



- [\[\]\[\]\[\]\[\]](#)
- [\[\] Mission Planner \[\]\[\]\[\]](#)
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- [\[\]\[\]\[\]](#)
- [\[\]\[\] SD \[\]](#)
- [\[\]\[\] GPS / \[\]\[\]\[\]](#)
- [\[\] ChibiOS \[\]\[\]\[\]\[\]](#)
- [\[\] Pixhawk \[\]\[\]\[\]](#)
- [\[\]\[\]\[\]](#)
- [Navio2 \[\]\[\]\[\]\[\]\[\]](#)
- [\[\]\[\]](#)



□□□□□□ “□□” □□□□ Pixhawk□□□□□□□□ Cop□□□□ □□ □□□□□□□□□□
** □□□□ **□

□ Mission Planner □□□□

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□□□□□□□□ ,□□ ** Load Firmware **□

□□□□□

□□□□ , □□□□□□□□ □□□□□□□□ /□□ ,□□□□□□□□ □ Windows □□□□□□□□
□□□□ USB□□ ,**□□□□□□□□ **,**, *□□ * IP□□□□ .

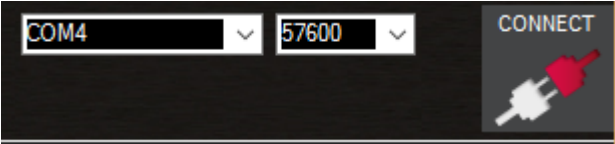
□□ □

□□□□□□□□□□□□□□ Windows □□□ □□□□□□ COM □□□□□□□□□□ □□
□□□□□□□□ .



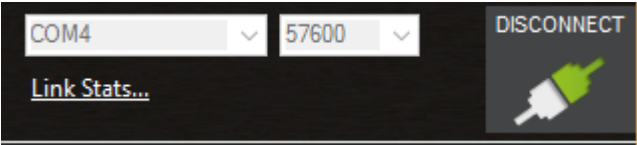
SiK

COM4 57600



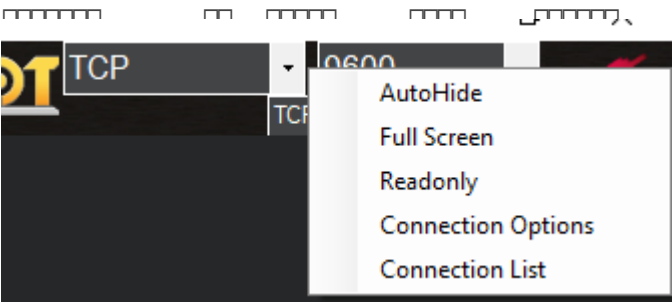
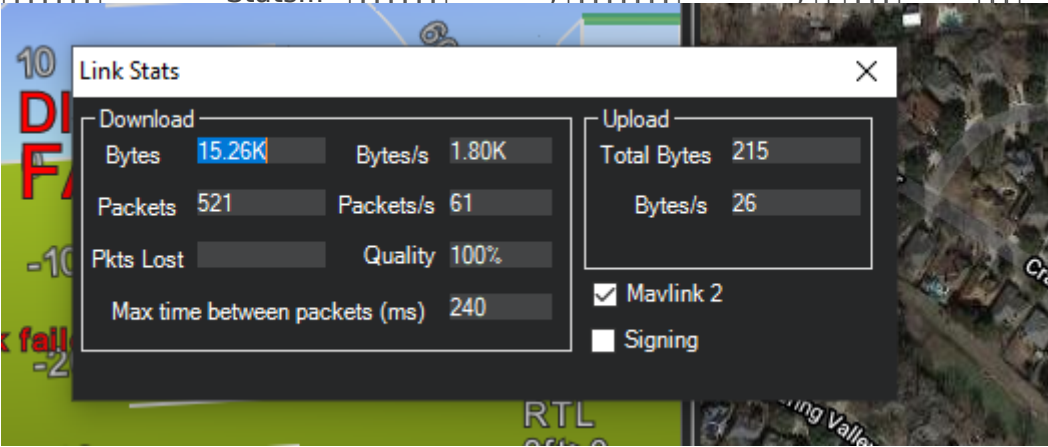
USB, Windows COM , ((USB) 115200, 57600.

ô TCP UDP ,



“ ” TCP UDP

“ Stats...” , ? , STAT



```
tcp://127.0.0.1:5670 ( ).
      00000000
      0000
      000:com4:115200
```

- ```

// 10 LEDs
// 5 LEDs
ArduPilot, // (5 LEDs)
LED

```

[illegible][illegible]

☐ ,MAVLink USB SERIAL0,SLCAN USB SERI .  
Mission Planner Windows , MAVLINK  
ArduPilot , COM ,.

[illegible]









|  |  |
|--|--|
|  |  |
|--|--|

```
GPS[] [] , [] ** []
Copter[] Rover[] Sub[] QuadPlane[] Plane[] (** common-
companyless)[][], [] , []
```

1. Copter 2. Rover 3. GPS 4. Compass 5. (6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839.

/  ,   **gps-**  ,   ,   - ek3-

../../../../images/gps-connection.jpg

**TX** **RX** **GPS** .

**ArduPilot** **Port 3**

**UART** **Serial Port 3**, **\*\* \*\*** .

**SERIALx** **SERIALx** **PROTOCOL** " 5"(

**GPS** , **GPS** , **GPS**

Pixhawk  ,



 , 

../../../../images/rx-connection.jpg

ArduPilot ☐☐☐☐☐☐      RC☐☐☐☐☐☐      :

1. ？
2. SBus
3. FPort ( -F )
4. (CRSF) ELRS ( , UART . )
5. Spektrum DSM DSM2
6. Spektrum DSM-X
7. IBUS
8. MULTIPLEX SRXL 1 2 .






```

ArduPilot 4.0 , UART RC , RCin S
, ,
PROTOCOL 23 , (SBUS,FPort),UART
. (0) RX , RC
. () ,
. RC ,
RC bit 10

```

UART 1 (TX) - RX  
UART 2 (TX) - RX

../../images/FRSkyTaranis.jpg\_

FRSKY 接收機

## 1 / Servo

ESC / PWM 接收機 PWM 輸出 .

MAIN/AUX 接收機 , 輸出 OUPU 接收機 . 接收機 ESC 接收機 PWM Dshot . 接收機 I/O 接收機 , 接收機 , 接收機 .

MAIN/AUX 接收機 , 接收機 / 接收機 , 接收機 , 接收機 RC 接收機 Main IOMCU, 接收機 , 接收機 A 接收機 X 接收機 . 接收機 OUPUTx Mx.

接收機 , 接收機 AUX 接收機 ( 接收機 AUPUT 接收機 ICPU 接收機 ) 接收機 PWM Dshot 接收機 PWM.

1 1

IOMCU 接收機 Main 接收機 , 接收機 GPIOs / DshotESC 接收機 . CUAV V5 Nano Holybro Pixhawk 4 Mini 接收機 .

接收機 , 接收機 3 接收機 接收機 , 接收機 ESC BEC 接收機 , 接收機 .

Rover 接收機

../../images/servo-motor-connection.jpg

接收機 接收機 , 接收機 ESC 接收機 接收機 .

../../images/pixhawk\_motor\_outputs.jpg\_

[ 接收機 ="copter"]. 接收機 , 接收機 \*\* 接收機 ESC 接收機 \*\*

接收機 PDB 接收機 PDB 接收機 , 接收機 (S) 接收機 :

- 接收機 1 = 接收機 1 - - 接收機 5 = 接收機 5

- 2 = 2 - - 6 = 6
- 3 = 3 - - 7 = 7
- 4 = 4 - - 8 = 8

[/ ]

[ = " "]. : :

- 1=Aileron
- 2=
- 3=
- 4=

[/ ]

[ = "rover"]. Rovers : :

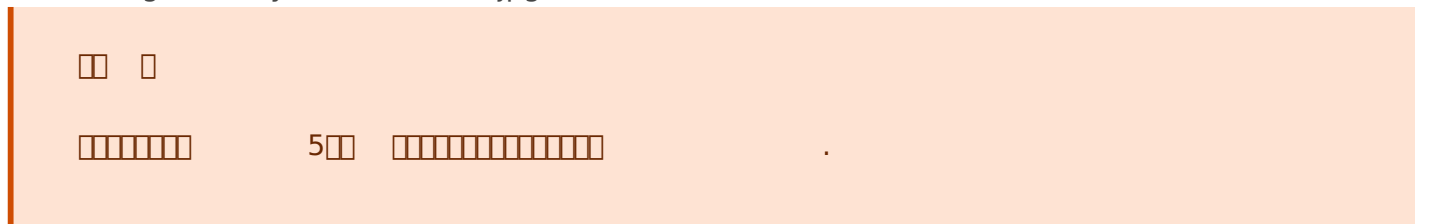
- 3=
- 1=

- ( ,  
 ). SERVOx F  
 \*\* [/ ] [ = "sub"]. \*\* [/ ]



, . . BUZZER  
 SWITCH

../../images/safetysw-connection.jpg



\*\* \*\*  
 ,



```
[##### = "copter"].
Quadcopter < ##### - Quadcopter- >
[/>]
```



```
ArduPilot**
```

  a  GCS,                                                                                                                                                             

□□□□□□□□ GCS□□□□□□□□□□ :

- **\*\*** (Linux Android): **\*\*** GCS ArduPilot  
 . Windows  
 .
- (Windows, Mac OS X, Linux, Android iOS). Android GCS,  
 . ,  
 .

“

-  \_\_\_\_\_ (  )
-  \_\_\_\_\_

- **\*\*APM Planner 2 \*\*** (Windows, Mac OS X, Linux): **\*\* Install APM Planner 2 \*\*** - [\[Link\]](#)  
[\[Link\]](#) .
- [\[Link\]](#) (Windows, mac OS X, Linux): ([\[Link\]](#) ([\[Link\]](#) ) ). **Alpha** [\[Link\]](#) - [\[Link\]](#) !  
[\[Link\]](#) , [\[Link\]](#) , [\[Link\]](#) UI [\[Link\]](#) . [\[Link\]](#) , [\[Link\]](#) ,  
[\[Link\]](#) , [\[Link\]](#) , [\[Link\]](#) , [\[Link\]](#) Lua [\[Link\]](#) , [\[Link\]](#) MAVLink [\[Link\]](#) . [\[Link\]](#) MSP [\[Link\]](#)  
BetaFlight [\[Link\]](#) iNav.
- [\[Link\]](#)
- [\[Link\]](#)

```
[copywiki ☐ ☐ = "copter,plane,rover,sub,blimp").
```



[copywiki 空 = 'copter,plane,rover,planner,blimp,sub'].



空空空空空 ArduPilot空空空空空 :空空空空空空空空空空 ,空空空空空空空空空空 ,  
空空空空空 .

```
空 空

空空空空空空空空空空 ArduPilot,空空空空空空空空空空 ,空空空空空 空 , 空 ,
空空 , 空 , 空空 , 空空 , 空空 , 空空 ..
```

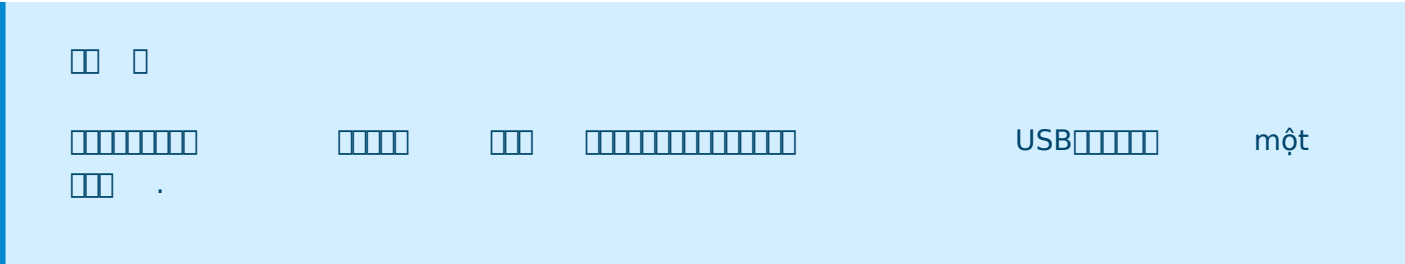
空 1:空空空空空空空空空空



Pixhawk USB 空

Khi bạn kết nối máy bay, nó sẽ tự động chuyển sang chế độ DFU/BOOT. Khi đó, bạn có thể tải firmware lên máy bay.

Windows và macOS.



Bước 2: Tải firmware



ArduPilot là một dự án mã nguồn mở, cho phép bạn tải firmware lên máy bay. Bạn có thể tải firmware từ trang web của ArduPilot hoặc từ các nguồn khác như PX4, Betaflight, INAV, v.v.

