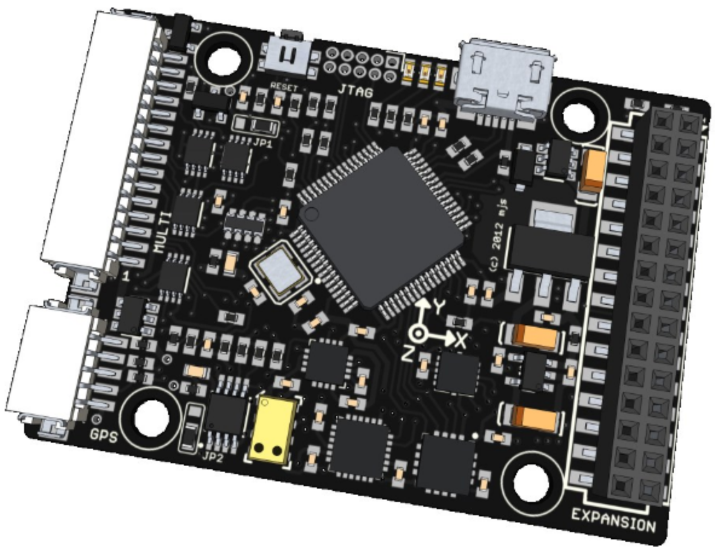
PX4 Development Kit for Simulink



POLAKIUM ENGINEERING

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I. Installation and Setup:

1. Download and install 'px4_toolchain_installer_v13_win.exe' to 'C:\px4\'.

2. Extract the contents of 'px4_simulink.zip' to 'C:\px4\'.

3. Launch PX4 Eclipse and select 'File > New > Makefile Project with Existing Code', browse to 'C:\px4\Firmware\' and choose "Cross GCC".

4. Create targets '**archives**', '**all**', '**distclean**', '**clean**' and '**upload px4fmu-v1_default**' (PX4FMU) or '**upload px4fmu-v2_default**' (Pixhawk).

5. Launch Matlab and set the workspace to 'C:\px4\Firmware\src\modules\simulink_app\'.

6. The configuration parameters for 'simulink_app.slx' have been preconfigured to utilize the embedded coder for the PX4. The commented blocks of the model are included as an example and may be removed. The red uncommented blocks must remain unaltered. Placing a 'from' tag will acquire data from the input port paired with the same tag name. Placing a 'goto' tag will send data to the output port paired with the same tag name.

Function	Tag Name	Description	Units
Radio Inputs	**ch1 ~ ch8**	PWM radio control input signals	µs
Gyroscope	**gyro_[x, y, z]**	Raw gyroscope measurements	rad/s
Accelerometer	**acc_[x, y, z]**	Raw accelerometer measurements	m/s^2
Magnetometer	**mag_[x, y, z]**	Field strength from magnetometer	ga
Pressure Altitude	**baro_alt**	Barometric pressure altitude	m
Visible Satellites *	**gps_sat**	Number of visible GPS satellites	
GPS Position *	**gps_lat, gps_lon**	NED GPS latitude and longitude	deg
GPS Altitude *	**gps_alt**	NED GPS altitude	m
GPS Velocity *	**gps_vel_[n, e, d]**	NED GPS velocity	m/s
Ultrasonic Distance *	**sonar_dist**	Ultrasonic range finder	m
Optical Flow *	**flow_x, flow_y**	Optical flow velocity	m/s
Angular Rate	**rate_[roll, pitch, yaw]**	Angular rates	rad/s
Attitude	**att_[roll, pitch, yaw]**	Attitude angles	rad
Quaternion	**q0, q1, q2, q3**	Attitude quaternion	
System Runtime	**runtime**	System runtime	µs
PWM Outputs	**pwm1 ~ pwm8**	PWM output signals	µs
Arm Trigger	**pwm_arm**	arm signal: true = arm; false = disarm	bool
Standard LED	**led_{color}**	LED switch: true = on; false = off	bool
RGB LED	**rgb_{color}**	LED intensity: 0 = min; 255 = max	uint8
Debug	**debug1 ~ debug8**	Terminal debug outputs	

** Requires additional hardware.*

7. Select "Build Model" within Simulink, and wait for successful completion of code generation for simulink_app.

8. Confirm that the folder 'simulink_app_ert_rtw' has been created in the directory 'C:\px4\Firmware\src\modules\simulink_app\'. *DO NOT rename or move this directory.*

9. Launch PX4 Eclipse and build the firmware by selecting the previously added targets '**distclean**' followed by '**archives**' and then '**all**'. Wait for each process to complete before proceeding to the next by observing the console tab for successful completion.

