_message, 148  
        StateMachine, 148  
    StateMachine< System, IDType, Message, delay\_ms, do\_log >::MaybeMessage, 80  
        has\_message, 81  
        MaybeMessage, 81  
        message, 81  
    StateMachine< System, IDType, Message, delay\_ms, do\_log >::State, 146  
StatsPage  
    screen::StatsPage, 149  
stop  
    Flywheel, 56  
    TankDrive, 161  
string\_or  
    Serializer, 141  
TakeBackHalf, 150  
    get, 151  
    init, 151  
    is\_on\_target, 151  
    set\_limits, 152  
    update, 152  
TankDrive, 152  
    BrakeType, 154  
    drive\_arcade, 154  
    drive\_forward, 155  
    drive\_tank, 156  
    drive\_tank\_raw, 157  
    drive\_to\_point, 157, 158  
    modify\_inputs, 159  
    None, 154  
    pure\_pursuit, 159, 160  
    reset\_auto, 161  
    Smart, 154  
    stop, 161  
    TankDrive, 154  
    turn\_degrees, 161  
    turn\_to\_heading, 162, 163  
    ZeroVelocity, 154  
test  
    AndCondition, 13  
    FunctionCondition, 64  
    IfTimePassed, 70  
    OrCondition, 110  
    TimesTestedCondition, 164  
timeout\_seconds  
    AutoCommand, 19  
TimesTestedCondition, 164  
    test, 164  
trapezoid\_profile\_segment\_t, 164  
TrapezoidProfile, 165  
    calculate, 167  
    calculate\_time\_based, 167

get\_movement\_time, 167  
 set\_accel, 168  
 set\_endpts, 168  
 set\_max\_v, 168  
 set\_vel\_endpts, 168  
 TrapezoidProfile, 166  
**tune**  
 Odometry3Wheel, 95  
**tune\_feedforward**  
 MotionController, 89  
**turn\_degrees**  
 TankDrive, 161  
**turn\_to\_heading**  
 TankDrive, 162, 163  
**TurnDegreesCommand**, 169  
 on\_timeout, 170  
 run, 170  
 TurnDegreesCommand, 170  
**TurnToHeadingCommand**, 171  
 on\_timeout, 172  
 run, 172  
 TurnToHeadingCommand, 171  
  
**update**  
 AutoChooser, 17  
 BangBang, 21  
 Feedback, 49  
 FlywheelPage, 57  
 MotionController, 89  
 MotionControllerPage, 91  
 Odometry3Wheel, 96  
 OdometryBase, 102  
 OdometryTank, 108  
 PID, 119  
 PIDFF, 124  
 screen::ButtonWidget, 30  
 screen::FunctionPage, 65  
 screen::OdometryPage, 104  
 screen::Page, 112  
 screen::PIDPage, 126  
 screen::SliderWidget, 143  
 screen::StatsPage, 150  
 screen::WidgetPage, 181  
 TakeBackHalf, 152  
 VideoPlayer, 177  
  
**Vector2D**, 172  
 get\_dir, 174  
 get\_mag, 174  
 get\_x, 174  
 get\_y, 174  
 normalize, 174  
 operator+, 175  
 operator-, 175  
 operator\*, 175  
 point, 176  
 Vector2D, 173  
**velocity**  
 CustomEncoder, 36  
 VideoPlayer, 176  
 draw, 176  
 update, 177  
  
 WaitUntilCondition, 177  
 run, 178  
 WaitUntilUpToSpeedCmd  
 Flywheel, 56  
 WaitUntilUpToSpeedCommand, 178  
 run, 180  
 WaitUntilUpToSpeedCommand, 179  
**wheel\_diam**  
 Odometry3Wheel::odometry3wheel\_cfg\_t, 97  
**wheelbase\_dist**  
 Odometry3Wheel::odometry3wheel\_cfg\_t, 97  
  
**zero\_pos**  
 OdometryBase, 103  
**ZeroVelocity**  
 TankDrive, 154