Để tải firmware, bạn cần biết tên của máy bay và phiên bản firmware mà bạn muốn tải. Ví dụ, nếu bạn có một máy bay PX4, bạn có thể tải firmware từ trang web của PX4.

Sau khi tải xong, bạn có thể chuyển sang bước tiếp theo.

Các bước tiếp theo:

- Tải firmware ArduPilot từ trang web của ArduPilot. Bạn có thể tải firmware từ trang web của ArduPilot hoặc từ các nguồn khác như PX4, Betaflight, INAV, v.v.
- Tải firmware ArduPilot từ trang web của ArduPilot. Bạn có thể tải firmware từ trang web của ArduPilot hoặc từ các nguồn khác như PX4, Betaflight, INAV, v.v.

Bước 3: Kết nối máy bay

Sau khi tải xong, bạn có thể kết nối máy bay với máy tính. Bạn có thể kết nối máy bay với máy tính bằng cáp USB hoặc bằng cách kết nối máy bay với máy tính thông qua một bộ chuyển đổi.



- `XXXXXXXXXXXXXXXXXXXX`
- `XXXXXXXXXXXXXXXXXXXX` :
  - `1:1` - `XXXXXXXXXX` , `XXXXXXXXXXXX` `ArduPilotXXXXXXXXXXXX`
  - `bl.hex` `XXXX` - `XXXXXXXXXXXX` , `DFUXXXX` `ArduPilotXXXXXXXXXXXX`
  - `XXX.abin` - `SDXXXX` `**`, `XXXXXXXXXXXX`
  - `XXX.bin` - `XXXXXX` , `dfu-util (XXXX)` `XXXXXXXXXXXX`

`XXXX` `XXXX`

`XXXXXXXXXXXXXXXXXXXX` , `XXXXXXXXXXXXXXXXXXXX` . `XXXXXXXXXXXX`  
`ArduPilot,XXXXXXXXXXXX` .

`XXXX`

`XXXX` `XXXXXXXXXX` , `XXXXXXXXXXXXXXXXXXXX` `XXXXXXXXXXXXXXXXXXXX` `XXXXXXXXXXXX`  
`XXXX` `XXXX` `XXXXXXXXXXXX` ; `XXXXXXXXXXXXXXXXXXXX` `XXXX-X.y.zXXXX`

`XXXX` `XXXX`

`ArduPilotXXXXXX` , `XXXXXXXXXXXXXXXXXXXXXXXXXXXX` `XXXXXX` , `XXXX`  
`XXXX` ? `XXXXXXXXXXXXXXXXXXXX` , `XXXXXXXXXXXX` `bugfixs.`

`XXXX`

`XXXXXXXXXX` `XXXX` `XXXX` , `XXXX` `XXXXXX` . `XXXXXXXXXXXXXXXXXXXXXXXXXXXX` ,  
`XXXXXXXXXXXX` . `XXXXXX` `"β"` `XXXX` , `XXXXXX` `bugs.` `XXXXXXXXXXXXXXXXXXXX` `XXXX` , `XXXX`  
`BetaXXXXXXXXXXXX` , `XXXXXXXXXXXX` . `XXXXXXXXXXXXXXXXXXXXXXXXXXXX`  
`XXXX` `XXXX` `XXXXXXXXXXXX` `ArduPilotXXXXXXXXXXXX`

`XXXXXX` `XXXXXXXXXX` `XXXXXXXXXXXX` , `XXXX` `XXXX` `XXXXXXXXXXXX` `XXXXXXXXXXXXXXXXXXXX`  
`XXXX`

`XXXXXXXXXXXX`

`XXXX` `ArduPilotXXXXXXXXXXXX` . `XXXXXXXXXXXX` , `XXXXXXXXXXXXXXXXXXXX` ,  
`XXXXXXXXXXXXXXXXXXXX` `XXXX` , `XXXXXXXXXXXXXXXXXXXX` `XXXXXXXXXXXX` , `XXXXXXXXXXXX` . `XXXX`  
`"alpha"` `XXXX` , `XXXXXX` `bugs,XXXXXX` `"crash approduction".` `XXXXXXXXXXXX` `49`  
`XXXXXXXXXXXX` , `XXXXXX` `**Upcoming features**` `XXXXXXXXXXXXXXXXXXXX`

`XXXXXXXXXXXX` `XXXX` `XXXX` `XXXXXX` `XXXXXXXXXXXXXXXXXXXX` , `XXXX` `DFU` `XXXX`



□     .   ,  
\*\*  \*\*



 ,  ,  ,  
  .  
  
 ,  ,  (  “  ”  )  
                                                                                                                                                                                                                                                                                                                                                                                                    

XXXXXXXXXXXXXXXXXXXX (XXXXXXXXXXXX2017-09-29). ardupilot.abin XXXXX SDXXXX ,  
XXXXXX 23. ركل ا راط XXX USBXXXXXX ,XXXXXX ,XXXXXX  
XXXXXX SD CardXXXXXX ,XXXXXX \*\*.



XXXXXXXXXXXXXXXXXXXX ArduPilotXXXX . XXXXXXX 1MBXXXXXX ,  
XXXXXX ,XXXXXX ũ.

- XXXXXXX :XXXX XXXX “ XXX ” XXXXXXX ,XXXX XXX  
XXXXXXXXXXXXXXXXXXXX :XXXX.txt XXXXXXX XXXXXXX XXXXXXX  
XXXXXXXXXXXX
- XXX 1MBXXXXXXXXXXXXXXXXXXXX .XXXXXXXXXXXX XXXXXXX XXX  
XXXXXXXXXXXXXXXXXXXX , XXXXXXXXXXXXXXXXXXXXXXX ,  
XXXXXXXXXXXXXXXXXXXX XXX XXX ,XXXX QuadPlane XXXXXXX Plane  
XXXXXX XXXXXXXXXXXXXXX ,XXXXXXXXXXXXXXXXXXXX .
- XXXXXXXXXXXXXXX ,XXXX StableXXXX BetaXXXX .



□□ Pãn □, □□□□□ (□ " Pitch90 " ) □□□□□□□□ 90□□ □□□□ □□□□ )

```

Yaw , : ("Yaw90") , .

```

../../../../images/MountingToFrame\_MPBoardOrientation.png















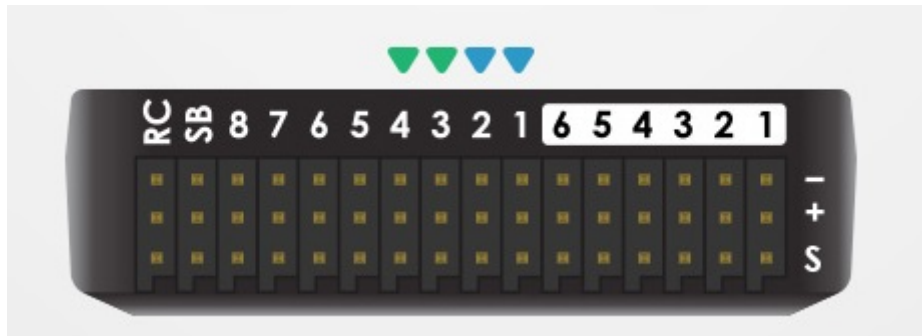
|  |  |  |  |  |  |  |
|--|--|--|--|--|--|--|
|  |  |  |  |  |  |  |
|--|--|--|--|--|--|--|



 ESC, 
 . Pixhawk  ,  

 .

ESC (+) (-) (s)



Pixhawk ( ). 4

|  |  |  |  |  |
|--|--|--|--|--|
|  |  |  |  |  |
|--|--|--|--|--|

```

XXXXXXXXXXXXX . XXXXXXXX (XXX ,CW)XXX (XX)XX .
XXXXXXXXXXXXX Mission PlannerXXXXXXXXXX XXXX XXXX SETUP - >
XXXXXXXXXX XXX , Name

```



CLOCKWISE ROTATION  
USE PUSHER PROPELLER



COUNTER-CLOCKWISE ROTATION  
USE NORMAL PROPELLER

|  |  |  |  |  |  |  |  |  |
|--|--|--|--|--|--|--|--|--|
|  |  |  |  |  |  |  |  |  |
|--|--|--|--|--|--|--|--|--|

# QU Anh:

11

[illegible]

1. “Yaw Torque”(NYT) **VTOL**   
 , QUAD ,   
 ya, ya .






(DJI)

( )

OCTO PL s ( ) X OCTO OCTO H OCTO X (DJ!) ( ( ) ). OCTO X( ) ) .

DECA 



00 01  
 0000000 ,0000 0000  
 00 ESC0000

The screenshot shows the Betaflight Configurator main menu. On the left is a dark sidebar with white text listing menu items: 'Install Firmware', 'Wizard', '>> Mandatory Hardware', '>> Optional Hardware', '3DR Radio', 'Battery Monitor', 'Compass/Motor Calib', 'Sonar', 'Airspeed', 'Optical Flow', 'OSD', and 'Camera Gimbal'. The 'Wizard' option is highlighted. The main area has a dark background. At the top, it says 'Throttle %' followed by a numeric input field containing '5' and a small up/down arrow icon. Below this are four green rectangular buttons with white text: 'Test motor A', 'Test motor B', 'Test motor C', and 'Test motor D'. In the top right corner, there are two status indicators: a battery level icon (four white bars) and a signal strength icon (four white bars).



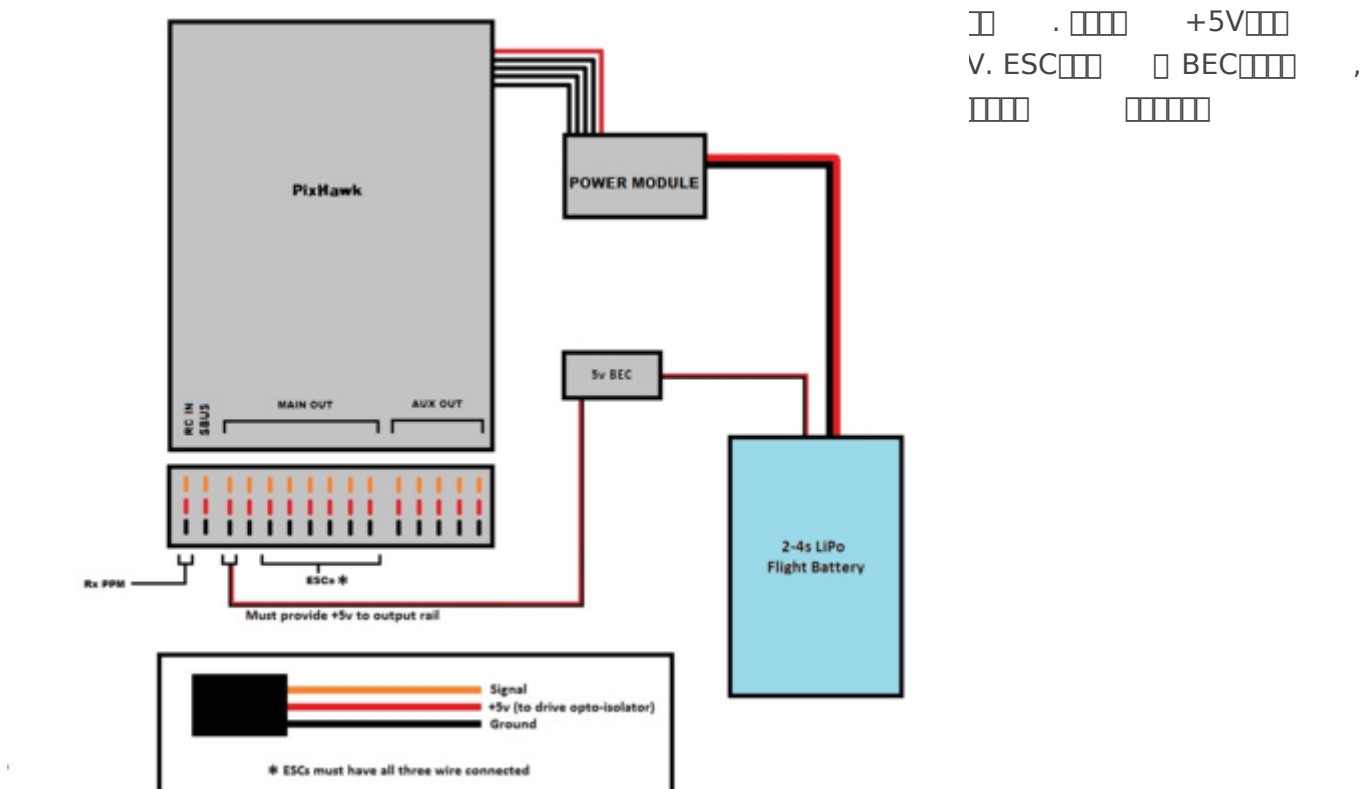
□□□□□□□□ . □□ □□□□□□ (ESCs) □□□□□□ OR □□□□□□ (PDB).

```

PDB , (+) (-) (s) ESC PDB. ,
 PDB (
). , PDB .
 , (-) (+)

```

KDE(  ) Opto  ESCs



### Pixhawk with traditional power module setup

KDE ESC [ ] PWM [ ] , [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] PWM[ ] [ ] [ ] [ ] , RCx MIN [ ] 1100,RCx MAX [ ] 1900us [ ] [ ] [ ]

# Pixhawk ESC

`[0][0]`, `[0]` ESC`[0][0][0][0][0][0][0][0]`.

