# Building an Open-Source Segway®

Geoffrey D. Bennett

January 17, 2007

# What

# What

- Two-Wheeled

# What

- Two-Wheeled
- Ride-On

# What

- Two-Wheeled
- Ride-On
- Self-Balancing

# What

- Two-Wheeled
- Ride-On
- Self-Balancing
- Robot

# How

# How

- Lean forward to go forward

# How

- Lean forward to go forward
- Lean more to go faster

# How

- Lean forward to go forward
- Lean more to go faster
- Lean back to slow down, stop, and go backwards

# How

- Lean forward to go forward
- Lean more to go faster
- Lean back to slow down, stop, and go backwards
- Joystick to turn

# Who

For people with:

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For people with:

- Some construction skills

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- Some electronic skills

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- Some electronic skills
- Some software skills

# Warnings

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- If it's powerful enough to move you around

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- If it's powerful enough to move you around
- Then it's powerful enough to throw you off

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- If it's powerful enough to move you around
- Then it's powerful enough to throw you off
- And run you over

# More Warnings

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- See `http://www.tlb.org/scootersafety.html`

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- Gaffer tape

# Wheels and Motors

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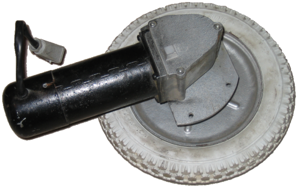

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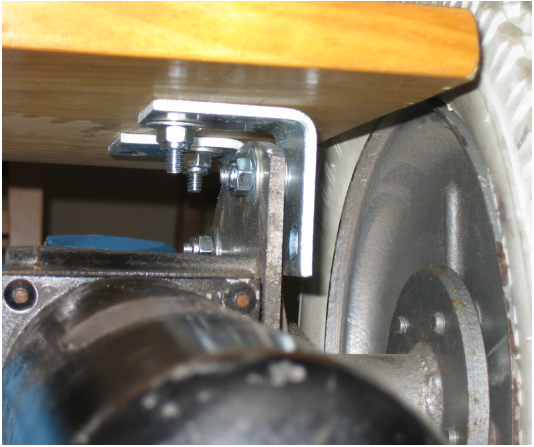
- No skill required
- At least, not if someone else takes to the wheelchair with the angle-grinder

# Platform



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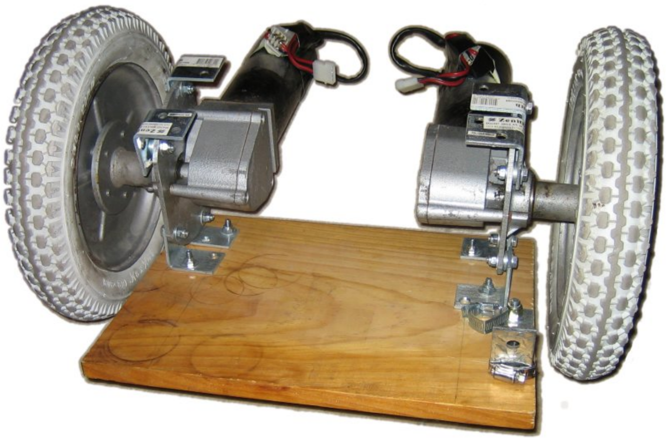

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- (Relatively) Cheap ($\approx$ \$240)
- (Relatively) Easy to Charge
- Heavy
- Output voltage proportional to remaining capacity

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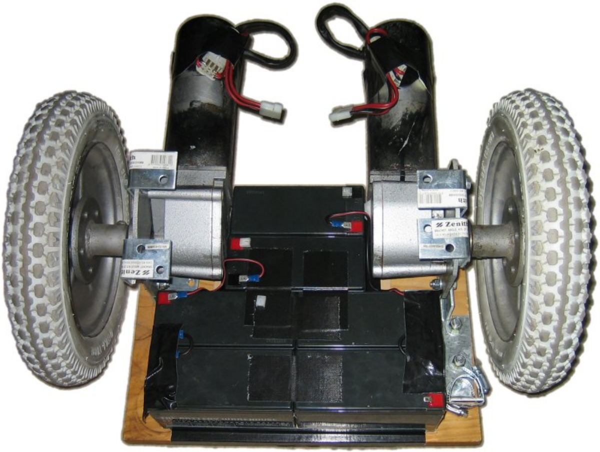