10. Upload the firmware by selecting the target '**upload px4fmu-v**_default**'. DO NOT connect the USB cable until the console window of Eclipse reads "Loaded firmware for **, waiting for the bootloader...".

11. Download and install '[qgroundcontrol-installer-win32-pixhawk.exe]'.

12. Erase all data from the memory card and return it to the flight controller.

13. Launch QGroundControl and connect the flight controller at a baud rate of '57600'. Select the configuration tab and choose sensor calibration. Calibrate all sensors.

14. Disconnect and close QGroundControl. Remove the memory card and place the folder 'etc' containing 'rc.txt' from 'C:\px4\Firmware\' onto the root of the memory card. Edit 'rc.txt' to allow for use with the PX4FMU, PX4IO, PX4FLOW or a GPS module.

15. Return the memory card. Now the PX4 is configured to automatically execute all startup drivers and applications associated with the Simulink application on boot.

II. Updating the Simulink Code:

1. Launch Matlab and set the workspace to 'C:\px4\Firmware\src\modules\simulink_app\'.

2. After applying changes to 'simulink_app.slx', select 'Build Model' within Simulink, and wait for "Successful completion of code generation for model: simulink_app" to display in the command window.

3. Launch PX4 Eclipse and build the firmware by selecting the target '**all**'. There is no longer any need to use the targets 'distclean' or 'archives' unless the source code has been modified.

4. Upload the firmware by selecting the target '**upload px4fmu-v**_default**'. DO NOT connect the USB cable until the console window of Eclipse reads "Loaded firmware for **, waiting for the bootloader...".

III. System Sample Time:

The fundamental sample time for simulink_app is 4ms (250Hz). This is limited by the maximum rate data can be acquired from the high-rate sensors. *DO NOT* modify the fixed-step size of simulink_app. Simulink will automatically handle the rate transition for data transfer provided that the sample time does not exceed 4ms. Rate transition blocks may also be used to force a desired sample time.

IV. Using the Terminal:

1. Connect via USB and wait for the flight controller to boot. Reboot if necessary using the reset button.

2. Launch TeraTerm from the PX4 Toolchain.

3. Open the setup drop-down menu and select "Serial port".

4. Select the correct COM port and set the baud rate to '57600'.

5. After connecting, press enter to display the "nsh> " prompt before issuing a command.

Command	Description
simulink_app {start|stop} *example: nsh> simulink_app start*	run or terminate Simulink generated code
sdlog2 {start|stop|status} [-r <log rate>] *example: nsh> sdlog2 start –r 250*	log sensor data to memory card at a fixed sample rate ('0' unlimited rate)
top (exit with 'escape' key)	list running applications and CPU status info
help	list available commands
reboot	reboot and disconnect flight controller