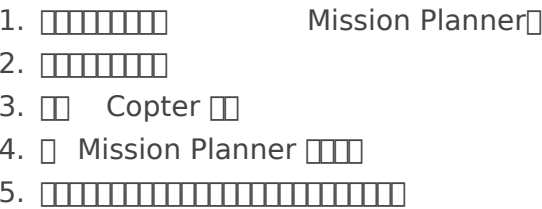
Pixhawk, ESC, RC ( ) ,EMAX  
ESC.

, ESC +5V  
 , ESC

.



☐ ☐



 ·  [initial-setup](#) · CC BY-SA 3.0



Go to ArduPilot [https://ardupilot.org](#), click on the "Build" button, and then click on the "Build Server" button. This will take you to the ArduPilot Build Server page. On this page, you can select the vehicle, version, and board for which you want to build the firmware. The "Vehicle" dropdown menu is set to "ArduCopter", the "Version" dropdown menu is set to "3.10.0", and the "Board" dropdown menu is set to "Pixhawk". You can also select the features you want to include in the firmware. The "Features" section has a "Default" button and a "Custom" button. The "Custom" button is selected, and the "Features" list is expanded. The "Features" list shows the default features for the selected vehicle, version, and board. You can select or deselect features by clicking on the checkboxes next to them. The "Build" button is at the bottom right of the page.

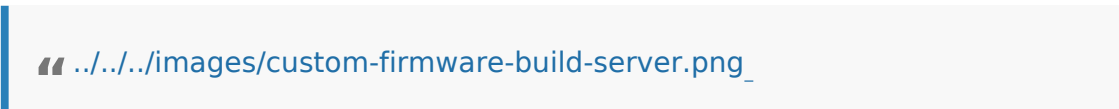


Follow these steps to build the firmware:

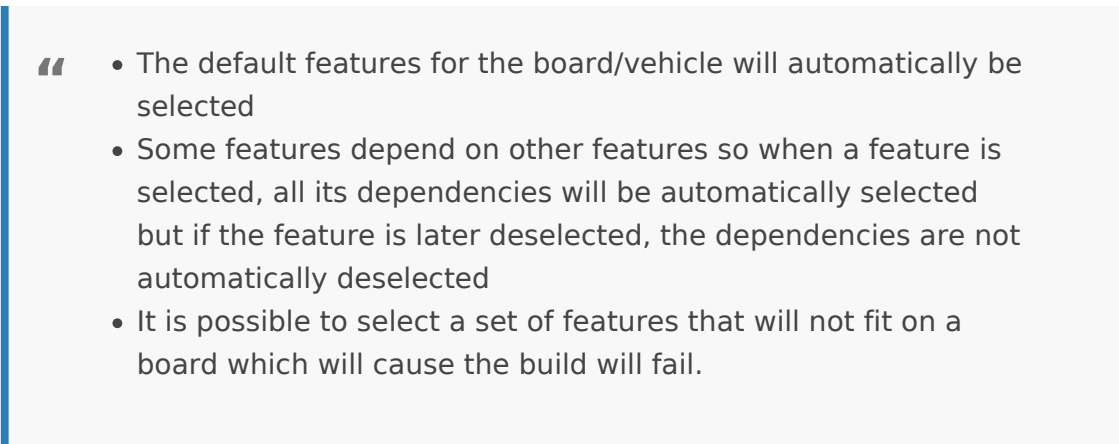
1. Click the "Build" button located at the top right corner of the homepage.



2. Choose the vehicle, version, and board, in that order, for which you want to build the firmware.



3. Select the features you wish to include in the firmware



- The default features for the board/vehicle will automatically be selected
- Some features depend on other features so when a feature is selected, all its dependencies will be automatically selected but if the feature is later deselected, the dependencies are not automatically deselected
- It is possible to select a set of features that will not fit on a board which will cause the build will fail.

4. Click the '**Generate**' button. You will be redirected to the homepage, and a build log for the request you just submitted will appear.
5. Once the build is complete the build artifact will be downloaded automatically, You can also download it manually by clicking the '**Download**' button next to your build request in the build list table. The button will be enabled only after a successful build.
6. Extract the downloaded build artifact. The extracted files will include the .apj firmware file along with other files
7. Use your GCS to install the .apj file onto your autopilot. If using Mission Planner, open the Install Firmware and click then "Load custom firmware" link

“ [../../images/mission-planner-load-custom-firmware.png](#) ”

# Versions

## Latest

This is the current development branch of ArduPilot. It includes new features, enhancements, clean-ups, etc. but has not been through a release cycle of beta testing. It has been alpha tested and thoroughly tested in ArduPilot's Continuous Integration auto-test suite. Many experienced users select this to get the latest features but it has the highest risk, in terms of potential bugs.

## Beta

This is a release of the development branch used for widespread testing and feedback. While the risk of major issues is low, it is expected that minor behavioral deviations may pop up. These are normally addressed in later beta releases of a major new release before declaring the code as a stable release.

## Stable

These are fully released versions of the code. There are usually several minor releases for each major release number which correct any anomalies found during the beta testing phases. These releases, have the lowest risk. It is recommended that the highest numbered major/minor release be used in a given release sequence, unless an older version is needed.



The ArduPilot project is very careful about what is merged into our "point releases". Anything that goes into one has either been evaluated as being strictly limited in what impact it can have on existing systems, or as being an important bugfix. We encourage users to upgrade to any point release which is released, as they sometimes contain very important bugfixes.

# Guide to Size Impacts

Often, the custom build server is used to create firmware with features that have been removed in the standard firmware to conserve flash space, but desired by the user. If a build fails to complete due to lack of flash, the user may remove features/sensors that are not needed in order to make room for those additional items wanted. In order to facilitate those choices, the table below shows what impact a feature's removal has on flash size. Note that a removed feature in this list automatically removed all features dependent upon it.



the exact numbers of bytes will change slightly over time due to code changes, but this table should be accurate enough to make decisions on removal candidates to gain flash space.

| FEATURE                         | PLANE  | COPTER | ROVER  |
|---------------------------------|--------|--------|--------|
| AP_SCRIPTING_ENABLED            | 175800 | 182160 | 171688 |
| HAL_NAVEKF3_AVAILABLE           | 171392 | 171400 | 170784 |
| HAL_QUADPLANE_ENABLED           | 139776 | na     | na     |
| HAL_ENABLE_DRONECAN_D<br>RIVERS | 97480  | 96120  | 95936  |
| HAL_LOGGING_ENABLED             | 88792  | 95704  | 86400  |
| HAL_MOUNT_ENABLED               | 67268  | 67300  | 67116  |
| AP_RANGEFINDER_ENABLE<br>D      | 46568  | 48056  | 46272  |
| HAL_GYROFFT_ENABLED             | 42396  | 42308  | 41772  |
| OSD_ENABLED                     | 40992  | 40568  | 40472  |
| AP_RCPROTOCOL_ENABLED           | 35888  | 35888  | 35904  |

| FEATURE                              | PLANE | COPTER | ROVER |
|--------------------------------------|-------|--------|-------|
| AP_FILESYSTEM_ROMFS_ENABLED          | 32920 | 32912  | 32912 |
| HAL_MSP_ENABLED                      | 31848 | 31808  | 31816 |
| AP_BOOTLOADER_FLASHING_ENABLED       | 31648 | 31648  | 31640 |
| AP_OPTICALFLOW_ENABLED               | 29232 | 33816  | 29216 |
| HAL_EXTERNAL_AHRS_ENABLED            | 29120 | 29112  | 29008 |
| HAL_ADSB_ENABLED                     | 25760 | 25800  | 19112 |
| AP_AIRSPEED_ENABLED                  | 25440 | 22984  | 23468 |
| AP_CAMERA_ENABLED                    | 25192 | 25192  | 25192 |
| AP_FRSKY_TELEM_ENABLED               | 24504 | 24288  | 24376 |
| AP_FRSKY_SPORT_TELEM_ENABLED         | 22088 | 21952  | 22040 |
| AP_FRSKY_SPORT_PASSTHROUGH_ENABLED   | 18376 | 18240  | 18328 |
| HAL_WITH_MSP_DISPLAYPORT             | 18328 | 18248  | 18240 |
| AP_FENCE_ENABLED                     | 17488 | 50360  | 44748 |
| HAL_SOLO_GIMBAL_ENABLED              | 17432 | 17192  | 17424 |
| HAL_EFI_ENABLED                      | 14724 | 14816  | 14784 |
| COMPASS_CAL_ENABLED                  | 14624 | 14592  | 14600 |
| EK3_FEATURE_OPTFLOW_FUSION           | 12824 | 12816  | 12832 |
| AP_GPS_UBLOX_ENABLED                 | 12504 | 12368  | 12440 |
| AP_RCPROTOCOL_CRSF_ENABLED           | 11648 | 11640  | 11648 |
| AP_BARO_PROBE_EXTERNAL_I2C_BUSES     | 11296 | 11296  | 11296 |
| OSD_PARAM_ENABLED                    | 11116 | 11596  | 8152  |
| HAL_VISUALODOM_ENABLED               | 10616 | 10520  | 10648 |
| AP_EXTERNAL_AHRS_INERTIALABS_ENABLED | 10328 | 10344  | 10224 |
| HAL_CRSF_TELEM_ENABLED               | 9680  | 9680   | 9680  |

| FEATURE                                 | PLANE | COPTER | ROVER |
|-----------------------------------------|-------|--------|-------|
| AP_RPM_ENABLED                          | 9616  | 5504   | 5648  |
| HAL_MOUNT_XACTI_ENABLED                 | 8984  | 8968   | 8976  |
| AP_VIDEOTX_ENABLED                      | 8956  | 9036   | 9060  |
| HAL_PICCOLO_CAN_ENABLED                 | 8920  | 8920   | 8920  |
| AP_BEACON_ENABLED                       | 8840  | 14424  | 14440 |
| AP_RCPROTOCOL_SRXL2_ENABLED             | 8592  | 8584   | 8584  |
| HAL_GENERATOR_ENABLED                   | 8424  | 8544   | 8416  |
| HAL_ADSB_SAGETECH_MXS_ENABLED           | 8376  | 8376   | 8592  |
| HAL_INS_TEMPERATURE_CAL_ENABLE          | 7952  | 8040   | 8000  |
| AC_PRECLAND_ENABLED                     | 7832  | 10144  | 8968  |
| HAL_SOARING_ENABLED                     | 7656  | na     | na    |
| HAL_PROXIMITY_ENABLED                   | 7272  | 26824  | 25472 |
| HAL_MOUNT_TOPOTEK_ENABLED               | 7092  | 7092   | 7092  |
| AP_INERTIALSENSOR_HARMONICNOTCH_ENABLED | 6368  | 9824   | 5128  |
| AP_GPS_NMEA_ENABLED                     | 6176  | 6176   | 6184  |
| HAL_MOUNT_SIIYI_ENABLED                 | 6000  | 5992   | 5992  |
| HAL_LANDING_DEEPSTALL_ENABLED           | 5712  | 120    | 120   |
| AP_CAMERA_RUNCAM_ENABLED                | 5616  | 5600   | 5592  |
| AP_OPTICALFLOW_PIXART_ENABLED           | 5536  | 5536   | 5536  |
| AP_SERVO_TELEM_ENABLED                  | 5520  | 4864   | 5344  |
| GPS_MOVING_BASELINE                     | 5096  | 5040   | 5088  |
| AP_NOTIFY_TONEALARM_ENABLED             | 4992  | 4984   | 4984  |
| EK3_FEATURE_DRAG_FUSION                 | 4984  | 4984   | 4984  |
| AP_GPS_SBF_ENABLED                      | 4904  | 4904   | 4904  |