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- Orientation

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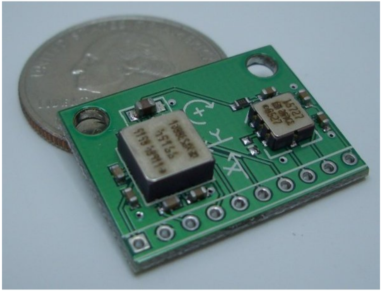
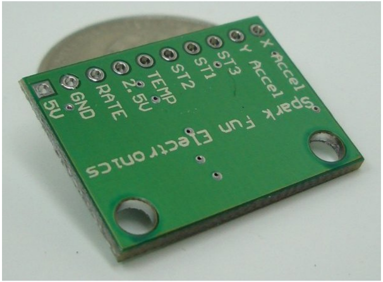
# Spark Fun Electronics

IMU Combo Board — USD$114.95






http://www.sparkfun.com/

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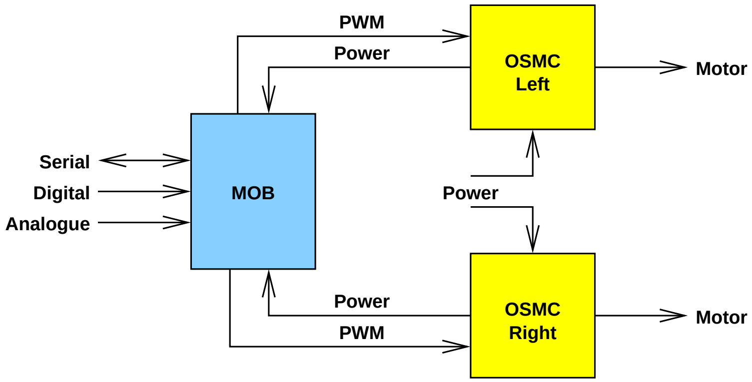
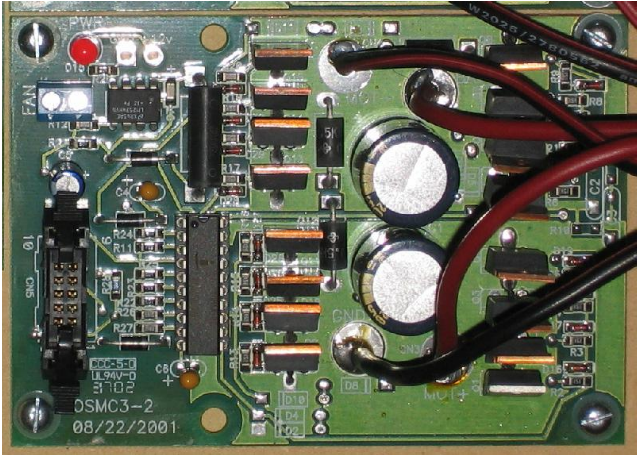
- Robot Power sell assembled boards (USD$475) `http://www.robotpower.com/`

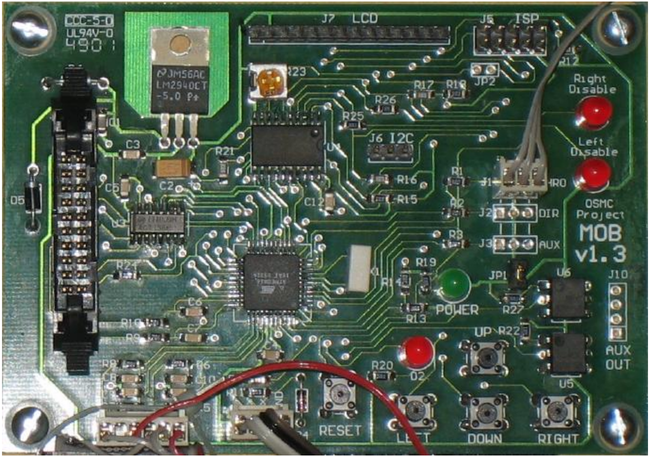
# OSMC and Modular OSMC Brain (MOB)