V. Accessing Debug Data:

1. Follow steps 1-5 of Section IV. "Using the Terminal" in order to access the command line interface.

2. Issue the command 'simulink_app stop' to ensure simulink_app has been terminated.

3. Restart simulink_app with the command 'simulink_app start'.

4. Debug signals will continuously output to the terminal at 10Hz, preceded by a timestamp.

VI. Recalibrating the Sensors:

1. Follow steps 13-16 of Section I. “Installation and Setup”.

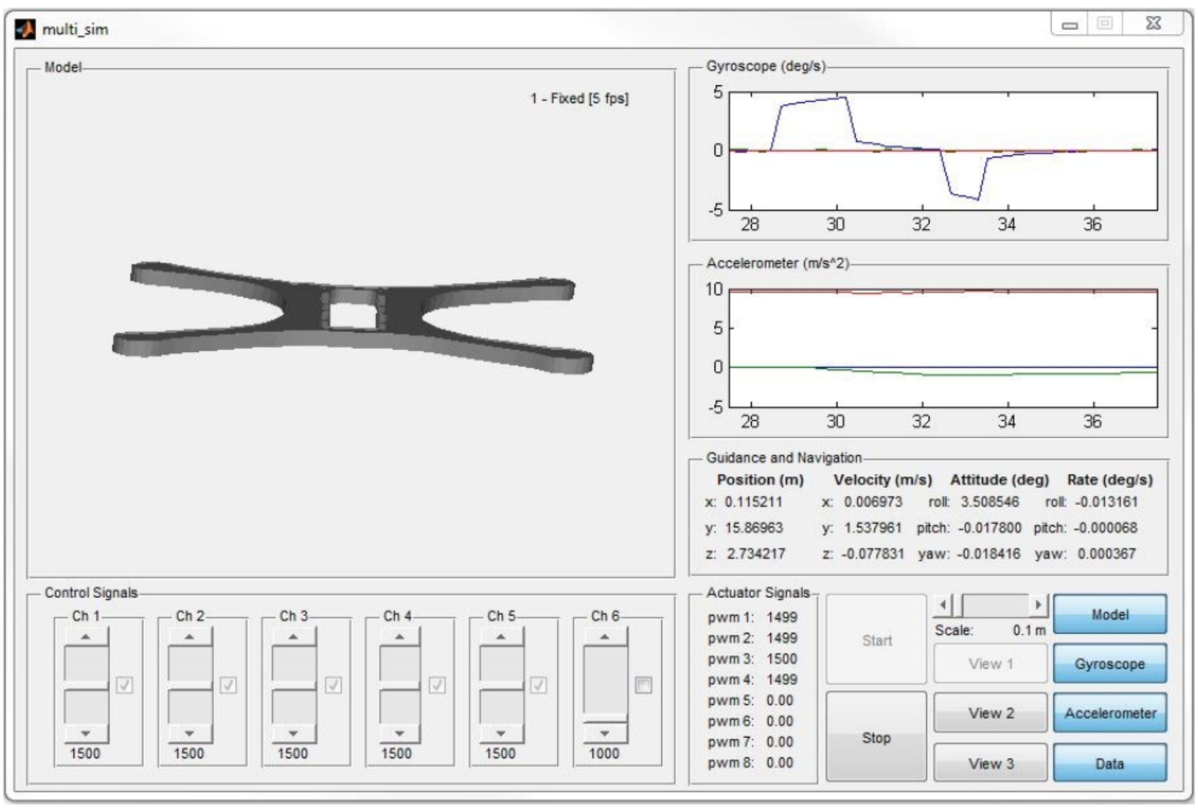
VII. Modeling and Simulation:

1. Locate the directory ‘C:\px4\multi_sim\’ and ensure that the files ‘model.stl’, ‘multi_model.slx’, ‘multi_sim.fig’ and ‘multi_sim.m’ are all located in the Matlab workspace.

2. Open ‘multi_model.slx’ to modify the simulation for a particular vehicle.

3. Replace ‘model.stl’ with any binary .stl file, units in meters, to render a representative model of the vehicle to the user interface.