| FEATURE                                | PLANE | COPTER | ROVER |
|----------------------------------------|-------|--------|-------|
| AP_EXTERNAL_AHRS_VECT<br>ORNAV_ENABLED | 4824  | 4816   | 4832  |
| HAL_MOUNT_VIEWPRO_ENA<br>BLED          | 4812  | 4812   | 4804  |
| AP_GPS_SBP_ENABLED                     | 4792  | 4864   | 4880  |
| AP_MAVLINK_FTP_ENABLED                 | 4656  | 4648   | 4648  |
| AP_CRASHDUMP_ENABLED                   | 4652  | 4636   | 4644  |
| AP_ICENGINE_ENABLED                    | 4600  | 144    | 144   |
| HAL_SPEKTRUM_TELEM_EN<br>ABLED         | 4576  | 4576   | 4576  |
| AP_RELAY_ENABLED                       | 4464  | 4376   | 4528  |
| AP_SERIALMANAGER_REGIS<br>TER_ENABLED  | 4376  | 4448   | 4456  |
| AP_PROXIMITY_DRONECAN_<br>ENABLED      | 4248  | 2024   | 2024  |
| HAL_DISPLAY_ENABLED                    | 4176  | 4168   | 4168  |
| AP_BATTERY_SMBUS_ENAB<br>LED           | 4172  | 4172   | 4172  |
| AP_RANGEFINDER_VL53L1X<br>_ENABLED     | 4160  | 4152   | 4152  |
| AP_QUICKTUNE_ENABLED                   | 4136  | na     | na    |
| AP_TUNING_ENABLED                      | 4072  | na     | na    |
| AP_ADVANCEDFAILSAFE_EN<br>ABLED        | 4032  | 472    | 472   |
| AP_CAN_SLCAN_ENABLED                   | 4016  | 4096   | 4032  |
| AP_RCPROTOCOL_GHST_EN<br>ABLED         | 3680  | 3672   | 3672  |
| HAL_WITH_FRSKY_TELEM_BI<br>DIRECTIONAL | 3632  | 3496   | 3592  |
| AP_CAMERA_INFO_FROM_S<br>CRIPT_ENABLED | 3480  | 3480   | 3480  |
| HAL_ADSB_UCP_ENABLED                   | 3424  | 3416   | 3416  |
| AP_FETTEC_ONEWIRE_ENAB<br>LED          | 3312  | 3296   | 3248  |
| EK3_FEATURE_EXTERNAL_N<br>AV           | 3272  | 3272   | 3272  |

| FEATURE                               | PLANE | COPTER | ROVER |
|---------------------------------------|-------|--------|-------|
| AP_FILESYSTEM_PARAM_ENABLED           | 3208  | 3208   | 3208  |
| AP_RANGEFINDER_VL53L0X_ENABLED        | 3200  | 3200   | 3200  |
| AP_SMARTAUDIO_ENABLED                 | 3160  | 3144   | 3144  |
| AP_GPS_BLENDED_ENABLE                 | 3096  | 3096   | 3096  |
| HAL_MSP_OPTICALFLOW_ENABLED           | 2944  | 2952   | 2952  |
| AP_COMPASS_DRONECAN_ENABLED           | 2872  | 2872   | 2872  |
| HAL_MSP_RANGEFINDER_ENABLED           | 2856  | 2864   | 2864  |
| AP_DRONECAN_SERIAL_ENABLED            | 2800  | 2800   | 2800  |
| AP_DRONECAN_HOBBYWING_ESC_SUPPORT     | 2792  | 2792   | 2792  |
| HAL_RALLY_ENABLED                     | 2768  | 2848   | 3016  |
| AP_COMPASS_BMM350_ENABLED             | 2656  | 2656   | 2656  |
| AP_FOLLOW_ENABLED                     | 2608  | 4448   | 3928  |
| AP_FILESYSTEM_SYS_ENABLED             | 2576  | 2576   | 2568  |
| MODE_AUTOLAND_ENABLED                 | 2488  | na     | na    |
| HAL_ADSB_SAGETECH_ENABLED             | 2472  | 2464   | 2464  |
| AP_AIRSPEED_DRONECAN_ENABLED          | 2456  | 2456   | 2456  |
| AP_COMPASS_HMC5843_ENABLED            | 2456  | 2448   | 2448  |
| AP_GENERATOR_IE_2400_ENABLED          | 2392  | 2392   | 2392  |
| AP_DRONECAN_SEND_GPS                  | 2360  | 2352   | 2352  |
| AP_EXTERNAL_AHRS_MICROSTRAIN7_ENABLED | 2336  | 2336   | 2336  |
| AP_GPS_SBP2_ENABLED                   | 2320  | 2376   | 2440  |

| FEATURE                                 | PLANE | COPTER | ROVER |
|-----------------------------------------|-------|--------|-------|
| AP_RANGEFINDER_LWI2C_ENABLED            | 2320  | 2320   | 2320  |
| AP_GHST_TELEM_ENABLED                   | 2304  | 2304   | 2304  |
| AP_BATTERY_INA2XX_ENABLED               | 2288  | 2280   | 2280  |
| HAL_MSP_SENSORS_ENABLED                 | 2288  | 2288   | 2288  |
| AP_AIRSPEED_MSP_ENABLED                 | 2272  | 2272   | 2272  |
| AP_BARO_MSP_ENABLED                     | 2272  | 2280   | 2280  |
| AP_COMPASS_MSP_ENABLED                  | 2272  | 2280   | 2280  |
| HAL_MSP_GPS_ENABLED                     | 2272  | 2280   | 2280  |
| AP_PLANE_OFFBOARD_GUIDED_SLEW_ENABLED   | 2264  | na     | na    |
| AP_AIRSPEED_SDP3X_ENABLED               | 2256  | 2248   | 2256  |
| AP_FILESYSTEM_MISSION_ENABLED           | 2200  | 2200   | 2200  |
| AP_GPS_GSOFF_ENABLED                    | 2192  | 2184   | 2184  |
| AP_FILTER_ENABLED                       | 2168  | 2128   | 2136  |
| AP_GENERATOR_RICHENPOWER_ENABLED        | 2168  | 2248   | 2168  |
| AP_GENERATOR_LOWEHEISER_ENABLED         | 4108  | 4104   | 4124  |
| HAL_HIGH_LATENCY2_ENABLED               | 2168  | 2024   | 1920  |
| AP_COMPASS_LIS3MDL_ENABLED              | 2128  | 2128   | 2128  |
| AP_COMPASS_MMC3416_ENABLED              | 2120  | 2112   | 2112  |
| AP_BARO_DRONECAN_ENABLED                | 2080  | 2080   | 2080  |
| AP_INERTIALSENSOR_BATC HSAMPLER_ENABLED | 2064  | 2072   | 2056  |
| AP_GPS_NMEA_UNICORE_ENABLED             | 2008  | 2000   | 2000  |

| FEATURE                                  | PLANE | COPTER | ROVER |
|------------------------------------------|-------|--------|-------|
| AP_COMPASS_CALIBRATION_FIXED_YAW_ENABLED | 1976  | 1976   | 1976  |
| HAL_BUTTON_ENABLED                       | 1960  | 1984   | 2072  |
| AP_EFI_SERIAL_MS_ENABLE D                | 1944  | 1936   | 1936  |
| AP_ROBOTISSERVO_ENABL ED                 | 1936  | 1872   | 1960  |
| HAL_PARACHUTE_ENABLED                    | 1912  | 1824   | 616   |
| HAL_MOUNT_SERVO_ENABL ED                 | 1880  | 1688   | 1688  |
| AP_LANDINGGEAR_ENABLE D                  | 1824  | 1360   | na    |
| AP_EFI_DRONECAN_ENABLE D                 | 1752  | 1752   | 1752  |
| AP_VOLZ_ENABLED                          | 1752  | 2048   | 1840  |
| AP_EXTERNAL_AHRS_MICRO STRAIN5_ENABLED   | 1744  | 1736   | 1736  |
| AP_SERVORELAYEVENTS_E NABLED             | 1696  | 1712   | 1712  |
| AP_EFI_CURRAWONG_ECU_ ENABLED            | 1680  | 1672   | 1672  |
| AP_RSSI_ENABLED                          | 1672  | 1728   | 1808  |
| AP_COMPASS_IST8310_ENA BLED              | 1656  | 1656   | 1656  |
| AP_EFI_SERIAL_HIRTH_ENAB LED             | 1656  | 1688   | 1648  |
| AP_AIRSPEED_MS4525_ENA BLED              | 1648  | 1640   | 1640  |
| AP_BARO_BMP085_ENABLE D                  | 1648  | 1648   | 1648  |
| AP_RANGEFINDER_WASP_E NABLED             | 1648  | 1640   | 1640  |
| AP_GRIPPER_ENABLED                       | 1644  | 2068   | 1756  |
| HAL_NMEA_OUTPUT_ENABL ED                 | 1632  | 1688   | 1688  |
| AP_SDCARD_STORAGE_ENA BLED               | 1624  | 1480   | 1488  |
| AP_GPS_ERB_ENABLED                       | 1616  | 1480   | 1552  |

| FEATURE                                    | PLANE | COPTER | ROVER |
|--------------------------------------------|-------|--------|-------|
| AP_AIRSPEED_MS5525_ENABLED                 | 1600  | 1600   | 1584  |
| AP_BARO_DPS280_ENABLED                     | 1600  | 1592   | 1592  |
| AP_BARO_SPL06_ENABLED                      | 1600  | 1592   | 1592  |
| AP_COMPASS_BMM150_ENABLED                  | 1600  | 1592   | 1592  |
| AP_TRAMP_ENABLED                           | 1584  | 1600   | 1568  |
| AP_COMPASS_RM3100_ENABLED                  | 1568  | 1560   | 1560  |
| AP_TEMPERATURE_SENSOR_ENABLED              | 1560  | 1560   | 1552  |
| HAL_MOUNT_GREMSY_ENABLED                   | 1560  | 1560   | 1560  |
| AP_AIRSPEED_AUAV_ENABLED                   | 1544  | 1544   | 1528  |
| AP_MOTORS_FRAME_QUAD_ENABLED               | 1544  | 1376   | na    |
| AP_CAMERA_MAVLINKCAMV2_ENABLED             | 1512  | 1512   | 1512  |
| AP_GPS_NOVA_ENABLED                        | 1512  | 1512   | 1512  |
| AP_RANGEFINDER_BENEWAKE_TFMINIPLUS_ENABLED | 1472  | 1472   | 1472  |
| HAL_MOUNT_ALEXMOS_ENABLED                  | 1472  | 1464   | 1464  |
| AP_RC_CHANNEL_AUX_FUNCTION_STRINGS_ENABLED | 1464  | 1456   | 1456  |
| AP_COMPASS_IST8308_ENABLED                 | 1424  | 1416   | 1416  |
| AP_BARO_FBM320_ENABLED                     | 1392  | 1392   | 1392  |
| AP_KDECAN_ENABLED                          | 1392  | 1248   | 1264  |
| AP_SCRIPTING_SERIALDEVICE_ENABLED          | 1376  | 1352   | 1336  |
| AP_RANGEFINDER_DRONECAN_ENABLED            | 1360  | 1360   | 1360  |
| AP_DRONECAN_HIMARK_SERVO_SUPPORT           | 1352  | 1344   | 1344  |

| FEATURE                               | PLANE | COPTER | ROVER |
|---------------------------------------|-------|--------|-------|
| AP_BARO_BMP388_ENABLED                | 1320  | 1320   | 1320  |
| AP_BARO_BMP280_ENABLED                | 1312  | 1304   | 1304  |
| AP_COMPASS_QMC5883L_ENABLED           | 1312  | 1304   | 1304  |
| AP_MOTORS_FRAME_OCTA_ENABLED          | 1312  | 1312   | na    |
| AP_RPM_PIN_ENABLED                    | 1248  | 1552   | 1552  |
| AP_CUSTOMROTATIONS_ENABLED            | 1216  | 1232   | 1216  |
| AP_OPTICALFLOW_HEREFLOW_ENABLED       | 1168  | 1160   | 1160  |
| HAL_MOUNT_STORM32SERIAL_ENABLED       | 1156  | 1148   | 1148  |
| AP_FRSKY_D_TELEM_ENABLED              | 1144  | 1136   | 1136  |
| HAL_CRSF_TELEM_TEXT_SELECTION_ENABLED | 1120  | 1120   | 1120  |
| AC_PRECLAND_IRLOCK_ENABLED            | 1112  | 1112   | 1112  |
| AP_GPS_SIRF_ENABLED                   | 1104  | 968    | 1048  |
| AP_BARO_LPS2XH_ENABLED                | 1040  | 1040   | 1040  |
| AP_RANGEFINDER_PULSEDLIGHTLRF_ENABLED | 1024  | 1024   | 1024  |
| AP_RANGEFINDER_JRE_SERIAL_ENABLED     | 1016  | 1008   | 1008  |
| HAL_ADSB_UAVIONIX_MAVLINK_ENABLED     | 992   | 984    | 984   |
| AP_RPM_DRONECAN_ENABLED               | 984   | 984    | 984   |
| AP_AIRSPEED_DLVR_ENABLED              | 976   | 976    | 976   |
| AP_RANGEFINDER_TRI2C_ENABLED          | 968   | 968    | 968   |
| HAL_PLUSCODE_ENABLE                   | 960   | 944    | 944   |
| AP_EXTENDED_ESC_TELEM_ENABLED         | 944   | 936    | 928   |