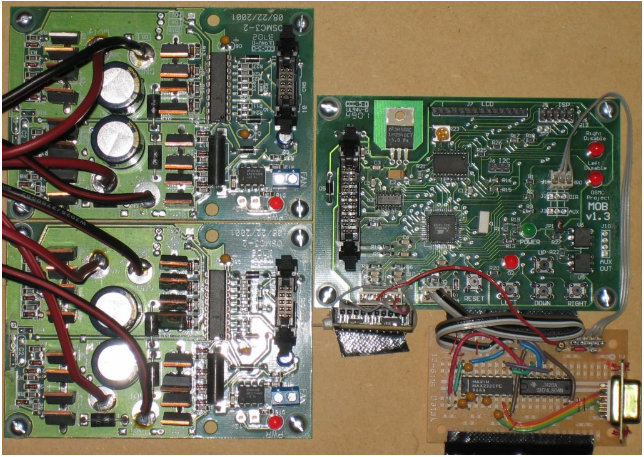
# OSMC



# MOB


J7 LCD
J5 ISP
Right Disable
Left Disable
OSMC Project
MOB
v1.3
J6 I2C
POWER
RESET
LEFT
DOWN
RIGHT
UP
AUX OUT

# OSMC and MOB


08/22/2001
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# Computing Power

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- Atmel ATMega16

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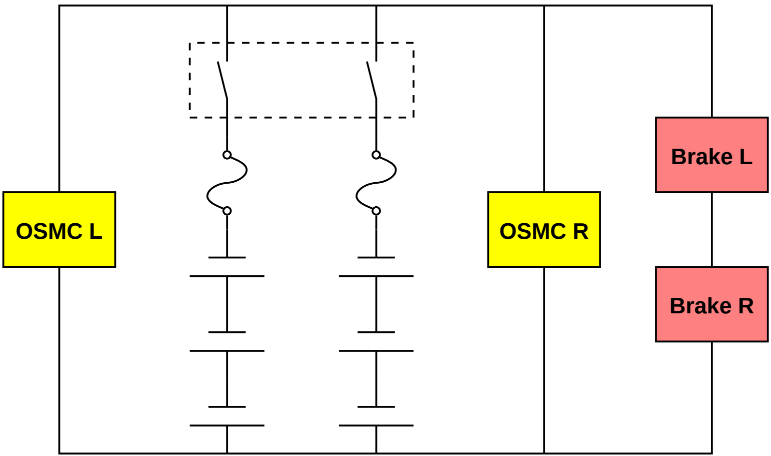
# Wiring it up



# Wiring it up

- MAX232 data sheet
- Spark Fun IMU Combo board documentation
- MOB schematic

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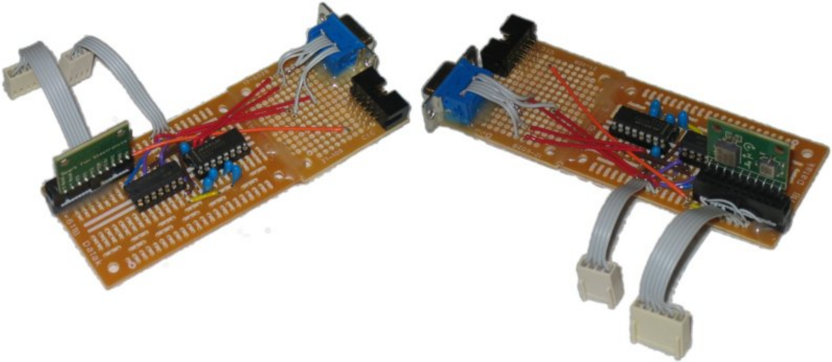

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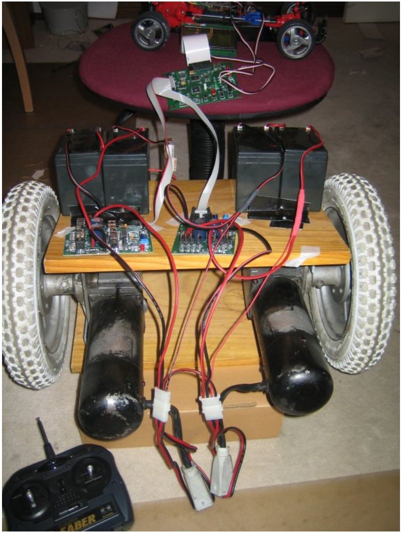
- Useful for testing

