Using Beagle as a Flight Controller

Open-source hardware Linux computers
Proven platform with professional community
Integration for real-time control

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Agenda

- Introduction to Beagle
- Choosing flight controller hardware
- Flight control software options
  - ArduPilot
    - MAVLink
    - APM planner
- Building out a quadcopter
- Installing ArduPilot
- Calibration
- Buying parts
- Mistakes and questions
BeagleBoard.org Roadmap

2008: Personally affordable BeagleBoard

2010: Extra MHz/memory BeagleBoard-xM

2011: Bare-bones BeagleBone

2013: Wildly popular BeagleBone Black

2016: BeagleBone Black Wireless uses EAGLE, Wilink8 and Octavo SIP

2016: Extreme power BeagleBoard-X15

2017: Complete robotics controller BeagleBone Blue

2017: PocketBeagle breaks out even smaller Octavo SIP

Mint tin sized BeagleBone

Smalls mint tin sized PocketBeagle

Robotics-focused BeagleBone Blue

Fanless open computer BeagleBoard

$250

$50

$25

$80
BeagleBone used in many applications

- Simple Mobile Robots
- Industrial Robots
- Network Security
- Medical
- Citizen Science
- Home Automation
- Localizing Information
- Assistive Technology
- LEGO Robotics
Robotics Cape

• Designed at UCSD by James Strawson

• Used in hundreds of student projects

• On fourth revision

• Supported by ‘libroboticscape’ software
  – C library
  – Examples for all major functions

• Features
  – 2-cell LiPo support with balancing and LED power gauge
  – 9-18V charger input
  – 4 DC motor & 8 servo outputs, 4 quadrature encoder inputs
  – 9 axis IMU, barometer
  – Easy connect JST interfaces for: I2C, SPI, UART, CAN, GPIOs, GPS, DSM2 radio, power, ADC
  – User-programmable LEDs and buttons

strawsondesign.com
Wireless + Robotics Cape = Blue

- Combines Wireless and cape
- 4 layer PCB
  - Designed in Autodesk EAGLE
- In mass production, lowering cost
- Simplifies system configuration
- Added CAN interface

$79
PocketBeagle

- Based on Octavo Systems OSD3358-SM SiP
  - ARM Cortex-A8 @ 1-GHz
  - 512 MB DDRs RAM integrated
  - ARM Cortex-M3
  - $2 \times 200$-MHz RISC Programmable Real-time Units (PRU)
  - Integrated power management

- Connectivity
  - Bootable microSD card slot
  - High speed USB 2.0 OTG (host/client) control signals
  - Dual 36-pin expansion headers
    - 8 analog inputs ($6 @ 1.8V$ and $2 @ 3.3V$)
    - 44 digital GPIOs
    - 3 UARTS
    - 2 I2C
    - 2 SPI
    - 4 PWM
    - 2 QEP
    - 2 CAN

$25

- Power and develop over USB
- Add up to 2 mikroBus Click boards
  - Over 300 available today
- Runs latest BeagleBone software images
Choosing flight controller electronics

- Are you looking to do autonomous flight?
- Will you utilize on-board computing?
- What type of connectivity do you require?
- How will you power it?
- What do you need in terms of motor drive?
BeagleBone Blue flight control options

- ArduPilot is the way to go to get the most working the quickest
- UCSD has developed its own controller software
- Papparazzi
- PX4
ArduPilot on BeagleBone Blue

- **BeagleBoard.org** mentored the original port of ArduPilot to Linux in 2014 as part of Google Summer of Code
  - BeagleBone Black + Erle Cape or Pixhawk Fire Cape
- Mirko Denecke and ArduPilot community continued work
  - 2015: BBBmini Cape for BeagleBone Black and SeeedStudio BeagleBone Green
  - 2017: Support for BeagleBone Blue
  - 2018: PocketPilot PocketCape for PocketBeagle
- Pre-built ‘ardupilot-copter-blue’ in the package feeds
- Requires some edits to the system configuration (/boot/uEnv.txt, /lib/systemd)
  - Needs a start-up script to configure and run on boot
  - Uses PRU eCAP on BeagleBone Blue software-based quadrature encoder input, E4, as radio controller input
  - Uses UIO to load PRU firmware
  - Uses RT kernel for reliable timing, which may break the USB gadget function, but WiFi works fine
Micro Air Vehicle Protocol (MAVLink)

- Protocol for communicating with an autopilot
- Can be sent over serial or network packets (UDP/TCP)
- Can be communicated over ROS
Out of Box

• Click “Getting Started” [https://beagleboard.org/getting-started](https://beagleboard.org/getting-started)
• Three Easy Steps
  – Download Latest Software Image and burn onto your microSD card
  – Insert your card, power your Beagle
  – Browse to the IP address for your PC OS and add :3000
  • For WiFi, SSID is ‘BeagleBone-XXXX’ and password is ‘BeagleBone’