| FEATURE                                       | PLANE | COPTER | ROVER |
|-----------------------------------------------|-------|--------|-------|
| AP_RANGEFINDER_BLPING_ENABLED                 | 936   | 936    | 936   |
| AP_RANGEFINDER_NMEA_ENABLED                   | 936   | 928    | 880   |
| AP_MOTORS_FRAME_OCTA_QUAD_ENABLED             | 896   | 896    | na    |
| AP_CAMERA_SOLOGIMBAL_ENABLED                  | 888   | 888    | 888   |
| AP_RCPROTOCOL_SRXL_ENABLED                    | 888   | 888    | 888   |
| AP_CAMERA_MOUNT_ENABLED                       | 880   | 872    | 872   |
| HAL_MOUNT_CADDX_ENABLED                       | 880   | 872    | 872   |
| AP_AIRSPEED_ASP5033_ENABLED                   | 856   | 856    | 856   |
| HAL_OSD_SIDEBAR_ENABLE                        | 848   | 848    | 848   |
| AP_RANGEFINDER_LIGHTWARE_SERIAL_ENABLED       | 832   | 832    | 832   |
| AP_EFI_NWPWU_ENABLED                          | 824   | 816    | 816   |
| AP_NOTIFY_MAVLINK_LED_CONTROL_SUPPORT_ENABLED | 824   | 824    | 824   |
| AP_RANGEFINDER_TOFSENSEF_I2C_ENABLED          | 824   | 824    | 824   |
| HAL_MOUNT_STORM32MAVLINK_ENABLED              | 824   | 824    | 824   |
| AP_MAVLINK_MSG_DEVICE_OP_ENABLED              | 816   | 816    | 816   |
| AP_OPTICALFLOW_PX4FLOW_ENABLED                | 816   | 808    | 808   |
| AP_RANGEFINDER_PWM_ENABLED                    | 808   | 800    | 800   |
| AP_BARO_EXTERNALAHRSENABLED                   | 792   | 792    | 800   |
| AP_RANGEFINDER_LEDDAR_VU8_ENABLED             | 776   | 776    | 776   |
| AP_NOTIFY_NCP5623_ENABLED                     | 768   | 760    | 760   |

| FEATURE                                   | PLANE | COPTER | ROVER |
|-------------------------------------------|-------|--------|-------|
| AP_OPTICALFLOW_CXOF_ENABLED               | 768   | 760    | 760   |
| AP_RANGEFINDER_RDS02UF_ENABLED            | 768   | 760    | 760   |
| AP_MAVLINK_MSG_SERIAL_CONTROL_ENABLED     | 760   | 760    | 760   |
| AP_CAMERA_SEND_FOV_STATUS_ENABLED         | 752   | 752    | 752   |
| AP_BARO_BMP581_ENABLED                    | 736   | 736    | 736   |
| AP_MAVLINK_MSG_FLIGHT_INFORMATION_ENABLED | 728   | 720    | 752   |
| AP_OPTICALFLOW_UPFLOW_ENABLED             | 728   | 728    | 728   |
| HAL_BARO_WIND_COMP_ENABLED                | 712   | 680    | 728   |
| AP_EFI_SERIAL_LUTAN_ENABLED               | 704   | 704    | 704   |
| AP_GPS_MAV_ENABLED                        | 704   | 704    | 704   |
| AP_MOTORS_FRAME_Y6_ENABLED                | 704   | 704    | na    |
| AP_RCPROTOCOL_ST24_ENABLED                | 704   | 704    | 704   |
| AP_BATTERY_FUELFLOW_ENABLED               | 696   | 696    | 696   |
| AP_RANGEFINDER_MAXSONARI2CXL_ENABLED      | 688   | 680    | 680   |
| AP_BATTERY_FUELLEVEL_ANALOG_ENABLED       | 680   | 672    | 672   |
| AP_BATTERY_SUM_ENABLED                    | 680   | 672    | 672   |
| AP_MOTORS_FRAME_HEXA_ENABLED              | 672   | 672    | na    |
| AP_RANGEFINDER_LEDDARONE_ENABLED          | 672   | 672    | 672   |
| AP_RANGEFINDER_USD1_SERIAL_ENABLED        | 640   | 640    | 640   |
| AP_RCPROTOCOL_SUMD_ENABLED                | 616   | 608    | 608   |

| FEATURE                                  | PLANE | COPTER | ROVER |
|------------------------------------------|-------|--------|-------|
| HAL_TORQEEDO_ENABLED                     | 608   | 608    | 7992  |
| AP_CAMERA_SERVO_ENABLED                  | 600   | 600    | 600   |
| AP_RCPROTOCOL_SBUS_ENABLED               | 592   | 584    | 592   |
| AP_COMPASS_EXTERNALAHRS_ENABLED          | 584   | 584    | 600   |
| AP_SBUSOUTPUT_ENABLED                    | 560   | 472    | 544   |
| AP_OPTICALFLOW_MAV_ENABLED               | 552   | 544    | 544   |
| AP_CAN_LOGGING_ENABLED                   | 544   | 416    | 488   |
| COMPASS_LEARN_ENABLED                    | 512   | 504    | 504   |
| AP_RANGEFINDER_HC_SR04_ENABLED           | 504   | 504    | 504   |
| AP_BATTERY_WATT_MAX_ENABLED              | 496   | na     | na    |
| AP_OAPATHPLANNER_ENABLED                 | 488   | 19016  | 16768 |
| AP_RANGEFINDER_ANALOG_ENABLED            | 488   | 480    | 480   |
| AP_RANGEFINDER_MAVLINK_ENABLED           | 488   | 488    | 488   |
| AP_GENERATOR_IE_650_800_ENABLED          | 472   | 464    | 464   |
| AP_MAVLINK_MSG_MISSION_REQUEST_ENABLED   | 456   | 448    | 448   |
| AP_RANGEFINDER_TERARANGER_SERIAL_ENABLED | 448   | 448    | 448   |
| AP_RANGEFINDER_NOOPLOOP_ENABLED          | 440   | 432    | 432   |
| AP_RCPROTOCOL_IBUS_ENABLED               | 440   | 432    | 432   |
| AP_AVOIDANCE_ENABLED                     | 432   | 15680  | 13232 |
| AP_BATTERY_FUELLEVEL_PWM_ENABLED         | 392   | 392    | 392   |
| AP_BATTERY_SYNTHETIC_CURRENT_ENABLED     | 392   | 392    | 392   |

| FEATURE                                | PLANE | COPTER | ROVER |
|----------------------------------------|-------|--------|-------|
| AP_RANGEFINDER_LANBAO_ENABLED          | 392   | 384    | 384   |
| AP_RANGEFINDER_GYUS42_V2_ENABLED       | 384   | 384    | 384   |
| AP_MAVLINK_MSG_RELAY_STATUS_ENABLED    | 376   | 376    | 376   |
| AP_RCPROTOCOL_MAVLINK_RADIO_ENABLED    | 376   | 368    | 368   |
| AP_MAVLINK_MAV_CMD_SE_T_HAGL_ENABLED   | 360   | na     | na    |
| AP_CAMERA_MAVLINK_ENABLED              | 352   | 344    | 344   |
| AP_RANGEFINDER_LUA_ENABLED             | 352   | 352    | 352   |
| AP_RANGEFINDER_MAXBOTIX_SERIAL_ENABLED | 352   | 344    | 344   |
| AP_MOTORS_FRAME_DODECAHEXA_ENABLED     | 344   | 344    | na    |
| AC_PRECLAND_COMPANION_ENABLED          | 320   | 312    | 312   |
| AP_EFI_MAV_ENABLED                     | 312   | 312    | 312   |
| AP_CAMERA_RELAY_ENABLED                | 304   | 296    | 296   |
| AP_MOTORS_FRAME_DECA_ENABLED           | 296   | 296    | na    |
| HAL_SPRAYER_ENABLED                    | 280   | 1224   | 1016  |
| AP_FILESYSTEM_FORMAT_ENABLED           | 272   | 272    | 272   |
| AP_RANGEFINDER_BENEWAKE_CAN_ENABLED    | 272   | 264    | 264   |
| AP_NOTIFY_NEOPIXEL_ENABLED             | 264   | 264    | 264   |
| AP_INERTIALSENSOR_KILL_I_MU_ENABLED    | 256   | 240    | 240   |
| AP_MAVLINK_SERVO_RELAY_ENABLED         | 256   | 248    | 248   |
| AP_RANGEFINDER_TOFSENSEP_CAN_ENABLED   | 256   | 256    | 256   |

| FEATURE                                         | PLANE | COPTER | ROVER |
|-------------------------------------------------|-------|--------|-------|
| AP_AIRSPEED_ANALOG_ENABLED                      | 248   | 248    | 248   |
| AP_NOTIFY_PROFILED_ENABLED                      | 224   | 216    | 216   |
| AP_MAVLINK_MSG_RC_CHANNELS_RAW_ENABLED          | 216   | 208    | 208   |
| AP_RANGEFINDER_USD1_CAN_ENABLED                 | 216   | 208    | 208   |
| AP_RCPROTOCOL_PPMSUM_ENABLED                    | 216   | 208    | 208   |
| AP_CAMERA_SEND_THERMAL_RANGE_ENABLED            | 176   | 176    | 176   |
| AP_RPM_HARMONICNOTCH_ENABLED                    | 176   | 176    | 176   |
| AP_RANGEFINDER_BENEWAKE_TF02_ENABLED            | 144   | 144    | 144   |
| AP_MAVLINK_MSG_VIDEO_STREAM_INFORMATION_ENABLED | 136   | 136    | 136   |
| AP_RANGEFINDER_BENEWAKE_TF03_ENABLED            | 136   | 136    | 136   |
| AP_RANGEFINDER_BENEWAKE_TFMINI_ENABLED          | 136   | 136    | 136   |
| AP_RPM_GENERATOR_ENABLED                        | 136   | 128    | 128   |
| AP_RPM_EFI_ENABLED                              | 128   | 128    | 128   |
| AP_RPM_ESC_TELEM_ENABLED                        | 128   | 120    | 120   |
| AP_NOTIFY_MAVLINK_PLAY_TUNE_SUPPORT_ENABLED     | 96    | 88     | 88    |
| AP_PROXIMITY_RANGEFINDER_ENABLED                | 80    | 792    | 792   |
| AP_WINCH_ENABLED                                | 64    | 5060   | 64    |
| AP_MISSION_NAV_PAYLOAD_PLACE_ENABLED            | 40    | 2096   | 32    |
| AP_AIS_ENABLED                                  | 24    | 1048   | 7404  |
| AP_PROXIMITY_CYGBOT_ENABLED                     | na    | 936    | 936   |

| FEATURE                                      | PLANE | COPTER | ROVER |
|----------------------------------------------|-------|--------|-------|
| AP_PROXIMITY_MR72_ENABLED                    | na    | na     | na    |
| AP_SERIALMANAGER_IMUOUT_ENABLED              | na    | na     | na    |
| AP_TEMPCALIBRATION_ENABLED                   | na    | 1328   | na    |
| AP_WINCH_DAIWA_ENABLED                       | na    | 2452   | na    |
| AP_WINCH_PWM_ENABLED                         | na    | 560    | na    |
| HAL_HOTT_TELEM_ENABLED                       | na    | na     | na    |
| HAL_MOUNT_XFROBOT_ENABLED                    | na    | na     | na    |
| MODE_BRAKE_ENABLED                           | na    | 688    | na    |
| MODE_FLIP_ENABLED                            | na    | 1296   | na    |
| MODE_FLOWHOLD_ENABLED                        | na    | 4616   | na    |
| MODE_FOLLOW_ENABLED                          | na    | 2296   | 1488  |
| MODE_GUIDED_NOGPS_ENABLED                    | na    | 240    | na    |
| MODE_SPORT_ENABLED                           | na    | na     | na    |
| MODE_SYSTEMID_ENABLED                        | na    | 4208   | na    |
| MODE_TURTLE_ENABLED                          | na    | 1896   | na    |
| MODE_ZIGZAG_ENABLED                          | na    | 4784   | na    |
| AP_COPTER_AHRS_AUTO_TRIM_ENABLED             | na    | 472    | na    |
| AP_DRONECAN_VOLZ_FEEDBACK_ENABLED            | na    | na     | na    |
| AP_INERTIALSENSOR_FAST_SAMPLE_WINDOW_ENABLED | na    | 2968   | na    |
| AP_PROXIMITY_LIGHTWARE_SF40C_ENABLED         | na    | 1816   | 1816  |
| AP_PROXIMITY_LIGHTWARE_SF45B_ENABLED         | na    | 1760   | 1760  |
| AP_PROXIMITY_RPLIDARA2_ENABLED               | na    | 1504   | 1504  |