4. Run ‘multi_sim.m’ to open the graphical user interface and begin the simulation.



VIII. Embedded Wrapper Code:

```
// Simulink wrapper code for PX4 (PX4FMU & Pixhawk)
// Developed by Adam Polak, Polakium Engineering 2014
// http://www.polakiumengineering.org

#include <nuttx/config.h>
#include <poll.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <uORB/uORB.h>
#include <uORB/topics/sensor_combined.h>
#include <uORB/topics/vehicle_attitude.h>
#include <uORB/topics/optical_flow.h>
#include <uORB/topics/vehicle_gps_position.h>
#include <drivers/drv_led.h>
#include <drivers/drv_rgbled.h>
#include <drivers/drv_pwm_output.h>
#include <drivers/drv_rc_input.h>
#include <drivers/drv_hrt.h>
#include <systemlib/systemlib.h>

__EXPORT int simulink_app_main(int argc, char *argv[]);

const char *dev_rgbled = RGBLED_DEVICE_PATH;
const char *dev_pwm = PWM_OUTPUT_DEVICE_PATH;

static int simulink_task;
static bool thread_exit;
static bool pwm_enabled;

struct rgbled_rgbset_t{
  uint8_t red;
  uint8_t green;
  uint8_t blue;
};

int step_size = 4; // fundamental sample time (ms)
int i = 1;

int simulink_main(int argc, char *argv[])
{
  simulink_app_initialize();

  // declare data subscriptions
  int sensors_sub = orb_subscribe(ORB_ID(sensor_combined));
  int pwm_inputs_sub = orb_subscribe(ORB_ID(input_rc));
  int attitude_sub = orb_subscribe(ORB_ID(vehicle_attitude));
  int flow_sub = orb_subscribe(ORB_ID(optical_flow));
  int gps_sub = orb_subscribe(ORB_ID(vehicle_gps_position));
```

```
struct sensor_combined_s sensors;
struct rc_input_values pwm_inputs;
struct vehicle_attitude_s attitude;
struct optical_flow_s flow;
struct vehicle_gps_position_s gps;

orb_set_interval(sensors_sub, step_size);

// declare output devices
int rgbled = open(dev_rgbled, 0);
int pwm = open(dev_pwm, 0);

// initialize outputs
ioctl(rgbled, RGBLED_SET_MODE, (unsigned long)RGBLED_MODE_ON);
ioctl(pwm, PWM_SERVO_SET_ARM_OK, 0);
ioctl(pwm, PWM_SERVO_ARM, 0);
pwm_enabled = 0;

struct pollfd fds[] = {
  { .fd = sensors_sub, .events = POLLIN },
};

// primary application thread
while (!thread_exit) {
  int poll_return = poll(fds, 1, 1000);
  if (poll_return > 0) {
    if (fds[0].revents & POLLIN) {
      // assign sensor data
      orb_copy(ORB_ID(sensor_combined), sensors_sub, &sensors);
      orb_copy(ORB_ID(vehicle_attitude), attitude_sub, &attitude);
      orb_copy(ORB_ID(optical_flow), flow_sub, &flow);
      orb_copy(ORB_ID(vehicle_gps_position), gps_sub, &gps);
      orb_copy(ORB_ID(input_rc), pwm_inputs_sub, &pwm_inputs);
      simulink_app_U.runtime = hrt_absolute_time();
      simulink_app_U.mag_x = sensors.magnetometer_ga[0];
      simulink_app_U.mag_y = sensors.magnetometer_ga[1];
      simulink_app_U.mag_z = sensors.magnetometer_ga[2];
      simulink_app_U.acc_x = sensors.accelerometer_m_s2[0];
      simulink_app_U.acc_y = sensors.accelerometer_m_s2[1];
      simulink_app_U.acc_z = sensors.accelerometer_m_s2[2];
      simulink_app_U.gyro_x = sensors.gyro_rad_s[0];
      simulink_app_U.gyro_y = sensors.gyro_rad_s[1];
      simulink_app_U.gyro_z = sensors.gyro_rad_s[2];
      simulink_app_U.rate_roll = attitude.rollspeed;
      simulink_app_U.rate_pitch = attitude.pitchspeed;
      simulink_app_U.rate_yaw = attitude.yawspeed;
      simulink_app_U.att_roll = attitude.roll;
      simulink_app_U.att_pitch = attitude.pitch;
      simulink_app_U.att_yaw = attitude.yaw;
      simulink_app_U.q0 = attitude.q[0];
      simulink_app_U.q1 = attitude.q[1];
      simulink_app_U.q2 = attitude.q[2];
      simulink_app_U.q3 = attitude.q[3];
      simulink_app_U.baro_alt = sensors.baro_alt_meter;
      simulink_app_U.sonar_dist = flow.ground_distance_m;
      simulink_app_U.flow_x = flow.flow_comp_x_m;
```

```
simulink_app_U.flow_y = flow.flow_comp_y_m;
simulink_app_U.gps_sat = gps.satellites_used;
simulink_app_U.gps_lat = 0.0000001*(double)gps.lat;
simulink_app_U.gps_lon = 0.0000001*(double)gps.lon;
simulink_app_U.gps_alt = 0.001*(double)gps.alt;
simulink_app_U.gps_vel = gps.vel_m_s;
simulink_app_U.gps_vel_n = gps.vel_n_m_s;
simulink_app_U.gps_vel_e = gps.vel_e_m_s;
simulink_app_U.gps_vel_d = gps.vel_d_m_s;
simulink_app_U.ch1 = pwm_inputs.values[0];