<table>
<thead>
<tr>
<th>IP Address</th>
<th>Connection Type</th>
<th>Operating System(s)</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>192.168.7.2</td>
<td>USB</td>
<td>Windows</td>
<td>Inactive</td>
</tr>
<tr>
<td>192.168.6.2</td>
<td>USB</td>
<td>Mac OS X, Linux</td>
<td>Inactive</td>
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<td>beaglebone.local</td>
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<td>mDNS enabled</td>
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<td>beaglebone-2.local</td>
<td>all</td>
<td>mDNS enabled</td>
<td>Inactive</td>
</tr>
</tbody>
</table>
Cloud9 IDE over USB/browser (no host install)

- Zero-install integrated development environment
- Go to http://192.168.8.1:3000
# Installing ArduPilot (1/3)

[https://gist.github.com/jadonk/6080ca92d6e225eb89d33ad7744e1775](https://gist.github.com/jadonk/6080ca92d6e225eb89d33ad7744e1775)

```bash
#!/bin/bash

cd /opt-scripts/tools

git pull

./update_kernel.sh --rt-channel --lts-4.4

yes | developers/update_bootloader.sh

# Be sure to not try to run "apt-get upgrade" from within Cloud9. "dpkg --configure -a" to fix.

apt-get upgrade -y

apt-get install -y ardupilot-copter-blue
```
sed -i 's/GOVERNOR="ondemand"/GOVERNOR="performance"/g' /etc/init.d/cpufrequtils

echo "uboot_overlay_pru=/lib/firmware/AM335X-PRU-UIO-00A0.dtbo" >> /boot/uEnv.txt

echo "enable_uboot_overlays=1" >> /boot/uEnv.txt

mkdir -p /var/APM/logs

mv /etc/rc.local /etc/rc.local.bak.$RANDOM

cat <<EOX > /etc/rc.local
#!/bin/sh

echo pruecapin_pu > /sys/devices/platform/ocp/ocp\:P8_15_pinmux/state

sleep 10

echo 4a334000.pru0 > /sys/bus/platform/drivers/pru-rproc/unbind

echo 4a338000.pru1 > /sys/bus/platform/drivers/pru-rproc/unbind

/usr/bin/ardupilot/blue-arducopter -A udp:10.0.0.10:14550 -l /var/APM/logs 2>&1 > /var/APM/logs/blue-arducopter.log &

exit 0

EOX

chmod +x /etc/rc.local
Installing ArduPilot (3/3)

https://gist.github.com/jadonk/6080ca92d6e225eb89d33ad7744e1775

```
xxd -r -a - /var/APM/ArduCopter.stg

0000000: 5041 0600 0002 0000 7000 0002 7003 0700 PA..............
0000010: 0001 0415 0000 0000 0000 0000 1400 ....................
0000020: 00bd 7a76 442a 0200 0000 0001 c500 000c ...zvD........1
0000030: 051f bc4e c2a7 b082 2463 b083 3907 0011 .._.N.<..S........
0000040: 0614 0003 c081 0000 0000 0000 0000 h5.................
0000050: 0600 0007 c087 0000 0000 0000 0000 8502 0000 .............
0000060: 0000 0007 c087 0000 0000 0000 0000 0003 0308 0000 .....
0000070: 0000 0006 0313 0000 0000 0000 0323 0094 ............#$
0000080: 6824 0003 c501 0000 0000 0000 0000 0000 h$..............
0000090: 0000 0003 c307 0000 0000 0003 8502 0000 ................
00000a0: 0000 0000 0000 0000 0000 0003 0308 0000 ................
00000b0: 0000 0006 0313 0000 0000 0000 0323 0094 ............#$
00000c0: 0000 0000 0000 0000 0000 0000 0006 0308 0000 ................
00000d0: 0000 0000 0000 0000 0000 0000 0006 0308 0000 ................
```

EOF
Calibration

- Must do it!
- Sometimes, ESCs must be calibrated separately
Buying parts

- Hobby King
- Horizon Hobby
- Banggood

- BeagleBoard.org/blue
- github.com/beagleboard/beaglebone-blue/wiki/Accessories
The Community

• Google Group support forum
  - beagleboard.org/discuss

• IRC or Riot.IM live chat
  - beagleboard.org/chat

• Newsletter
  - beagleboard.org/newsletter-subscribe

• References
  - beagleboard.org/getting-started
  - beagleboard.org/blue
  - beagleboard.org/pocket

• Projects
  - beagleboard.org/p

• Related communities
  - eLinux.org
  - diydrones.com
Teaching with BeagleBone

• How do you get going?
• Attend a tutorial
• Derek Molloy [http://derekmolloy.ie/beaglebone/](http://derekmolloy.ie/beaglebone/)
• Yoder’s wiki [http://elinux.org/Category:ECE497](http://elinux.org/Category:ECE497)
• Barrett/Kridner Book
• 30+ Books [bbb.io/books](http://bbb.io/books)
• univ@ti.com
• [bbb.io/asee](http://bbb.io/asee)
Mistakes and Questions

- ESC/prop orientation
- Pre-flight check

- beagleboard.org/discuss
- beagleboard.org/chat