SD

```
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□□ SD □□□□ □□ □□

SD ( )  
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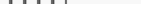
11

SD H7 36 Revolution MMC

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 SD 

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- The SD card must be enabled in its bootloader
- The bootloader code and flashing firmware must be enabled in the autopilot's firmware definition files (hwdefs)

To see if a given autopilot has this capability, you can check in its firmware folder on the [Firmware build server](#) to see if it has a `xxxxxx.abin` file present.

# The Bootloader

A bootloader capable of flashing from the SD card is required (and the autopilot must have SD card capability, obviously). Newer autopilot's with SD cards may or may not have this capability and a capable bootloader included in their hardware definition (if not, see **\*\*Building capable firmware yourself\*\***).

If the autopilot firmware currently provides this capability, updating your current bootloader may be required to support flashing from SD card. Note that updating the autopilot's bootloader is an operation which can make your board non-operational, and difficult to recover. More-so with boards that do not expose a "boot0" pin, such as the CubeOrange. Be aware of this risk, and be prepared to spend considerable time recovering a board if something bad happens when updating the bootloader.

**\*\*The instructions on updating the bootloader\*\*** can be followed to update your bootloader; be aware that you must use a recent firmware (4.5 or higher) to obtain a suitable bootloader.

# The Firmware File

The file to be loaded onto the SD card is of a specially named "xxxxx.abin" file created for this purpose. This is a binary file with a small amount of text providing some information about the binary. Most notably, a checksum which the bootloader will verify before attempting to flash the board.

Boards which support flash-from-sdcard will also have `.abin` files available for download from the [Firmware build server](#).

# Firmware File Name

The filename which is used when generating firmware is **\*not\*** the correct name to use when placing the firmware on the SD card. When the `.abin` files are generated they contain the vehicle name, for example, "arduplane.abin".

There is only one correct filename that may be used to flash-from-sdcard; this is `ardupilot.abin`. When placing the file on the SD card, ensure the file has been renamed to `ardupilot.abin`.

# Transferring the File to the SD card

This can be done in your operating system as you would ordinarily interact with the SD card (e.g. file browser).

You can also transfer the file to the SD card's base directory via `MAVFTP` using Mission Planner or similar GCS

[../../images/MP-install-firmware-sdcard.png](#)

Ensure the file is the correct size before continuing.

After the transfer is complete, the directory listing should look something like this:

“

```
RTL> ftp put /home/pbarker/arducopter.abin ardupilot.abin
RTL> Putting /home/pbarker/arducopter.abin as ardupilot.abin
Sent file of length 1847687
RTL> ftp list
RTL> Listing /
D APM
 ardupilot.abin 1847687
Total size 1804.38 kByte
```

# Triggering the Flash Update

Power cycle the board to enter the bootloader which will automatically check for the firmware update file and begin flashing it. Alternatively to avoid the powercycle the autopilot may be rebooted via a [PREFLIGHT REBOOT SHUTDOWN](#) command with the 'Param1' field set to 3 (ie. "Reboot autopilot and keep it in the bootloader until upgraded")

It should take roughly 1 minute to verify the firmware and flash it to the vehicle's internal flash.

If the process completes successfully the file will be renamed to `ardupilot-flashed.abin`. The vehicle should proceed to boot the firmware once flashing is complete.

# Troubleshooting

Several things can go wrong with the firmware flash, but some diagnostics are available to help work out what the problem might be.

- At each stage of the flashing process, the `ardupilot.abin` file is renamed to reflect the stage
- if the file is called `ardupilot-verify.abin` then the process failed when trying to checksum the file, or the board was interrupted when doing so.
- if the file is called `ardupilot-verify-failed.abin` then the checksum the bootloader calculated did not match the bootloader in the `.abin` metadata.
- if the file is called `ardupilot-flash.abin` the process failed when writing the firmware, or the board was interrupted while doing so. The board is unlikely to boot into an ArduPilot firmware if this has happened, so a re-flash will be required.
- if the file is called `ardupilot-flashed.abin` you should not need this "troubleshooting" section, as the flash process has succeeded!

# Building the firmware yourself

If the autopilot has an SD card capability but no SD Card flash-able firmware is present on the [Firmware build server](#), you can build the firmware yourself. You must setup a build environment and then modify the autopilot's hwdefs to build a capable bootloader and an `xxxx.abin` firmware, see **building-the-code**.

In the `hwdef-bl.dat` file you must include this:

```
define AP_BOOTLOADER_FLASH_FROM_SD_ENABLED 1
define FATFS_HAL_DEVICE SD_CD1
define HAL_OS_FATFS_IO 1
FATFS support:
define CH_CFG_USE_MEMCORE 1
define CH_CFG_USE_HEAP 1
define CH_CFG_USE_SEMAPHORES 0
```

```
define CH_CFG_USE_MUTEXES 1
define CH_CFG_USE_DYNAMIC 1
define CH_CFG_USE_WAITEXIT 1
define CH_CFG_USE_REGISTRY 1
```

- Also you must include the SD card setup. See the [MatekH743 autopilot definition](#) for an example.

In the `hwdef.dat` file you must include this:

```
env BUILD_ABIN True
```

When you build the firmware you will see, note the .abin file is created:

“

BUILD SUMMARY

Build directory: /home/pbarker/rc/ardupilot/build/CubeOrange

| Target        | Text (B) | Data (B) | BSS (B) | Total Flash Used (B) | Free Flash (B) | Ext |
|---------------|----------|----------|---------|----------------------|----------------|-----|
| bin/arduplane | 1868612  | 3536     | 258740  | 1872148              | 93928          | Not |

Build commands will be stored in build/CubeOrange/compile\_commands.json

'plane' finished successfully (24.283s)

pbarker@fx:~/rc/ardupilot(master)\$ ls -l build/CubeOrange/bin

total 18792

-rwxrwxr-x 1 pbarker pbarker 3135448 Sep 29 19:15 arduplane

-rw-rw-r-- 1 pbarker pbarker 1872247 Sep 29 19:15 arduplane.abin

-rw-rw-r-- 1 pbarker pbarker 1684192 Sep 29 19:15 arduplane.apj

-rwxrwxr-x 1 pbarker pbarker 1872152 Sep 29 19:15 arduplane.bin

-rw-rw-r-- 1 pbarker pbarker 5148900 Sep 29 19:15 arduplane.hex

-rw-rw-r-- 1 pbarker pbarker 5509380 Sep 29 19:15 arduplane\_with\_bl.hex

# Demo Video

<https://youtu.be/hCdXe1UTjK4>

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# GPS /

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## UBlox GPS +

UBlox GPS + Compass ArduPilot GPS.  
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../../images/gps-connection.jpg\_

# PIXHAWK : PIXHAWK Pixhawk

GPS 6-pin DF13 Pixhawk "GPS" I2C 4 I2C I2C

../../images/pixhawk\_with\_dual\_gps.jpg

2GPS \*\*GPS Blending page \*\* page .

PIXHAWK

baud UBlox ( SERIAL4 BAUD = 38 is ignored).

PIXHAWK

ArduPilot supports many attached compasses, but only up to 3 compasses can be used during operation. See **common-compass-setup-advanced**.

## Mounting the GPS Module

This module permits the GPS to be mounted separately from the flight control module so that it can have the best clear (view) of the sky and allows the compass to be distanced from interfering magnetic fields.

PIXHAWK

The recommended orientation is to mount the module with the arrow facing toward the front of the vehicle and in the same direction as the arrow on the autopilot.

When mounting the GPS+Compass module:

- Place the module on the outside of your vehicle (in an elevated position if appropriate) with a clear view of the sky, as far as possible from the motors and ESCs, with the arrow facing forward.
- Distance the module from DC power wiring and the batteries by at least 10cm. Use of a GPS mast is highly recommended.

../../images/gps-mast.jpg

- ../../../../images/GPS\_sampleMouting.jpg

**\*\*Compass Calibration in Mission Planner \*\*** explains the simplest way to calibrate a compass mounted in the recommended orientation (arrows for autopilot and compass facing to front of vehicle).

# LED Indicators

| LEDs:    | Behavior:                                      |
|----------|------------------------------------------------|
| Power    | Solid <b>red</b> when powered                  |
| GPS lock | Flashing <b>blue</b> when 3D GPS lock acquired |

Advanced configuration of the UBlox GPS's internal settings is documented in **\*\*UBlox GPS Configuration\*\***. But this is never used by the average user. ArduPilot automatically configures the gps during initialization.



# ChibiOS

```
[copywiki] = 'copter,plane,rover,planner,blimp,sub'].
```

 ArduPilot



```

ArduPilot
Betaflight,INAV,
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ArduPilot bootloader
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ArduPilot

- 
-   bl.hex  
-  DFU 

# Download driver and flashing tool

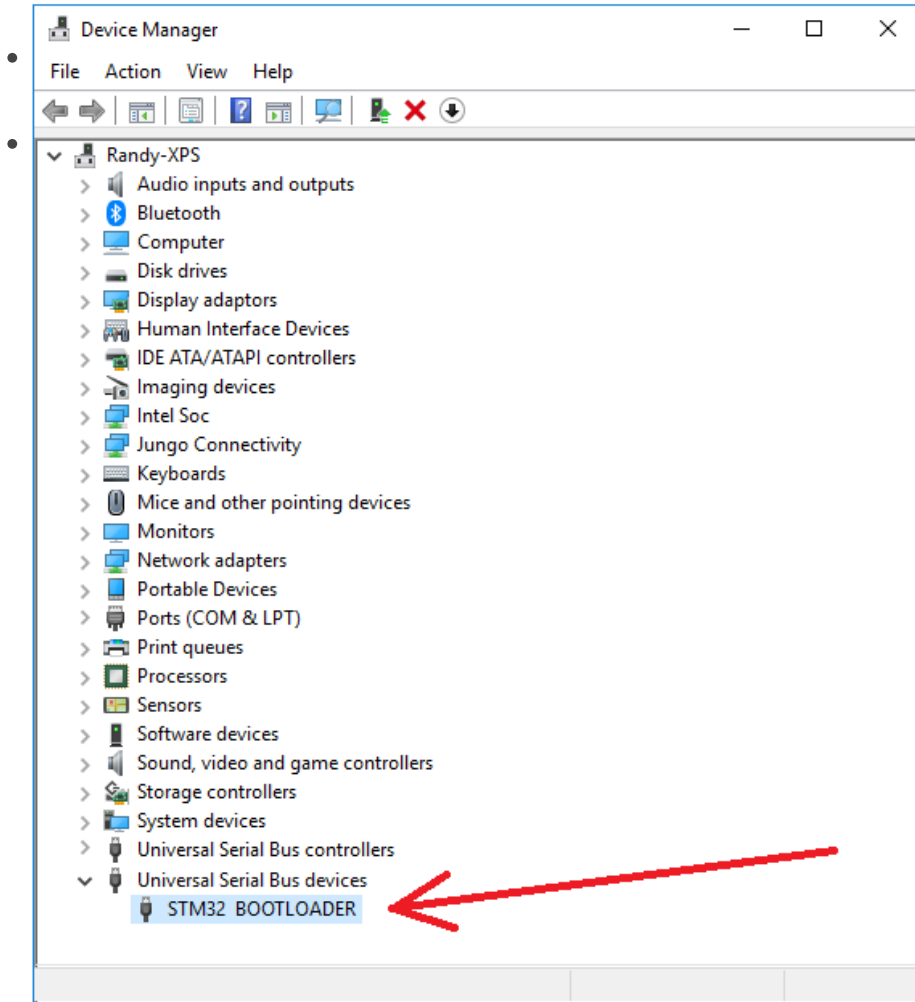
The [STM32CubeProgrammer](#) will install the required DFU drivers and can be used to flash the firmware to autopilots in DFU mode. This is available for Windows, Linux, and MacOS systems.

Download and install this program. You may be required to also install [JAVA](#) in order to setup this program.

## Download the ArduPilot firmware

Follow **\*\*Download the Firmware \*\*** to obtain the firmware for your board, selecting the `arduXXX_with_bl.hex` file. This file contains both the ArduPilot bootloader and the firmware, which is what DFU loading requires; the `.apj` files cannot be used here.

# Upload the firmware to autopilot



OT" pins, and plug in a  
ce powered.  
erial Bus devices" for  
e.

- Start the STM32CubeProgrammer

[../..../images/STM32CubeProgrammer1.jpg](#)

1. Select the connection method: USB
2. Make sure a USB port shows...that means the board is detected in DFU mode.
3. Press "Connect"
4. Then the boards cpu specifics will appear here.
5. Press "Open file" to select the "arduXXX\_with\_bl.hex" file you downloaded.
6. The file name will appear in the tab.

../..../images/STM32CubeProgrammer2.jpg

7. Press "Download" to flash the file to the board.

You may now reboot the board and **confirm the firmware is running \*\***. **Future firmware uploads can be done with the normal ground station method, see \*\*common-loading-firmware-onto-pixhawk.**

# Loading firmware onto Boards with external flash

Some recent boards, most notably those from Seriously Pro Racing (<http://www.seriouslypro.com/>), use MCUs with small amounts of internal flash but with much larger externally connected flash chips. These boards require extra steps to load ArduPilot firmware. Typically some kind of bootloader resides on the internal flash and then the main firmware resides on the external flash.