simulink_app_U.ch2 = pwm_inputs.values[1];
simulink_app_U.ch3 = pwm_inputs.values[2];
simulink_app_U.ch4 = pwm_inputs.values[3];
simulink_app_U.ch5 = pwm_inputs.values[4];
simulink_app_U.ch6 = pwm_inputs.values[5];
simulink_app_U.ch7 = pwm_inputs.values[6];
simulink_app_U.ch8 = pwm_inputs.values[7];
if (i < 25) { // 10Hz loop
  i = i++;
} else {
  // check arm state
  if (simulink_app_Y.pwm_arm == 1 && pwm_enabled == 0) {
    // arm system
    pwm_enabled = 1;
    printf("\t  ARMED \n");
  } else if (simulink_app_Y.pwm_arm == 0 && pwm_enabled == 1) {
    // disarm system
    ioctl(pwm, PWM_SERVO_SET(0), 1000);
    ioctl(pwm, PWM_SERVO_SET(1), 1000);
    ioctl(pwm, PWM_SERVO_SET(2), 1000);
    ioctl(pwm, PWM_SERVO_SET(3), 1000);
    ioctl(pwm, PWM_SERVO_SET(4), 1000);
    ioctl(pwm, PWM_SERVO_SET(5), 1000);
    ioctl(pwm, PWM_SERVO_SET(6), 1000);
    ioctl(pwm, PWM_SERVO_SET(7), 1000);
    pwm_enabled = 0;
    printf("\tDISARMEDn");
  }
  // output FMU LED signals
  if (simulink_app_Y.led_blue == 1) {
    led_on(LED_BLUE);
  } else {
    led_off(LED_BLUE);
  }
  if (simulink_app_Y.led_red == 1) {
    led_on(LED_RED);
  } else {
    led_off(LED_RED);
  }
  // output RGBLED signals
  rgbled_rgbset_t rgb_value;
  rgb_value.red = simulink_app_Y.rgb_red;
  rgb_value.green = simulink_app_Y.rgb_green;
  rgb_value.blue = simulink_app_Y.rgb_blue;
  ioctl(rgbled, RGBLED_SET_RGB, (unsigned long)&rgb_value);
```

```
          // print debug data
          printf("%8.4f\t%8.4f\t%8.4f\t%8.4f\t%8.4f
              \t%8.4f\t%8.4f\t%8.4f\t%8.4f\n",
              (double)(simulink_app_U.runtime/1000000),
              (double)simulink_app_Y.debug1,
              (double)simulink_app_Y.debug2,
              (double)simulink_app_Y.debug3,
              (double)simulink_app_Y.debug4,
              (double)simulink_app_Y.debug5,
              (double)simulink_app_Y.debug6,
              (double)simulink_app_Y.debug7,
              (double)simulink_app_Y.debug8);
          i = 1;
        }
        // output pwm signals
        if (pwm_enabled == 1) {
          ioctl(pwm, PWM_SERVO_SET(0), simulink_app_Y.pwm1);
          ioctl(pwm, PWM_SERVO_SET(1), simulink_app_Y.pwm2);
          ioctl(pwm, PWM_SERVO_SET(2), simulink_app_Y.pwm3);
          ioctl(pwm, PWM_SERVO_SET(3), simulink_app_Y.pwm4);
          ioctl(pwm, PWM_SERVO_SET(4), simulink_app_Y.pwm5);
          ioctl(pwm, PWM_SERVO_SET(5), simulink_app_Y.pwm6);
          ioctl(pwm, PWM_SERVO_SET(6), simulink_app_Y.pwm7);
          ioctl(pwm, PWM_SERVO_SET(7), simulink_app_Y.pwm8);
        } else {
          ioctl(pwm, PWM_SERVO_SET(0), 1000);
          ioctl(pwm, PWM_SERVO_SET(1), 1000);
          ioctl(pwm, PWM_SERVO_SET(2), 1000);
          ioctl(pwm, PWM_SERVO_SET(3), 1000);
          ioctl(pwm, PWM_SERVO_SET(4), 1000);
          ioctl(pwm, PWM_SERVO_SET(5), 1000);
          ioctl(pwm, PWM_SERVO_SET(6), 1000);
          ioctl(pwm, PWM_SERVO_SET(7), 1000);
        }
        // execute simulink code
        simulink_app_step();
      }
    }
  }
  // disable pwm outputs
  ioctl(pwm, PWM_SERVO_SET(0), 1000);
  ioctl(pwm, PWM_SERVO_SET(1), 1000);
  ioctl(pwm, PWM_SERVO_SET(2), 1000);
  ioctl(pwm, PWM_SERVO_SET(3), 1000);
  ioctl(pwm, PWM_SERVO_SET(4), 1000);
  ioctl(pwm, PWM_SERVO_SET(5), 1000);
  ioctl(pwm, PWM_SERVO_SET(6), 1000);
  ioctl(pwm, PWM_SERVO_SET(7), 1000);
  ioctl(pwm, PWM_SERVO_DISARM, 0);
  // disable LEDs
  led_off(LED_BLUE);
  led_off(LED_RED);
  ioctl(rgbled, RGBLED_SET_MODE, (unsigned long)RGBLED_MODE_OFF);
```

```
// close sensor subscriptions
  close(sensors_sub);
  close(attitude_sub);
  close(flow_sub);
  close(pwm_inputs_sub);
  close(gps_sub);
  // terminate application thread
  exit(0);
}

int simulink_app_main(int argc, char *argv[])
{
  // start primary application thread
  if (!strcmp(argv[1], "start")) {
    thread_exit = false;
    simulink_task = task_spawn_cmd("simulink_app",
      SCHED_DEFAULT,
      SCHED_PRIORITY_MAX - 15,
      10240,
      simulink_main,
      NULL);
    exit(0);
  }
  // terminate primary application thread
  if (!strcmp(argv[1], "stop")) {
    thread_exit = true;
    exit(0);
  }

  exit(1);
}
```