# Testing



# Testing

# Test Software

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- AVR-GCC

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# Tethered Operation

- Implement the balancing algorithm on your PC
- MOB and OSMC do nothing but A-D and D-A conversion
- First test that the wheels go in the right direction
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- Or pull it off the desk

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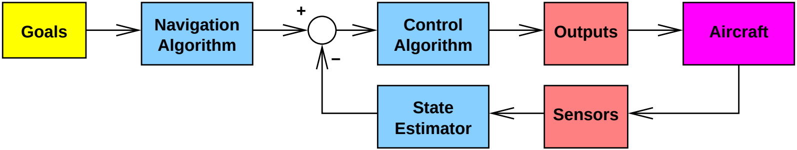

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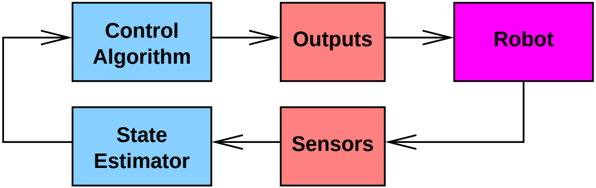

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- Derivative — if you lean quickly, go faster
- Integral — if you're still leaning, go faster

# Turning

- Make one wheel go slightly faster
- Make the other wheel go slightly slower
  (by the same amount, to not affect the balance!)

# Turning

- Make one wheel go slightly faster
- Make the other wheel go slightly slower
  (by the same amount, to not affect the balance!)
- Turn faster when stationary. Turn slower when travelling.

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- and is susceptible to vibration
- but it doesn't drift
- How to combine them?

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- Track angle changes with the gyro
- If the tracked angle is different to the angle from the accelerometer, track towards it slowly
- Subtract any acceleration force we apply to the motors from the accelerometer reading
- When moving, rely less on the accelerometer reading

# No Trigonometry Necessary!

- $\sin(x) \approx x$ (for small $x$)

# Sensor Positioning

- If the accelerometer isn't centered between the wheels, turning can be detected as leaning

# Soft-start

- In the first few seconds of running, slowly ramp up to avoid lurching.

# Regulator Voltage

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# Regulator Voltage

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- Use to measure regulator voltage and scale inputs appropriately

# Battery Voltage

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- OSMC and MOB have wired $V_{batt}/10$ to an ADC input

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- OSMC and MOB have wired $V_{batt}/10$ to an ADC input
- Use to measure battery voltage and scale outputs appropriately

# Parameter Tuning

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- Perl-Gtk

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- Wireless Bluetooth Serial

# Open Issues

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- Remove backlash in the hubs

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- Remove backlash in the hubs
- Current monitoring

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- Low battery voltage warning

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- Replace joystick with strain gauge

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- Current monitoring
- Low battery voltage warning
- Larger wheels
- Replace wood with metal
- Replace joystick with strain gauge
- Detect when rider not present

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- (implemented, but not test or tuned yet, so is disabled)

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- If the kill or dead-man switch is tripped, shut down
- If the battery voltage is getting low, limit the maximum speed more than usual
- If the motor current is too high, warn the user

# Thanks to...

# Thanks to...

- Trevor Blackwell

# Thanks to...

- Trevor Blackwell

# Thanks to...

- Trevor Blackwell
- Paul Schulz

# Thanks to...

- Trevor Blackwell
- Paul Schulz
- Michael Bennett

# Thanks to...

- Trevor Blackwell
- Paul Schulz
- Michael Bennett
- Mark Pulford

# Thanks to...

- Trevor Blackwell
- Paul Schulz
- Michael Bennett
- Mark Pulford
- Lindy Bennett

# Thanks to...

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# Questions?

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- How fast can you go?

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- How much do the parts cost?
- How far can you go on one charge?
- How long can you go for on one charge?
- How fast can you go?
- Project Web Page?
  `http://www.netcraft.com.au/geoffrey/meta/`