## Loading firmware using SSBL

The SPRacing series of boards come pre-installed with a proprietary bootloader on the internal flash and require the use of a second stage bootloader to load further firmware. There are a couple of options to load firmware with these boards, but whichever option you choose you will need to initially load ArduPilot using SSBL. Please follow the "INSTALLATION" instructions at <https://github.com/spracing/ssbl> in order to load SSBL onto your board. Once SSBL is loaded please follow the PX4 instructions to load ArduPilot onto the board <https://github.com/spracing/ssbl#px4-installation-to-external-flash> but instead of using PX4 firmware please use the arducopter.bin firmware image. A summary of the steps follows:

- Download <https://github.com/spracing/ssbl/releases> and install SSBL to external flash following <https://github.com/spracing/ssbl#installation-to-external-flash>
- Download the latest ArduPilot external flash binary, for instance <https://firmware.ardupilot.org/Copter/latest/SPRacingH7/arducopter.bin>
- Use dd to pad the binary to 2MB:

```
dd if=/dev/zero ibs=1k count=2048 of=AP_2MB.bin
dd conv=notrunc if=arducopter.bin of=AP_2MB.bin
```

- Put the board into SSBL dfu mode - power off, hold BIND (not BOOT), power on - LED flashes fast, release BIND, LED flashed slow - DFU mode enabled
- Flash the binary using

```
dfu-util -D AP_2MB.bin -s 0x90100000:0x200000
```

- Verify the flash. The dfu-util command below copies the contents of the flash back to the computer, the diff command will tell you if the contents are identical or different. Do not attempt to fly if diff doesn't say the files are identical - retry.

```
dfu-util -U AP_2MB-VERIFY.bin -s 0x90100000:0x200000
diff -sb AP_2MB.bin AP_2MB-VERIFY.bin
```

- Power off, install an SD card (.note: you *must* install an SD card, the firmware will not boot without it), power on
- Configure the board as normal using Mission Planner

At this point you should have working firmware on the board. If you want to load new firmware you will need to follow steps 2-7 again (you cannot use Mission Planner to load firmware). If you are certain that you will never want to load betafly on the board then you can install the ArduPilot bootloader.

## Installing the ArduPilot bootloader



installing the ArduPilot bootloader is a one-way operation. You cannot restore the board to factory configuration or load betafly after this step - you would have to return the board to Seriously Pro to be re-flashed with factory firmware, assuming that is possible

**If you are certain that you only want to use ArduPilot on the board**, then flashing the ardupilot bootloader enables much simpler subsequent upgrades.

- You must initially have a working version of ArduPilot installed on the board - follow the steps above.
- You now must remove the copy protection on the internal flash. This is a destructive operation requiring complete erasure of the flash. ArduPilot provides support to make this easy. Set **BRD\_OPTIONS** = 16.
- Power off and power on the board. The board will not appear to boot but the flash sector is being erased. Wait a few seconds and then power off the board.
- Hold down the `boot` button (boot *not* bind this time) and power on the autopilot. This will put the board in dfu mode.
- Download the ArduPilot bootloader, e.g.

[https://github.com/ArduPilot/ardupilot/blob/master/Tools/bootloaders/SPRacingH7\\_bl.bin](https://github.com/ArduPilot/ardupilot/blob/master/Tools/bootloaders/SPRacingH7_bl.bin)

- Install the bootloader via dfu:

```
dfu-util -a 0 --dfuse-address 0x08000000 -D SPRacingH7_bl.bin
```

- Reboot the board.
- You can now use your favorite tool to upload the ArduPilot firmware



▢ *ArduPilot Copter ▢ Loading Firmware to Boards without an ArduPilot Compatible Bootloader ▢* ·

 · CC BY-SA 3.0

## ☐ Pixhawk ☐☐☐☐

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ArduPilot

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COM

COM   \*\*    or the specific port for your board. Set the Baud rate to **115200** as shown. Do not hit **Connect** just yet.

../../../../images/Pixhawk\_ConnectWithMP.png

# Install firmware

In Mission Planner's **SETUP | Install Firmware** screen select the appropriate icon that matches your vehicle or frame type (i.e. Quad, Hexa). Answer **Yes** when it asks you "Are you sure?".

../../../../images/Pixhawk\_InstallFirmware.jpg

## Mission Planner: Install FirmwareScreen

some boards are specifically targeted to a particular vehicle type and firmware is not automatically built for other vehicles. However, ArduPilot could still be built for those other vehicles using the [Custom Firmware Server](#).

Mission Planner will try to detect which board you are using. It may ask you to unplug the board, press OK, and plug it back in to detect the board type.

[../../images/Pixhawk\\_InstallFirmware2.png](#)

Mission Planner: Install Firmware Prompt

Often you will be presented with a dropdown box of firmware variants for the board, which you can select from (such as bi-directional DShot variants, if available). For boards which share the Pixhawk board id, the list will be extensive, as shown below:

[../../images/pixhawk-firmware.png](#)

Select the appropriate firmware for your board. For boards marked "Pixhawk", Pixhawk1 firmware is usually the best choice.



some boards labeled as Pixhawk 2.4.x may have sensor substitutions which may lead to pre-arm checks or no secondary IMU. Please see the BARO\_OPTIONS parameter for a workaround for a known sensor substitution on some boards of a MS5607 barometer where a MS5611 should be used. IMUs may also be substituted. Where possible, please source autopilots from ArduPilot partners.

If all goes well, you will see a status appear on the bottom right including the words: "erase...", "program...", "verify..", and "Upload Done". The firmware has been successfully uploaded to the board.

It usually takes a few seconds for the bootloader to exit and enter the main code after programming or a power-up. Wait to press CONNECT until this occurs. See **\*\*Testing that it Worked\*\*** for how to confirm the result.

## Installing a Beta, Development, or Custom Build

The firmware icons above install the current [Stable](#) release. To install a [Beta](#), [latest](#), or custom build, **\*\*download the .apj file \*\*** for your board first, then load it with Mission Planner's "Load

custom firmware" option:

- connect the ground station PC to the autopilot using a USB cable
- select the COM port and baud rate (normally 115200, but you can choose higher if your hardware allows) for the board. These are selected on the top right of the screen. Do **not** press the Connect button
- go to MP firmware install screen (select "Setup >> Install Firmware")
- click the "Load custom firmware" link and select the .apj file you downloaded (do not select the .hex files, which are only meant to be used with DFU/JTAG/SWD methods). If the "Load custom firmware" link is not visible select "Config >> Planner" and set the "Layout" drop-down to "Advanced".
- you may need to click on "Force bootloader" before the step above (assuming the board has been previously flashed with Ardupilot's bootloader)

[../..../images/mission-planner-load-custom-firmware.png](#)

- follow any instructions displayed regarding plugging/unplugging the board
- if all goes well some status should be displayed at the bottom of the screen. i.e. "erase...", "program...", "verify.." and "Upload Done".



Mission Planner also offers a **Beta firmware** option on its Install Firmware page, which does not require a manual download. A later **Stable** release may already be newer than the **Beta** on offer, so check the normal vehicle upload option first.





```
[mode="copter"]. mode Loiter,RTL,AUTO [mode]
```

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2. 
3. 
4. Replace the PDB and ESCs with a 4-in-1 ESC because they tend to produce less interference probably because their wires are shorter and closer together and they also have an aluminum plate on top which may help reduce the interference.
5. Add aluminum shielding (even gutter tape) around the wires from the ESC to the motors may reduce the AC interference. Aluminum will not help reduce the primary DC interference from the PDB, ESCs and the wires connecting them.

../../../../images/3281\_dimg2.jpg

# Maxwell's Equations - The Magnetic Field on the Axis of a

# Current Loop

Geometric details (from [this web page.](#))  
[loopa](#)

The application of the [Biot-Savart law](#) on the centerline of a [current loop](#) involves integrating the z-component.  
[image4](#)  
The symmetry is such that all the terms in this element are constant except the distance element  $dL$ , which when integrated just gives the circumference of the circle. The magnetic field is then:  
[image5](#)

There are 3 things to get from this drawing and the equation for the magnetic field  $B$  as you move away from a current loop along the  $Z$  axis:

1. The magnetic field increases as a function of the enclosed loop area  $\pi R^2$ 
  - Big loop = big magnetic field
  - Reduce the magnetic field by twisting the loop to close it. aka twist the wires together and keep your return path close to the source
  - In the case where you have a PDB and 4 ESCs you have 4 loops that start at the Deans connector on the PDB, go out to the ESC and return back to the Deans connector. In the case of the 4 in 1 ESC the current flow is much more concentrated in one area and you don't have the big loops so consequently you decrease the magnetic field.
2. The magnetic field increases as a function of current
  - Where there is the option, you can deliver the same power and decrease the magnetic field by increasing the voltage and decreasing the current.
3. The magnetic field decreases as a function of the cube of the distance
  - It is more complicated when you are close to the loop but when  $z \gg R$  the denominator goes to  $z^3$

There is one more thing and that is that the direction of the magnetic field depends on the direction that the current flows so when you rotate a battery it changes the magnetic field produced by the current flowing in the battery.

It can't be stated enough that minimizing the enclosed loop areas and moving the compass away from the current will help things work better and "yes", power distribution boards with big circular thick high current PC traces on them produce significant semi-spherical fields as large or larger than their diameter.

## Natural and Artificial Magnetic Anomalies Warning



The following information has not been objectively tested to determine its impact on a vehicle's compass accuracy in flight.

1. Many things can distort the earth's magnetic field in the area you are flying:
  - Steel framed or reinforced concrete buildings, bridges and roadways, iron pipes and culverts, high power electric lines, heavy equipment, trucks and automobiles, steel tanks, electric motors and even computers.
  - Flying between steel framed or reinforced high rise buildings will distort the magnetic field in addition to causing GPS multi-pathing.
2. Safe distances for compass calibration
  - 6" (15 cm) minimum: Metal rim glasses, pen/pencil, metal watch band, pocket knife, metal zipper/buttons, belt buckle, batteries, binoculars, cell phone, keys, camera, camcorder, survey nails, metal tape measure.
  - 18" (50 cm) minimum: Clipboard, data collector, computer, GPS antenna, 2-way radio, hand gun, hatchet, cell phone case with magnetic closure.
  - 6 ft (2 m) minimum: Bicycle, fire hydrant, road signs, sewer cap or drain, steel pole, ATV, guy wire, magnets, chain-link fence, bar-wire fence, data collectors that use a magnet to hold the stylus.
  - 15 ft (5 m) minimum: Electrical box, small car/truck, powerline, building with concrete & steel.
  - 30 ft (10 m) minimum: Large truck, metal building, heavy machinery.

# GPS for yaw

ArduPilot supports the use of GPS heading information to reduce malfunctions caused by changes in the magnetic field in certain environments.

- Configure GPS for yaw

[https://youtu.be/Kh\\_6TynYqEI](https://youtu.be/Kh_6TynYqEI)

“ 

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# Navio2

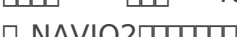
 [\\*\\*NAVIO2\\*\\*!\[\]\(d36e1eed4a169dbc03d23aa9a290a5d9\_img.jpg\) Raspberry Pi!\[\]\(b390d9fd100375fa9a3407f263a82915\_img.jpg\)](#)

## NAVIO2

Navio2 ArduPilot :

-  3 B
-  2 B

 NAVIO2:

-  Raspberry Pi,  .
-   40 pin gpio  
-  NAVIO2
-  NAVIO2.

[../..../images/navio2-mount.jpg\\_](#)

Raspberry Pi2 USB Wi-Fi dongle.  Dongles .

## Powering NAVIO2

Navio2 has three power sources, all of them can be used simultaneously as they are protected by ideal diodes.

For testing and development purposes: Connect 5V 1A power adapter to the Raspberry Pi's microUSB port. Raspberry Pi will provide power to the NAVIO2.

In a drone: NAVIO2 should be powered by a power module connected to the "POWER" port on NAVIO2. NAVIO2 will provide power to the Raspberry Pi.

[../..../images/navio2-power.jpg\\_](#)

Redundancy: In case of power module failure NAVIO2 will switch to power from the servo rail.



All power sources should provide voltage in 4.8-5.3V range, otherwise you can damage your NAVIO2 and Raspberry Pi.

## Connect remote control inputs

NAVIO2 supports PPM and SBUS signals as an RC input. To connect receivers that do not support PPM output you can use PPM encoder. PPM receiver is powered by NAVIO2 and does not require power on the servo rail.



Do not connect servos to the RC receiver! Servos can consume a lot of power which RC receiver port may not be able to provide and that may lead to Raspberry Pi and NAVIO2 shutting down and even getting damaged.

Some of the receivers with PPM output:

For ACCST (most FrSky transmitters):

- FrSky D4R-II 4ch 2.4Ghz ACCST Receiver
- FrSKY V8R7-SP ACCST 7 Channel RX with composite PPM
- FrSKY D8R-XP

For FASST (Futaba & some FrSky transmitters):

- FrSky TFR4 4ch 2.4Ghz Surface/Air Receiver FASST Compatible

[../..../images/navio2-rc-receiver.jpg\\_](#)

## GNSS Antenna

GNSS antenna is plugged into the MCX port on top of NAVIO2.

../../../../images/navio2-gnss-antenna.jpg\_

# Connect Motors

ESCs are connected to RC outputs labeled from 1 to 14 on a 2.54mm header.

../../../../images/navio2-escs.jpg\_

For typical ESCs setup schemes visit [NAVIO2 documentation](#) which includes copter, plane, rover setups.



Only one ESC power wire (central) should be connected to Navio2 servo rail, otherwise BECs built in ESCs will heat each other.

# Connect other peripherals

Depending on your hardware there may be any number of other peripherals attached, including sensors, cameras, grippers etc.

# Telemetry

Radio modems can be connected either over UART or over USB.

- UART radio

For UART port use /dev/ttyAMA0 serial.

../../../../images/navio2-uart-radio.jpg\_

- USB radio

Use /dev/ttyUSB0 virtual serial port for USB.

../../../../images/navio2-usb-radio.jpg\_

# Servos

Servos are connected to RC outputs labeled from 1 to 14 on a 2.54mm header.

../../../../images/navio2-servos.jpg



Power module does not provide power to servos. To provide power to servos connect BEC to the servo rail. BEC would also serve as back-up power supply to Navio2.

## Related information

Detailed information for NAVIO2 configuration and setup can be found in [documentation](#).





1. Cut a piece of 1cm x 2cm foam (1cm wide, 2cm high) from the bottom of the autopilot.
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Plane

Rover

# 3M, Du-Bro, HobbyKing

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- 3M (discontinued), (discontinued), (discontinued)
- HobbyKing
- Holybro
- Du-Bro 1/4" / (discontinued)
- (discontinued) (discontinued)

For the last two options "carpet fixing tape" will be required to attach the foam to the autopilot and vehicle frame.

[../../images/Vibration\\_3MFoam.jpg](#)

For vehicles with **internal combustion engines**, the autopilot should be mounted on an intermediate plate with [self adhesive lead weights](#) added to increase its mass.

## Gel pads

1. Cut one of the recommended gels into 1cm ~ 2cm squares and attach to each corner of the autopilot. Possible gels include:
  - [Kyosho Zeal Gel Tape](#) performs best and is available from Amazon, E-Bay and A-Main Hobbies
  - [United States Silicone Gel Tape and Pads \(V10Z62MGT5 tape recommended\)](#)
  - [United Kingdom Silicone Gel Tape, Pads](#) and [grommets](#)
  - [Moon Gel Pads](#) (also available in music stores). Caution: Moon Gel has been shown to fail in heat above 100 degrees Fahrenheit so it should be used cautiously.
2. Secure the autopilot to the frame with 1cm) wide velcro retaining strap or a rubber band. Be careful the strap does not hold down the controller so securely that it interferes with the damping of the pads. Consider putting a layer of soft foam between the strap and the autopilot.

[../../images/Flamewheel330PX4onZeal2.jpg\\_](#)

FlameWheel F330 with PX4FMU Mounted on Intermediate platform

The blog [Testing simple anti-vibration solutions for GoPro on an ArduCopter](#) has a video demonstrating vibration isolation using Moon Gel on a Go-Pro camera.

## 3D Printed Anti-Vibration Platform

GuyMcCaldin's 3D Printed vibration mount on [Thingiverse](#) using [dampers like these](#).

[../../images/guymccaldin-vibration-mount.jpg\\_](#)

The mount can be installed using double sided tape, or M3 screws.

## 3D Printed Anti-Vibration Platform for NAVIO2

Anti-vibration for NAVIO2 can be easily 3D printed. It significantly simplifies mounting and eliminates vibrations. You can find STL files [here](#).

Anti-vibration with Navio2 mounted on frame:

[../../images/anti-vibration-mount.jpg\\_](#)

## O-ring Suspension Mount

1. Create a platform upon which to mount your autopilot with holes or screws on the four corners. Mount your autopilot on this board with double sided foam tape.
2. Mount 4 standoffs on the top of your frame spaced 1/10" to 1/8" further apart than the width of the platform upon which the control board has been mounted.
3. Insert 1/16" nylon O-rings through each corner of the autopilot and the standoffs so that the autopilot has no hard connections to the frame. Link [\(Here!\)](#)
  - The overall O-ring diameter should be chosen to firmly retain the board while providing for light to moderate initial but rapidly snubbed movement of the board (generally 1/2" to 3/4" OD) and Silicone O-rings should generally damp better than Buna-N O-rings (Sizes 15 - 21) if you can acquire them.

[../../images/330FOringSuspPlate45.jpg\\_](#)

FlameWheel F450 O-Ring Suspension Platform Mount

Vibrations are short coupled, so all that leaving excess corner clearance does is to require higher initial O-ring tension which reduces vibration damping responsiveness and allows the board to physically tilt more (which is undesirable as it throws the sensor to airframe relationship off).

The disadvantage to O-ring suspension versus Gel pads is that it is mechanically more complex and it requires tuning of both of O-ring diameter and cross section.

You can combine O-ring and gel pad design by using an intermediate plate and benefit from dual rate damping.

## Ear Plug Mount

1. Purchase slow response silicon or urethane foam or PVC foam earplugs such as [these from 3M](#).
2. Create a platform upon which to mount your autopilot with holes at the four corners. The holes should be large enough to allow the ear plugs to be inserted into them but not so loose that the board comes loose during hard landings. Ensure the holes are smooth so

they do not cut into the ear plugs. Also keep the holes near the corners of your electronic module plate as possible to minimize unnecessary module movement.

3. Mount your autopilot on this board with double sided foam tape. Extra mass added to the board may improve vibration damping.
4. Squeeze the earplugs through existing holes in the frame (or cut new holes) and the holes in the board upon which the autopilot is mounted. "Tuning" is possible by varying the amount of earplug left exposed in the middle.

[../../images/EarPlugVibrationMount.jpg\\_](#)

Ear Plug Vibration Mount

## Bulb Damper + Ear Plug Vibration Mount

1. Mounting plate with a 100g soft rubber bulb type "gimbal" damper at each corner and a half a urethane foam earplug placed inside each one.
2. Gimbal bulb type dampers themselves can work in tension or compression.
3. The earplugs provide an additional damping medium with a different frequency damping range than the bulb dampers by themselves.
4. The ear plugs also stiffen the bulb mounts up a bit preventing excessive free motion being caused by normal flight maneuvers.
5. This was successful at damping a Flamewheel clone with flexible arms and over size 12" propellers into the .05 G range.

[../../images/vibration\\_flamewheel\\_clone\\_closeup.jpg\\_](#)

6. The autopilot is also mounted on anti-vibration grommets available from [McMaster Carr](#) (package of 25 each part #9311K64 recommended).
7. The 100G bulb type gimbal vibration dampers can be ordered direct from a variety of vendors: [copter-rc.com](#)

## Advice for reducing vibrations

For copters the largest source of vibration is normally the blades passing over the arms but other sources of vibration also exist and may be reduced by following this advice:

- Frame flex especially arm flex is a big cause of asynchronous vibration, Frame arms should be as rigid as possible.

- Original DJI Flamewheel copters have sufficiently rigid injection molded arms, the many clones do not
- Aluminum or carbon fibre arms twist and bend less which reduces vibrations
- Copters with injection molded exoskeletons or arms like the Iris are sufficiently rigid
- Cheap, light frames tend to flex more than high quality stronger ones and the heavier you load the copter the more flex it gets (not good)
- Motor to frame arm and frame arm to central hub mounts need to be secure and flex free (sometimes a problem for carbon tube arms)
- Motors need to run smoothly (bearings not worn-out or "screeching")
- Prop adapters connecting the propellers to the motors need to be concentric and very straight
- Propellers should be fully balanced using a good manual prop balancer
- Motor balancing (or really well factory balanced motors like T-Motor) can have a major effect
- Propellers that are not well matched to the frame and weight or do not have the same flex for CCW and CW are very problematic
- Good propellers vibrate less
- Carbon fiber props are rigid and vibrate less which reduces vibration but are very sharp which is a major safety hazard

# Summary of the vibrations that should be damped

1. The vibration frequency and amplitude we primarily need to reduce is a characteristic of the motor / prop units turning at flight speed.
2. That is, it is a fairly high frequency with fairly low amplitude.
3. This requires that we provide a short coupled damping and isolation range.
4. The board itself does not need to have nor benefit from a range of motion that exceeds the amplitude of the vibration.
5. Because the board does not apply any force to the airframe, the only thing we need to be concerned with Damping / Isolating is the weight (mass) of the board itself plus the forces applied to it by airframe's normal flight maneuvering.
6. Since excellent broad frequency range, high damping materials are available our biggest concern will be to use the proper amount of them to optimally damp our autopilot (too much is just as bad as too little).
7. Combining the autopilot and receiver onto a separate vibration damped electronics module "plate" or enclosure can increase the mass of the module making it easier to damp effectively as well as reducing the interconnecting wiring and making the whole system more modular.

# Additional Vibration Reduction Considerations

1. [Hard Disk Drive Anti-Vibration Grommets](#). can provide sufficient or supplemental vibration reduction
2. Significant gains in vibration isolation can also be realized by using a high flex wire and strain relief approach to all wires connected to the autopilot (and using the minimum number of wires necessary as well).
3. Some frames have lower than normal vibration characteristics due to frame stiffness / flex and isolated centralized mass can greatly influence motor/prop vibration transfer to the central flight controller.
4. Isolation and damping can be improved somewhat by sandwiching the autopilot / enclosure between damping pads on both sides in about twenty percent compression. 30 durometer Sorbothane is actually specified at 15 to 20 percent compression for optimal damping.
5. Although 30 durometer Sorbothane seems an excellent candidate, experience indicates that it becomes permanently compressed and is not as effective at vibration reduction as the Gel solutions.
6. A link to a Blog about the first APM anti-vibration mounting system to achieve 0.05 G damping (2/20/2013 improved to 0.02 G), a dual zone isolation system, combining O-ring suspension and silicone pad is [\(Here!\)](#)
7. Motor balancing can also reduce vibration and especially so for cheaper or larger motors. Balancing involves:
  - Tightly fasten a small tie wrap around a motor (WITH NO PROP), trim off the extended tab and spin it up.
  - Try multiple times, each time turning the tie wrap on the motor housing a bit until the vibration reduces or goes away.
  - A small piece of Scotch tape can be re-positioned instead of the tie wrap if desired or for smaller motors.
  - When you locate the spot where there is the least vibration (and you should be able to hear it), mark the spot directly under the clasp of the tie-wrap with a felt pen.
  - Add a small dot of hot glue gun glue where the Tie-Wrap clasp was and increase the glue a bit at a time till the vibration is minimized.
  - If you put too much glue on it can be removed with an X-acto knife.
8. Camera Mounts also need to be effectively isolated and damped from vibration, but they already have a number of "soft" mounting solutions.
9. The camera servos need to be vibration isolated as well, either in the isolated camera mount itself or with their own vibration reduction solution.
10. You should use high quality ball joints on your camera servo arms and adequate bearings or bushings in the mount itself with zero free play to prevent inertial slop.
11. Quality servos without free play are also a must for precision camera work.

12. At this point in time it seems that the more rigid the frame the better because frame flex introduces undesirable mechanical delay (hysteresis) in translating motor induced actions to the centrally located autopilot. (Do NOT shock mount the motor Arms).
13. The amount and type of damping medium needs to be carefully matched to the weight (mass) of the item we are trying to isolate as well as the frequency and amplitude of the vibrations we are seeking to damp. We are trying to isolate an autopilot that weighs less than 2 ounces and this is a very small mass.
14. Virtually all off the shelf solutions (either pad or stud type) are designed for an isolated mass that would weigh at least 5 to 10 times what an average autopilot weighs for optimal effectiveness. This includes all pre-made Sorbothane, Alpha gel, EAR, memory foam or other silicone or urethane gel or foam mounts as well as Lord Micro mounts.
15. A threaded stud or sleeve type mount gel mount properly designed for the mass of our autopilot or electronics module undergoing the stress's of normal flight would be a much better long term solution.

# Terminology

The methods used will typically incorporate both damping and isolation:

- *Isolation* is simple undamped (spring or rubber band support) which allows the movement of the isolated object largely separate from the containing object (Automobile spring for instance).
- *Damping* is the conversion of vibration into heat energy by a shock absorbing medium (automobile shock absorber for instance).

## Links to related discussions

- [RC Groups page on Vibration Effects relating to a camera mounts](#)
- [DIYDrones discussion related to Vibration Control](#)
- [Gary McCray's DIYDrones BLOG re Vibration Control](#)

